The 3 Counties Alliance Partnership (3CAP)

The Effect of Climate Change on 3CAP's Highway Network Policies and Standards

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EXECUTIVE SUMMARY

This report forms the concluding task (Task 5) of a 3 Counties Alliance Partnership (3CAP) project to assess the effect of climate change on their highways policies and standards. The project, undertaken against climate change predictions by the UK Climate Impacts Programme 2002 (UKCIP02), which leads towards the development of an adaptation plan using a risk and probability management approach, is based on predictions made for the year 2050. The key UKCIP02 general predictions for climate change in the UK are:

- Annual average temperatures will increase;
- Summers will become hotter and drier;
- Winters will become milder and wetter;
- Soils will become drier on average;
- Snowfall will decrease;
- Heavy and extreme rainfall will become more frequent; and
- There could be more extreme winds and storms.

These climate changes are set to have significant impacts on the construction and maintenance of local authority highways. Drier and hotter summers will lead to more incidences of pavement deterioration and subsidence. Wetter winters and more frequent heavy rainfall events will result in more frequent incidences of flooding, particularly in low-lying areas and floodplains, and a higher risk of landslides. This will have an impact on pavement performance and resilience, drainage capacity and condition, utilities and highways structures (such as; bridges, culverts, road signs and street lighting).

Predictions for increased storminess and extreme winds may have safety impacts and will have the potential to cause damage to structures and trees on or close to the highway. Reduced snowfall will reduce the need for gritting and snow and ice removal but will not necessarily reduce the need for the winter maintenance capacities and abilities that are available for utilisation.

Changes to the growing season as a result of warmer year-round temperatures will mean that plants will grow faster and for longer periods; and new plant species may start to thrive. This will lead to more intensive maintenance programmes being needed to prevent vegetation intrusion on the highway and 'sight-line' impairments due to the increased growth of the soft estate. Increased vegetation may also pose problems for drainage through gully blockages and erosion.

Existing highways construction and maintenance policies and standards are typically based on historical climate data but attention now needs to shift to future predictions. In order for the highway network to be resilient in the face of a changing climate, local authorities need to take action to adapt their policies and standards to help to both reduce CO_2 emissions from their activities, and to minimise the disruption and costs caused by climate change in the future.

Local authorities should take into account their geography, topography, geology and risks particular to their area when developing adaptation plans. The 3CAP region is ahead of many other regions in terms of predicting changes and implementing plans to tackle both the causes and effects of climate change. **This project has provided a much-needed, comprehensive, local risk and probability based assessment of the vulnerabilities to climate change, both now and in the future, and has identified the most effective adaptation responses in order to achieve Level 2 of National Indictor 188 for Local Authorities: Adapting to Climate Change. Further, an adaptation action plan has been developed by 3CAP to address the biggest risks posed by climate change on their highway network, thereby achieving Level 3 of NI 188. An outline timescale has been agreed for implementation of this adaptation action plan which moves the 3CAP councils towards achieving Level 4 of NI188.**

A Risk and Probability Assessment of the effects of climate change on the highway network has identified the ten effects posing the biggest risks from climate change to the highway network (extracted from Table 9). These being:

- Pavement failure from prolonged high temperatures;
- Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate;
- Lack of capacity in the drainage system and flooding of the network;
- Surface damage to structures from hotter and drier summers;
- Scour to structures from more intense rainfall;
- Damage to pavement surface layers from more intense rainfall;
- Subsidence and heave on the highway from more intense rainfall;
- Scour and damage to structures as a result of stronger winds and more storminess;
- Severe damage to light-weight structures from stronger winds and more storminess; and
- Less disruption by snow and ice due to warmer winters.

These, and the full range of risks identified, have been used to assess and prioritise the adaptation responses developed in the adaptation plan for seven key policy areas; 'bridges and other structures', 'drainage', 'grass cutting', 'materials', 'resurfacing', 'tree and hedge maintenance', and 'winter maintenance'. The adaptation options developed in response to the identified risks have undergone a structured multi-criteria analysis using thirteen evaluation criteria (Ref. Figure 6). The highest scoring responses were then reviewed by representatives from the 3CAP councils and the feedback was used to form the climate change adaptation plan (i.e. Level 3 of NI188) for the region. This plan and associated timescale for action is shown in the table below and covered in detail in Chapter 8.

Policy/Standard Type	Adaptation Response	Timescale
Bridges and other Structures	**AR1**. Carry out a risk assessment to identify which structures are most at risk from climate change. Identify the nature and frequency of changes that are needed to the inspection and maintenance regimes of bridges and other structures.	**Immediate**
	AR2. Increase the number and frequency of maintenance works carried out to increase the BCI values for bridges risk assessed as liable to risks from climate change. Ensure that all strengthening and repair work that is outstanding for failed or below standard bridges is carried out.	**Immediate**
	AR3. Carry out flood studies with the help of other agencies and organisations.	**Immediate**
	AR4. Ensure that all data (new and historical) is transferred into a single system to make assessments of maintenance and repair priorities, and needs, more effective.	**Immediate**
Drainage	**AR5**. Invest in asset management and location reviews, carry out drainage surveys and improve the knowledge of drainage assets, hydraulic capacity and ownership, and carry out flood studies with the help of other agencies and organisations	**Immediate**
	AR6. Undertake a risk assessment to determine vulnerable areas and establish a prioritised scheme for maintenance	**Immediate**
Grass cutting	**AR7**. Increase the frequency of grass cutting and the length of the grass cutting season	Grass cutting/ retardant treating season to extend to Feb to Oct by 2020, to Jan to Nov by 2050 and year-round by 2080 (with less growth in the summer)
	AR8.Treat grass with growth retardant and/or fertiliser to produce slower growing and/or better quality grass	

Materials	**AR9**. Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat	**Immediate**
	AR10. Review current material specifications to assess their suitability for resistance to the effects of climate change. Consider changing to end performance specifications which address the adverse effects of climate change	**Immediate (by the end of 2009)**
Resurfacing	**AR11**. Undertake a risk assessment to identify the most vulnerable areas of the network and develop priority actions to be carried out. Implement a targeted programme of improvement	**Immediate**
	AR12. Ensure infrastructure asset management plans take account of adaptations required for climate change in resurfacing programmes	As soon as feasibly possible
	AR13. Review new material and treatment choices and specify appropriate replacements	**Immediate**
	AR14. Use polymer modified binders that are less prone to binder stripping and other materials with a greater 'stiffness'	By 2020
	AR15. Increase verge maintenance and grass cutting frequencies to reduce the risk of 'root invasion' and vegetation ingress on the highway	See GC1 and GC2 for timescales
Tree and Hedge Maintenance	**AR16**. Improve the knowledge of existing tree stock. Undertake a risk assessment to determine vulnerable trees and establish a prioritised scheme for maintenance. Increase the frequency of tree and hedge inspections and maintenance	**Immediate**
	AR17. Review the species choice for new trees to ensure the most appropriate species is selected	As soon as feasibly possible
Winter Service	**AR18**. Carry out risk assessment surveys to establish which routes have the highest risk of ice formation	**Immediate**
	AR19. Re-assess and re-classify priority routes based on future climate change predictions	By 2020
	AR20. Review established resources for winter service provision and consider if changes need to be made	By 2020
	AR21. Provide a more flexible and responsive winter service	By 2020

Implementation of this adaptation action plan moves the 3CAP councils towards **achieving Level 4 of National Indicator 188: Adapting to Climate Change (implement an adaptation action plan and establish a process for monitoring and review to ensure progress)**. In order to best adapt to the effects of climate change, the 3CAP councils must be aware of the level at which different parts of their network are vulnerable and most in need of attention. By the 3CAP councils beginning to take action now to identify the work that needs to be carried out (monitoring, maintenance, strengthening, reconstruction etc), the highway network will be more resilient to the biggest risks posed by the changing climate.

The findings from this study, and specifically the adaptation responses shown in the table above, should be considered and applied during the preparation of any new asset management and lifecycle plan documents. This will ensure that the 3CAP councils are implementing the adaptation actions effectively and that they are integrated firmly within all council policies and plans. A review of current 3CAP policies and standards for materials is to be carried out in 2009.

CONTENTS

1. INTRODUCTION

This report forms the final task of the 3 Counties Alliance Partnership (3CAP) project to identify 'The Effect of Climate Change on 3CAP's Highways Network Policies and Standards'. This project, led by 3CAP's designer Scott Wilson, with direction and input from key representatives from Derbyshire County Council (DCC), Leicestershire County Council (LCC) and Nottinghamshire County Council (NCC), aims to investigate the current and likely future impact of climate change on 3CAP's existing highways policies and standards. This project has identified the most effective adaptation responses based on a risk and probability management approach (specifically, a 'multi-criteria analysis'), in order to achieve Level 2 of National Indicator 188 (NI188) for Local Authorities: Adapting to Climate Change, and has gone further, to develop an adaptation action plan, thereby achieving Level 3 of NI188 (full definitions of the levels of NI188 are provided in Appendix 1).

The project has been undertaken against a backdrop of the UK Climate Impacts Programme 2002 (UKCIP02) predictions for climate change. The findings lead towards the development of an adaptation plan based on predictions made for year 2050 and the key expectations that:

- Summers will be drier and hotter;
- Winters will be milder and wetter;
- There will be more extreme rainfall events, droughts and storminess; and
- There will be a rise in sea level.

This research specifically looks at the likely impact of climate change on the construction and maintenance of highways within the 3CAP region (i.e. Derbyshire, Leicestershire and Nottinghamshire). Updates on the UKCIP02 predictions are expected to be published later this year and whilst not expected to include any major changes, they should be considered.

Existing guidance on adaptation to climate change is currently weak, with strategies that in practice turn out to be unrealistic or unfocused. This is partly a result of the perceived conflict between the objectives of mitigation and adaptation [Local Government Association, 2007]. This project has assessed potential actions that need to be carried out now in order to accommodate the current and future effects of climate change. These adaptation actions **must** be carried out alongside actions to reduce greenhouse gas emissions. Both of these issues need to be considered as interdependent in order for any policy and standards adaptation action plans to be effective.

1.1 BACKGROUND

Climate change is happening now and due to the inertia that exists in our climate, past greenhouse gas (including CO_2) emissions mean that changes are now inevitable over the next 40 years. After that period, any further climatic changes will be determined by a number of key factors, including; increases or reductions in local and global emissions, technological advances to reduce or mitigate emissions and their effects, and any social change. Therefore, local authorities need to adapt their policies and standards for these inevitable changes to our climate for at least the next 40 years, and assist in reversing these changes thereafter by reducing CO_2 emissions now.

Historically, policy making decisions have been based on past climatic conditions but now it is necessary to base them on predictions for the future so as to minimise the impact of changing weather patterns and events.

There is evidence that climate change is already having an influence on the UK's highways, specifically as a result of:

- Drier summers causing greater subsidence and pavement deterioration;
- Wetter winters and more severe heavy rain causing flooding and drainage related pavement failures; and

- Increased 'storminess' leading to increased damage to highway structures and increased safety concerns.

Climate change will not affect all areas of the UK uniformly. Drought and high temperatures are more of a threat in South-East England and flooding, storms and heavy rain are the biggest threat in Scotland [Baldachin et al, 2007b]. The impacts of climate change on pavements are influenced by factors including; soil type, geography, topography, geology, pavement condition and levels of trafficking. Therefore, the research carried out in this project has been specifically appropriate for the East Midlands region.

1.2 PURPOSE AND SCOPE OF THE PROJECT

The original purpose of this project was to:

- **Identify the predicted climate change scenarios** for the UK, and specifically for the 3CAP East Midlands region of Nottinghamshire, Derbyshire and Leicestershire;

- **Identify the potential impacts** of climate change on the construction and maintenance of highways;

- **Identify existing and potential methods** of adaptation that can be implemented to minimise the effect of climate change on the highways network;

- **Develop a comprehensive, local risk-based assessment** of 3CAP's highway network's vulnerabilities to weather and climate, both now and in the future, and to identify possible adaptation responses in order to achieve Level 1 of NI188; and

- **Identify the most effective adaptation responses** based on a risk and probability assessment (i.e. a 'multi-criteria analysis' methodology), in order to achieve Level 2 of Ni188.

The commitment by 3CAP and the momentum gained during this project was used to extend the original purpose (within the original target cost) to also include;

- **Develop an adaptation action plan**, thereby achieving Level 3 of NI188.

*N.B. Where discussed, **climate** is classed as the regular weather conditions of the region, and **weather** is classed as the day-to-day manifestation of this climate.*

2. INVESTIGATION METHODOLOGY

2.1 OUTLINE

The work in this project has been conducted in five distinct but overlapping and complementary tasks. Each task was clearly defined and provided the necessary stepping-stones towards achieving the ultimate project aim to; investigate the current and likely future impact of climate change on 3CAP's existing highway network policies and standards, and to identify the most effective adaptation responses based on a risk and probability management approach, in order to achieve Levels 1 and 2 of National Indicator 188: Adapting to Climate Change. Split over a project duration of 19 weeks, the project's five tasks were:

- **Task 1: Brief literature review**
- **Task 2: Individual meetings with the 3CAP counties**
- **Task 3: Desk-top study of highway network policies and standards**
- **Task 4: Workshop**
- **Task 5: Adaptation plan development**

Sections 2.2 to 2.6 give detail on each of the five project tasks.

2.2 TASK 1: LITERATURE REVIEW

Task 1 of the project was to carry out a literature review of the impact of climate change on the construction and maintenance of highways. This review looked at existing literature and research relating to the impact of climate change on highways, with attention paid to factors specific to the East Midlands region. The findings from the review were to be fed into subsequent stages of the project and establish a context for identifying the likely climate changes and challenges that will be faced by the 3CAP region now and in the future.

The full literature review is available upon request.

2.3 TASK 2: INDIVIDUAL MEETINGS WITH THE 3CAP COUNTIES

Following on from the completion of the first draft of the literature review, individual meetings were arranged with the 3CAP counties. These meetings were designed to obtain an understanding of the main issues relating to the current and likely future climate change impact on the construction and maintenance of highways from key personnel within each of the three counties (Derbyshire, Leicestershire and Nottinghamshire). Attendees included Highway Network Managers, Highway Asset Managers, Policy and Standard Managers, Environment Officers and Divisional Directors. The meetings also introduced the project to the attendees and informed them about the proposed Task 4 Workshop and its expected content.

Full meetings were held with Derbyshire and Leicestershire County Councils, with more informal contact made with key individuals within Nottinghamshire County Council. Notes from these meetings are available upon request.

2.4 TASK 3: DESK-TOP STUDY OF HIGHWAY NETWORK POLICIES AND STANDARDS

Task 3 of the project was to carry out a desk-top study of existing Derbyshire, Leicestershire and Nottinghamshire County Council highway policy and standards documents. These documents included; Highway Network Management Plans, Transport Asset Management Plans, Winter Service Plans and Structure Lifecycle Plans. The study was conducted to identify the policies and standards within each of the documents that are likely to be affected by climate change in the future.

A risk and probability assessment was then conducted to identify which of these policies and standards will have the highest risk of impact from climate change (Table 9 summarises the findings of Task 3). This task was fed into and expanded by the Task 4 Workshop and the results of the risk and probability assessment were the basis for the work carried out in Task 5.

2.5 TASK 4: WORKSHOP

The Workshop was held on Tuesday 8 July 2008 at the East Midlands Conference Centre and attended by 25 delegates from Derbyshire, Leicestershire and Nottinghamshire County Councils. The delegates represented an appropriately diverse range of skills and responsibilities within the councils' highways and environment teams. The aim of the Workshop was to build on the findings from the Task 1 Literature Review and the Task 2 Individual Meetings to obtain the views and ideas of the delegates on the effects of climate change on their highway networks, and to begin to identify possible adaptation responses. As the Workshop was held half-way through Task 3 (desk-top study of policies and standards), it also helped to confirm and identify the documents being reviewed and provided direction for the conclusion of Task 3 and the plan for Task 5 (adaptation plan development).

Figure 1: Delegates working in groups during Workshop activities

During the Workshop, delegates were asked to work in pre-defined groups of 'counties' (Derbyshire County Council, Leicestershire County Council or Nottinghamshire County Council) or groups of 'discipline' ('Drainage', 'Structures' or 'Environment') to gather their thoughts, knowledge and opinions by working through the six structured challenges shown in Figure 2.

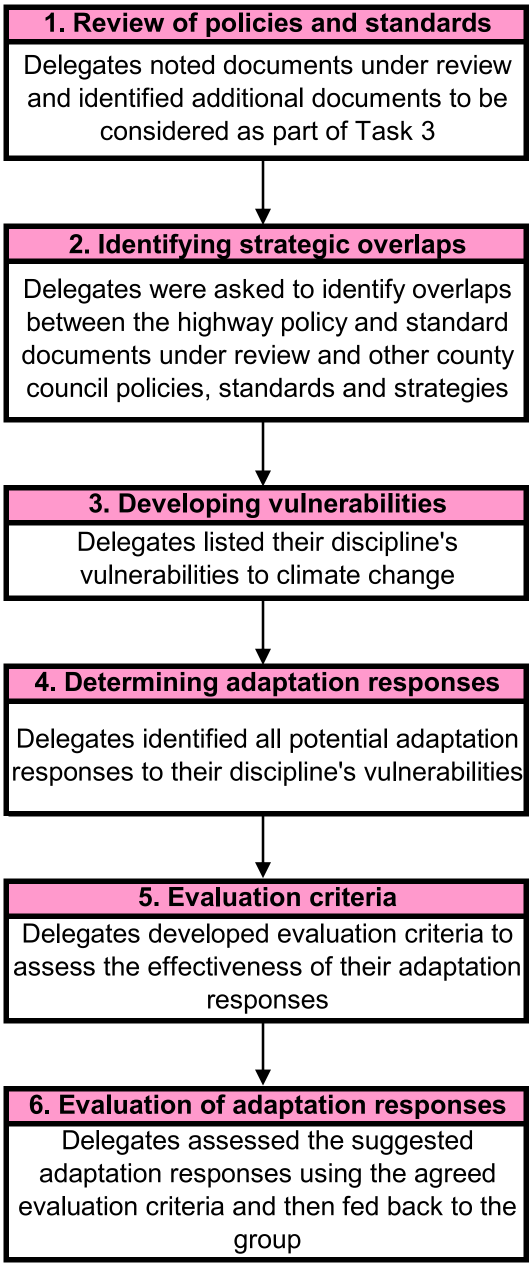


Figure 2: Outline of the Task 4 Workshop

The Workshop delegates: identified additional documents to be considered as part of Task 3; identified strategic overlaps that exist between their various policy and standard documents and other wider county council policy and standard areas; identified their specific 'discipline's' vulnerabilities to climate change; developed potential adaptation responses to these impacts on their 'discipline'; and developed an agreed list of 13no. evaluation criteria to be used to assess and interrogate the adaption response options.

The full Task 4 Workshop Report is available upon request.

2.6 TASK 5: ADAPTATION PLAN DEVELOPMENT

The final task of this project was to produce a comprehensive, local risk and probability based assessment of current and future vulnerabilities to weather and climate change; to identify possible adaptation responses (to achieve National Indicator 188: Adapting to Climate Change – Level 1); and to identify the most effective adaptation responses (to achieve National Indicator 188: Adapting to Climate Change – Level 2).

The production of an adaptation plan which identifies the most effective responses to the effects of climate change, in line with UKCIP recommendations and National Indicator 188, allowed 3CAP to identify their targets and timescales for implementing adaptation responses and realign and co-ordinate their policies and standards in order to achieve NI 188 Level 3. Implementation of the plan will ultimately achieve NI188 Level 4.

3. RESULTS OF BIBLIOGRAPHICAL RESEARCH, MEETINGS AND WORKSHOP

General climate change research literature and the specific local knowledge and understanding of the 3CAP counties (Derbyshire, Leicestershire and Nottinghamshire) have been the major contributors to the results of this project. Through a literature review, individual meetings with the three counties and a one-day interactive workshop for county council representatives, knowledge, opinions and concerns have been gathered. A summary of the findings from each stage are found in Sections 3.1 to 3.3, with full documentation from these tasks available upon request.

3.1 LITERATURE REVIEW (TASK 1)

Climate change is happening now and the inertia that exists in our climate means that past greenhouse gas emissions will lead to inevitable changes to our climate over the next 40 years. After that, any further climatic changes will be determined by future changes in greenhouse gas emissions, technological advances to reduce or mitigate these emissions and any significant social or population changes. The UK Climate Impacts Programme 2002 (UKCIP02) has developed models to predict future trends in climate change based around four future emissions scenarios; 'Low', 'Medium-Low', 'Medium-High' and 'High'. These scenarios account for the uncertainties that exist about future trends and behaviours. The changes predicted for the next 40 years are similar for all scenarios as they are based on past and current emission levels. After this period, predictions for the four scenarios are based on differing theoretical emission levels.

In summary, UKCIP predictions for climate change in the East Midlands are [Waters, 2004]:

Temperature:
- For all emissions scenarios, average annual temperature will rise by between 0.5°C and 1.5°C by 2020, and by an average of 2.5°C and 3.0°C by 2080.

Precipitation
- Annual rainfall averages show little change
- Winter rainfall is predicted to increase by up to 30% (High Emissions scenario) by 2080
- Summer rainfall is predicted to decrease by up to 50% (High Emissions scenario) by 2080

Soil Moisture Content
- Relatively small predicted changes in annual, winter and spring soil moisture content
- Predicted soil moisture content decreases of up to 30% and 50% in summer and autumn respectively by the 2080s

Wind speed
- Possible increase of up to 10% in the winter months

Snowfall
- Predicted 60% to 90% decrease by the 2080s

Historical highways construction and maintenance policies and standards are typically based on past climate data but as the climate is expected to change more rapidly than ever over the next 60 years, attention needs to be now paid to future predictions instead. Changes need to be made to ensure that the UK's highway network can cope with future changes to the climate and can avoid the negative effects of these changes. In particular, the effects of hot and dry summers, wetter winters and more extreme rainfall events, and warmer winters need to be adapted to.

There have been an increasing number of very hot days (i.e. with temperatures over 25°C) in the East Midlands over the last 40 years. Extremely hotter summers have been experienced in 1976, 1983, 1990, 1995 and 2003, where high temperatures were sustained over a number of days [Capps and Lugg, 2005]. Typically drier and hotter summers will lead to increased incidences of pavement deterioration and subsidence. As seen in the hot summer of 2003, regions such as Cambridgeshire and Hampshire reported significant problems with cracking and deformation of the highway as a result of a prolonged hot and dry period leading to a severe reduction in soil moisture content and soil shrinkage. Incidences similar to this are expected to increase in frequency and severity as climate change develops.

However, hotter and drier summers do have the potential to provide some benefits for highway construction and maintenance. Although prolonged high temperatures can cause asphalt roads to soften and deform and concrete roads to crack, it also means that roads can be resurfaced rapidly and grass growth is reduced during the very hot periods, thus producing a short-term reduction in the need for grass cutting [Capps and Lugg, 2005]. These effects will help to reduce the costs and disruption associated with these particular maintenance activities during these particular periods of hot and dry weather.

Wetter winters and more extreme rainfall events will lead to increased occurrences of flooding, as seen in the summer of 2007. This will particularly be a problem in low-lying areas as well as floodplains, and will increase the risk of landslips and embankment erosion. Flooding will also have implications on pavement maintenance as water ingress and binder stripping can lead to premature deterioration and failure of the pavement structure. More intense rainfall, increased storminess and more severe winds will have impacts on pavement resilience, drainage capacity and condition, utilities and highways structures (such as; bridges, culverts, road signs, street lighting).

Warmer winters will lead to less snow and ice which should reduce the need for winter maintenance activities (salting etc). However, this will not necessarily reduce the need for winter maintenance resources and capabilities that are available for utilisation – conservative forecasting and an increase in the number of 'marginal' nights may in fact mean that the number of 'turn-outs' in winter is likely to remain the same or may even increase.

Warmer winters and more intense rainfall events will also lead to a lengthened growing season. This will result in an increased demand and need for maintenance of the soft estate and new plant species may begin to thrive. This in turn will have additional potential impacts such as; drainage blockages, impaired 'sight-line' vision of road signs, and vegetation ingress onto the highway leading to pavement damage and deterioration.

A number of adaptation techniques are already being implemented across the UK to deal with the effects of climate change on the highway network. Examples of these are shown in Table 1.

Table 1: Systems and procedures to mitigate the effect of predicted climate change [Roads Liaison Group, 2005] and Loveday [2007]

Flooding	Subsidence, heave and high temperatures	Increased wind speeds
• Undertake a risk assessment to determine vulnerable areas of the network • Increase gully emptying activities • Define alternative routes and ensure they are adequate, well signposted and well maintained • Improve flood protection • Prepare contingency plans in consultation with other authorities • Ensure that all bridges openings and culverts can deal with increased flooding • Carry out regular inspection, clearance and maintenance of drainage systems • Implement a targeted programme of improvement • Provide sealed edges and a bounded layer to maximise pavement life and minimise silted drains • Pay greater attention to drainage maintenance • Encourage and adopt innovations in permeable paving (SUDS etc) to control surface run-off and prevent flooding • Capture and store water to be released gradually (using tanks, containers etc)	• Sanding of bituminous surfaces in summer to prevent loss of skid resistance • Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat and develop priority actions from this assessment • Consider tree felling to reduce soil moisture deficits (trees remove moisture from the soil and can cause deformation of the road). However, this has political and public implications • Change materials and methods over time to mitigate the effect of high temperatures	• Assess which parts of the network are most at risk from damage by strong winds (falling signs and trees etc) • Develop an Emergency Plan with the emergency services and local communities • Increase the use of warning signs on major roads to provide advice and warnings to drivers on the dangers of high winds • Undertake a structural appraisal and considered programmes of strengthening and/or removal • Carry out clearance of potentially dangerous trees and debris • Increase support to the emergency services

In summary, from the literature reviewed, there are a number of clear key negative implications for highway construction and maintenance activities as a result of current and future climate change. These effects should form the basis for any decision-making carried out when assessing highway network policies and standards, and include:

- **Increased risk of flooding from rivers;**
- **Increased risk of flooding from inadequate drainage;**
- **Increased risk of landslides;**
- **Increased risk of deterioration and damage from subsidence, heave and high temperatures;**
- **Damage to bridges, signs and other structures from increased wind speeds and scour from both intense rainfall and high temperatures;**
- **Increased road safety problems due to adverse driving conditions and deterioration of infrastructure; and**
- **Increased number of routes becoming unavailable which will in turn increase the level of disruption experienced.**

These impacts will have a major influence on the UK's highways in future years, some of which are being experienced already. It is important that those responsible for the design, construction and maintenance of highways take these effects into account and take action to adapt their policies, standards and practices to cope with the effects of predicted future climate change. The East Midlands is ahead of many other regions in terms of implementing plans and targets to tackle the cause and effects of climate change, particularly in the areas of energy use and reducing carbon emissions. However, progress still needs to be made in the areas of adaptation and getting local authorities and the general public to accept that the issue needs addressing immediately and that council policies, standards, practices and strategies need to be changed to do this.

3.2 INDIVIDUAL MEETINGS (TASK 2)

With the objective of the meetings with the individual 3CAP counties being to introduce the project to the county council representatives and to obtain their understanding of the main issues relating to the current and likely future effects of climate change on the construction and maintenance of their highway network, the primary outcome was confirmation and expansion of the existing scope of study.

Feedback during the meetings highlighted the main areas of operation and policy types where concern exists over the impact of climate change. This confirmed the findings from the literature review and include; **structures, surfacing materials, surface dressing, drainage, pavement construction materials, recycled materials, street lighting, grass cutting, gully emptying, biodiversity, winter maintenance, Sustainable Drainage Systems (SuDS) and tree planting and maintenance**.

Individual county concerns were also raised. These included, but were not limited to:

- Concern that some potential methods of adaptation introduced to deal with the effects of climate change (such as increased grass cutting frequency) will lead to increased carbon emissions, thus contributing to the root cause of climate change;
- Concern over the lack of knowledge about drainage assets within the individual counties;
- High costs associated with asphalt roads deforming during prolonged high summer temperatures;
- Lack of understanding and confidence in the use of recycled materials in road construction and maintenance;
- An increased number of "marginal" nights (in terms of freezing temperature) making winter maintenance difficult to plan and prioritise;
- Lack of county council records on gully emptying frequencies, locations and associated costs;
- A lack of county council control over drainage capacity due to ownership and control by water companies and private land owners;
- Concern over water courses that cross county council highways flooding;
- Confusion over who is responsible for the management, maintenance and operation of drainage systems within the counties;
- Lack of confidence in the effectiveness of Sustainable Drainage Systems (SuDS) in providing a solution to the problem of excess surface water;
- Confusion regarding the most effective surfacing materials to use to reduce the effect of hotter and drier summers and most intense rainfall periods; and
- Confusion about whether grass cutting should be done on a proactive or reactive basis.

These concerns will be incorporated into the risk and probability assessment of the effects of climate change on 3CAP's highway network policies and standards and will be considered in the production of the final adaptation plan.

3.3 WORKSHOP (TASK 4)

The aim of the one-day Workshop was to expand on the knowledge and direction gathered from the literature review and individual meetings, to obtain the views and ideas of the delegates on the effects of climate change on their highway networks, and to begin to identify possible adaptation responses. The Workshop had a number of key outcomes, including:

- The identification of additional policy and standard documents to be considered for review;
- Identification of any strategic overlaps that exist between highway network policy and standard documents and other wider county council areas of operation;
- Identification of the vulnerability of drainage, structures and the environment to climate change;
- Identification of potential adaptation responses to climate change to the three specific discipline areas (drainage, structures and environment) considered; and
- Development of a list of confirmed evaluation criteria to be used to assess the suitability of the proposed adaptation responses.

Table 2 shows a summary of the vulnerabilities identified by the delegates relating to the three selected disciplines of 'drainage', 'structures' and 'environment'.

Table 2: Vulnerabilities to climate change identified during the Task 4 Workshop

Drainage	Structures	Environment
• Lack of information on the asset in terms of location, condition and capacity • Lack of capacity • Differences in the maintenance regimes between the authorities and the asset owner(s) • Lack of records on damage to utilities • Property flooding • Problems with network availability during periods of flooding • Pavement damage • Embankment slips • Increased maintenance costs • Impact on the soft estate • Public health risk from sewer overflows • Road safety issues • Increased budget demands • Costs associated with clearing up after flooding • Staff and resource issues • Top soil run-off • Damage caused by tree roots • Rising water tables • Effects of development on floodplains and hard paving	• Surface damage to structures from high temperatures • Bridge bearing and joint damage • Increased deterioration to paint on steel structures • Lack of capacity to deal with increased rainfall • Scour • Saturated backfill leading to instability • Risk of landslips • Embankment erosion • New structures will require greater capacity than currently specified • Subsidence and heave of shallow foundations • Differential settlement of foundations • Road sign and gantry damage from strong winds • Vehicles blown over on high bridges • High risk to lightweight structures (suspension bridges etc) • More risk to trees and saplings from scour, flooding and prolonged high temperatures • Vegetation ingress onto structures • Lengthened growing season and increased biodiversity leading to fewer opportunities for maintenance activities	• Temporary or permanent loss of parts of the network to flooding • Issue of waste disposal after flooding and potential pollution issues • Heat damage to concrete and asphalt roads • Structural damage and shrinkage • Fire risk from dry verges • Risk of tree damage from high winds • Increased accidents on the network • Impact on the travel plans of pedestrians and cyclists • Safety, visual and mowing regimes will need to be increased to meet the lengthened growing season • Increased leaf-fall blocking drains • More vegetation on the soft estate • Some tree and plant species will die and others will thrive • Increased to clear vegetation away from road signs and street lights • Unpredictable requirements from mowing during hot and dry summers • Potential for increased contamination of water sources during periods of flooding • Impacts on traffic flows, increased delays road-works

These vulnerabilities and the possible adaptation responses identified by the delegates in response to them have been considered in the risk and probability assessment and the development of the adaptation plan.

The key output from the workshop was the agreed list of evaluation criteria identified by the delegates. This list has been used to form the method of assessing the possible adaptation responses identified to help manage the effect of climate change on 3CAP's highway network. The criteria has also been adapted and applied to develop a 3CAP region adaptation plan by prioritising and demonstrating the most efficient and realistic methods of adapting their highway network policies and standards to the effects of climate change. The evaluation criteria and its application to assessing the suitability of suggested climate change adaptation responses is presented in Section 5.

4. RISK AND PROBABILITY ASSESSMENT

A risk and probability assessment of current highway policies and standards has been carried out to assess the likely impact of climate change on the condition of the highway network. In order for this to be achieved, a review of the main policy and standards documents has been carried out to identify which are likely to be impacted upon by current and future climate change (Section 4.2 lists the documents reviewed). Typical risk and probability assessments involve the use of impact costs to quantify the level of risk. However, the uncertainty about the costs associated with the impacts of climate change and how these costs may vary over time mean that assessments of the current and future risk have to be based on other or additional criteria (probability, scale, local authority influence etc). This is explained in further sections of this report.

4.1 BACKGROUND TO THE PROCESS: COSTING THE IMPACTS OF CLIMATE CHANGE

Currently there is a lack of reliable information that exists on the costs of climate change. This makes it difficult for local authority decision-makers to judge the level of resources that they should allocate to adaptation responses.

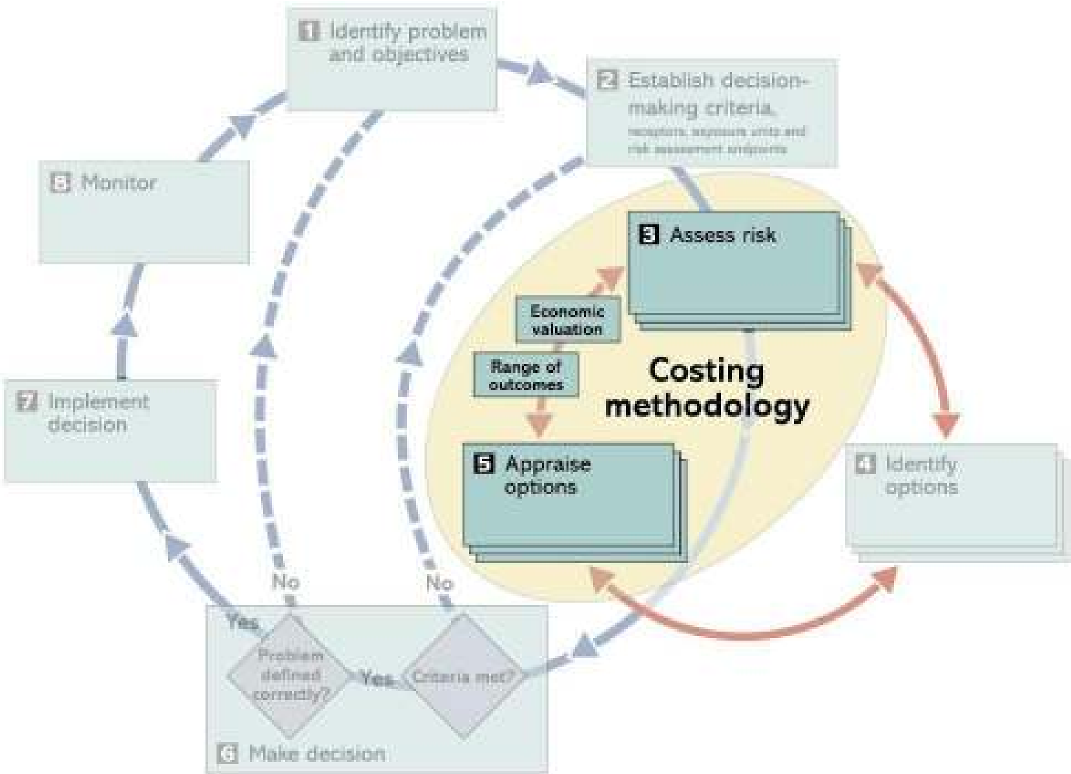
UKCIP have published guidelines to provide a standard methodology for costing climate change impacts, and comparing these with the costs of adaptation measures. This standard methodology allows decision-makers to estimate the costs and to rank them by magnitude. By being able to effectively order them in this way, climate change risks can be prioritised and appropriate adaptation responses can be investigated. The costing guidelines can be applied across a range of sectors and at local, regional or national levels [Metroeconomica, 2004].

The UKCIP guidelines ultimately help decision makers to:

1. 'Assess, prioritise and rank **risks** to generate valid "order of magnitude" estimates for climate change risks of interest, so that their relative importance can be established'; and

2. 'Appraise **adaptation options** to generate 'order of magnitude' estimates of the net benefits of options to adapt to significant climate risks, so that the "best" (or preferred) option(s) can be implemented'.

UKCIP's standard methodology allows users to estimate the costs of climate change, both with and without adaptation, and provides an auditable way for the threats and opportunities to be valued [Metroeconomica, 2004]. Figure 3 shows the entire decision making process to be carried out when costing the impacts of climate change, assessing the risks and probability of these impacts, and developing possible adaptation responses.



[Metroeconomica, 2004]

Figure 3: Costing guidelines for decision making in the face of climate change risk

In recent years there has been significant improvements made in understanding the Earth's climate. However, there still remains much uncertainty as to the exact impacts that are expected to accompany any possible changes to it. Due to this, deciding the most appropriate action to take to adapt to climate change is complex.

As it is not possible to finance all desirable methods of adapting to climate change, decision makers need to decide whether or not a particular climate change risk should be adapted to, and which adaptation responses should be selected for implementation [Metroeconomica, 2004].

There is much uncertainty about the nature and magnitude of future climate change. Therefore, there is also difficulty establishing how the impacts should be valued, and how best to develop adaptation measures. Decision-makers should effectively manage this uncertainty by considering a range of climate change prediction scenarios and identifying the risks associated with the scenarios [Metroeconomica, 2004].

The Treasury Green Book [HM Treasury, 2003] has been published to provide guidance to public sector bodies on how any policy or standard proposal should be assessed and appraised prior to change or adoption. The guidance states that all new policies, programmes, and projects should be subject to an assessment, wherever it is practicable, so as to best promote public interest. The Green Book provides guidance in carrying out these assessments. Ultimately, it provides guidelines to ensure that no policy, programme or project is adopted without the following two questions first being answered:

1. Are there better ways to achieve this objective?; and
2. Are there better uses for the resource?

As a result, the guidelines promote an efficient method of policy development and resource allocation across government activities [HM Treasury, 2003].

When appraising a policy, programme or project proposal, government intervention is validated, objectives are set and options for change are created and reviewed, typically using a cost-benefit analysis framework, i.e. 'analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including terms for which the market does not provide a satisfactory measure of economic value' [HM Treasury, 2003].

The aim of the method of option appraisal outlined in the Treasury Green Book is to help ensure that a value-for-money solution which meets the objectives set out by the government is found. By creating and reviewing options in this way, decision-makers can understand the full range of solutions available to them and be able to select the most effective option.

The first stage of this option appraisal is to establish a list of potential actions that could be undertaken to achieve the required objective(s). This list should ideally include a 'do nothing' or 'do minimal' option where the public sector body in question does the minimal amount of action necessary. This allows for the argument for a more interventionist approach to be judged.

The options should then be valued using a cost and benefit appraisal. The decision maker can then compare the results and select the best option. The costs and benefits should be, if practicable, assessed for the entire lifetime of the option. Social and environmental costs and benefits are more difficult to assess as they have no market price. However, these are as important as monetary effects and so should also be considered. To establish values for these costs and benefits for which there is no readily available market data, a range of techniques can be applied, many of which are subjective [HM Treasury, 2003].

Most climate change impacts will be felt more intensely over the coming decades. Individuals tend to attach less importance to a cost or benefit in the future than they do to a cost or benefit now. As a result, a form of discounting needs to be applied when costing future impacts [Metroeconomica, 2004]. The Treasury Green Book also provides guidance for calculating the discount rates to apply to impacts in different future time periods. This discounting method should aim to be applied in all public sector costing studies.

Valuing risks should be carried out to assess the true expected value of an impact. This can be done simply by multiplying the likelihood of the particular risk occurring by the size of the outcome (in monetary terms) and then adding the specific risks together.

Costs and benefits that cannot be valued in monetary terms also need to be described and assessed. Research should be carried out to determine a suitable unit of measurement. Non-monetary units of measurement may include 'time saved' or 'reduction in congestion' etc. These savings can then be measured and attached an aggregate monetary value. Annex 2 of the Treasury Green Book provides guidance on how non-market impacts (such as; time-savings, health benefits, design quality and environmental improvements) can be valued. These impacts are complex but are equally as important as market impacts.

As described in the Treasury Green Book, the most common technique used to compare unvalued costs and benefits is weighting and scoring (multi-criteria analysis). This method of weighting and scoring involves weights being assigned to criteria, and then scoring options in terms of how well they perform against those weighted criteria. The weighted scores are then summed, allowing for the options to be ranked. The weighting given to criteria is often based on the combined judgements of experts, stakeholders and the decision makers.

The specific solution should then be developed and implemented following the identification of all costs, benefits and risks. The consideration of unvalued costs and benefits is less simple than the consideration of purely monetary considerations. As the scores are not expressed in monetary values, judgement is required to compare the results of weighting and scoring with the cost benefit or cost effectiveness analysis [HM Treasury, 2003]. These two analyses should be complementary to each other and can indicate if further investigation is required before a decision can be made.

4.2 RISK AND PROBABILITY ASSESSMENT

As there still exists much uncertainty about the patterns and magnitude of future climate change, a risk assessment must be carried out before any cost valuation can be done. This uncertainty has to be managed in order for effective outcomes to be developed.

The magnitude of climate risks must be estimated so that their relative importance can be measured. This feeds into the adaptation response development stage. The prioritisation and ranking of risks is carried out in order to estimate the positive or negative impacts of climate change in the absence of any adaptation method (i.e. in a 'do nothing' scenario).

Task 3 of this project was to carry out a desk-top study of the existing policies and standards contained with the 3CAP region's key documentation where the impact of climate change will be highest, using a broad risk and probability assessment technique. The key documents assessed, but not limited to, include:

Derbyshire County Council

- Highway Network Management Plan (HNMP)
- HNMP Technical Annexes
- Policies and Standards 1981 (Volumes 1 and 2)
- Maintenance Policies and Standards 1997 (Volumes 1 and 2)
- Winter Service: Statement of Policy
- Winter Service Operational Plan (Draft)
- Consulting and Contracting Winter Services Procedure
- Partnership Agreement for Derbyshire Partnership Forum
- Environmental Management Manual

Leicestershire County Council

- Highways Transport and Development
- Highways Inspection Operational Manual 2006
- Highways Maintenance Policy and Strategy
- Landscape and Woodland Strategy
- Leicestershire County Council Transport Asset Management Plan (TAMP)
- Specification for Highway Works for New Developments
- Standard Conditions Applying to Highway Works for New Developments

Nottinghamshire County Council

- Highway Network Management Plan (HNMP)
- Highway Structures Lifecycle Plan
- Street Lighting Lifecycle Plan
- Traffic Signal Control Lifecycle Plan
- Winter Service Operational Plan 2007-08
- Nottinghamshire's Local Area Agreement 2008-11
- Flooding, Drainage and Watercourse Draft Report

These documents were reviewed to identify which policies and standards currently exist and are being implemented within the 3CAP region. To ensure that the risk and probability assessment and the development of an adaptation action plan is as effective as possible, four key climate change types have been focused on during this work:

1. Hotter and drier summers;
2. More intense rainfall;
3. Stronger winds and more storminess; and
4. Warmer winters.

Table 3 shows the highway network policies and standards that have been identified as being likely to be affected by these four predicted aspects of current and future climate change. The table shows the policies and standards considered against each of these four climate change effects. This will be applied in further stages of the assessment.

Table 3: Identification of the 3CAP highway network policies and standards likely to be affected by climate change

	Climate Change Type			
Policy / Standard	**Hotter and drier summers**	**More intense rainfall**	**Stronger winds and more storminess**	**Warmer winters**
Carriageway patching and minor repair	✓	✓	✓	
Carriageway resurfacing	✓	✓		
Overlay and reconstruction	✓	✓		
Carriageway surface treatment*	✓	✓		
Skidding resistance policy (SCRIM)	✓	✓	✓	
High skid resistant surfacing		✓	✓	
Early life skidding resistance		✓	✓	
Highway inspections	✓	✓	✓	✓
Materials*	✓	✓	✓	✓
Drainage*	✓	✓	✓	
Earthworks	✓	✓	✓	
Maintenance of street furniture	✓	✓	✓	
Street lighting	✓	✓	✓	
Bridges and other structures*	✓	✓	✓	
Footbridges and subways	✓	✓	✓	
Maintenance of monuments and historic structures in the highway	✓	✓	✓	
Grass cutting*	✓	✓	✓	✓
Maintenance of soft landscaped areas	✓	✓	✓	
Tree and hedge maintenance*	✓	✓	✓	✓
Verge maintenance	✓	✓	✓	
Weed treatment	✓	✓	✓	
Edge cutting back (siding)	✓	✓	✓	
Cultivation licences		✓	✓	
Biodiversity	✓	✓	✓	
Conservation	✓	✓	✓	
Tree planting	✓	✓	✓	
Mud or dung on the highway		✓	✓	
Flooding		✓	✓	
Traffic management	✓			
Emergencies		✓	✓	✓
Emergency road closures and diversions		✓	✓	✓
Hazards on the highway		✓	✓	✓
Road traffic accidents		✓	✓	
Severe weather warnings		✓	✓	✓
Consultation with parish and town councils	✓	✓	✓	✓
Safety fencing		✓	✓	
Tourism signing	✓			
Temporary signs	✓	✓		✓
Traffic calming	✓			
Vehicle-activated interactive road signs		✓	✓	✓
Road safety		✓	✓	
Park and ride sites	✓			
Public transport policies	✓			
Carriageway markings for cyclists	✓			
Speed limits			✓	
Health and safety			✓	
Winter maintenance*		✓	✓	✓

*** Selected for adaptation response development and evaluation (Section 5)**

Table 3 shows that some policies and standards will be affected by more than one of the climate change types (such as; carriageway patching and minor repair, consultation with parish and town councils, conservation, and bridges and other structures). Others will only be impacted upon by one climate change effect (such as; public transport policies, traffic management and tourism signing).

The risk and probability assessment on the effects of climate change on 3CAP's highway network policies and standards, comprises of a number of stages of analysis, as shown in Table 4.

Table 4: Risk and probability assessment methodology

Stage of the Risk and Probability Assessment	**Process**
1. Climate Change Type	Identifying the primary climate change types (4 no.) based on UKCIP02 predictions and findings from the Task 1 Literature Review.
2. Effect	Identifying the likely effects on highway network as a result of these climate change types. This is based on findings from the literature review, feedback obtained during the Task 2 Individual Meetings and Task 4 Workshop, and direction from the project partners.
3. Policies and Standards Affected	Identifying the highway network policies and standards likely to be affected by the climate change effects. This is based on findings from the Task 3 desk-top study of policies and standards, and as shown in Table 3.
4. Impact	Assessing the likely impact of the climate change effect in terms of magnitude and severity. The impact is given a numerical score of between 1 and 3 (with 3 being the highest level of predicted impact). This is based on findings from the literature review, feedback obtained during the Task 2 Individual Meetings and Task 4 Workshop, and direction from the project partners.
5. Probability	Assessing the probability of the climate change type and effect occurring. The probability is given a numerical score of between 1 and 3 (with 3 being the highest level of probability). This is based on UKCIP02 predictions, findings from the literature review and guidance from the project partners.
6. Local Authority Influence	Assessing the influence and responsibility of the 3CAP authorities on the likely effects of climate change on their highway networks. The level of influence is given a numerical score of between 1 and 3 (with 3 being the highest level of influence and responsibility). This is based on feedback obtained during Task 2 Individual Meetings and the Task 4 Workshop, and from direction from the project partners.
7. Overall Risk Score	Calculating the overall Risk Score. This is a result of the scores for impact and probability being multiplied together (to obtain a score between 1 and 9) and this figure then being multiplied by the level of local authority influence. This final Risk Score (out of a maximum of 27) can then be used to rank the climate change effects in order of significance to 3CAP's highway network policies and standards. The effects are given a colour code according to their overall Risk Score. The highest scores **(27 or 18)** being coloured **red**, followed by those with a score of **12 or 9** being coloured **orange**, those with a score of **6 or 8** being coloured **yellow**, and those with a score **<5** being coloured **beige**
8. Effect Code	Based on the overall Risk Score and colour coding, each climate change effect is given an Effect Code. This code represents where each effect sits in the hierarchy of risk (i.e. those coded **Rn** are the most significant effects with the greatest probability and risk, followed by those coded **On**, **Yn** then **Bn**). These Effect Codes are carried forward to the development and analysis of the adaptation plan.

Tables 5 to 8 show the risk assessments for the effects of the four identified key climate change types (hotter and drier summers, more intense rainfall, stronger winds and more storminess, warmer winters) on 3CAP's highway network.

Table 5: Risk and Probability Assessment – Hotter and Drier Summers

Climate Change Type	Effect	Policies and Standards affected	Impact (I)	Probability (P)	Score (I x P)	Local Authority Influence	Overall Risk	Effect Code
Hotter and drier summers	Pavement failure from prolonged high temperatures	Carriageway patching and minor repair; carriageway resurfacing; carriageway surface treatment; overlay and reconstruction; carriageway surface treatment; skidding resistance (SCRIM) policy; highway inspections; materials	**3** The impact on the highway network is likely to be significant	**2** There is already evidence of this and the magnitude of the problem will increase over time	6	**3** The LAs are responsible for the maintenance and operation of their highway network	18	R1
	Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate	Grass cutting; tree and hedge maintenance; verge maintenance; weed treatment; edge cutting back (siding); highway inspections; consultation with parish and town councils; biodiversity; maintenance of soft landscaped areas; bridges and other structures; drainage; materials; carriageway surface treatment; carriageway resurfacing	**3** There will be significant financial and resource implications as a result of a lengthened growing season. There will also be increased waste from grass and tree cuttings	**2** There is already evidence of this and the magnitude of the problem will increase over time	6	**3** The LAS are responsible for the maintenanec of the soft estate	18	R2
	Plant and animal species changing, shifting patterns of migration and plants flowering earlier	Grass cutting; tree and hedge maintenance; verge maintenance; weed treatment; edge cutting back (siding); conservation; tree planting; highway inspections; consultation with parish and town councils, biodiversity; maintenance of soft landscaped areas; materials	**2** This may lead to significant financial and resource implications and may put pressure on the soft estate	**1** There is beginning to be some evidence of changes in plant species and growing patterns	2	**1** The LAs have little control over the behaviour and migration of animal and plant species	**2**	B1
	Increased recreation and leisure based travel in the summer months	Carriageway patching and minor repair; carriageway resurfacing, overlay and reconstruction; carriageway surface treatment; highway inspections; materials; public transport policies; carriageway markings for cyclists; tourism signing; temporary signs; traffic calming; traffic management; park and ride sites; consultation with parish and town councils; bridges and other structures; biodiversity	**2** This will put pressure on the highway network and increase the need for maintenance work	**1** Unknown probability	2	**1** The LAs have little control over the behaviour and leisure choices of the public	**2**	B2
	Modal shift. Increased number of cars and bikes on the road as people move away from public transport in hot tempertures	Carriageway patching and minor repair; carriageway resurfacing, overlay and reconstruction; carriageway surface treatment; highway inspections; materials; public transport policies; carriageway markings for cyclists; tourism signing; temporary signs; traffic calming; traffic management; park and ride sites; biodiversity	**2** This will put pressure on the highway network and increase the need for maintenance work	**1** Unknown probability	2	**2** The LAs have some control over modal choices and can promote and encourage the use of public transport	**4**	B3
	Surface damage to structures	Maintenance of street furniture; street lighting; bridges and other structures; footbridges and subways; maintenance of monuments and historic structures in the highway; earthworks; materials; highway inspections; carriageway surfacing, carriageway patching and minor repair; carriageway surface treatment	**2** This will have significant effects on the maintenance needs of structures and will put pressure on the 3CAP region's financial and workforce resources	**2** There is already some evidence of this and it is likely to increase in magnitude as climate change develops	4	**3** The LAs are responsible for the maintenance and operation of the structures within their highway network	**12**	O1
	Fire risk on the soft estate	Grass cutting; maintenance of soft landscaped areas; tree and hedge maintenance; verge maintenance; weed treatment; consultation with parish and town councils; biodiversity; materials	**1** This will have some irregular and unpredicatable impacts on the emergency department within the 3CAP authorities	**1** Unknown probability	1	**3** The LAs are responsible for the maintenance of the soft estate on their highway network	**3**	B4

Key

(red)	Very high risk
(orange)	High risk
(yellow)	Medium risk
(light orange)	Low risk

Table 6: Risk and Probability Assessment – More Intense Rainfall

Climate Change Type	Effect	Policies and Standards affected	Impact (I)	Probability (P)	Score (I x P)	Local Authority Influence	Overall Risk	Effect Code
More intense rainfall	Lack of capacity in the drainage system and flooding of the highway network	Carriageway patching and minor repairs; carriageway surface treatment; carriageway resurfacing; high skid resistant surfacing; skidding resistant (SCRIM) policy; early life skidding resistance; flooding; emergency road closures and diversions; severe weather warnings; temporary signs; vehicle-activated interactive road signs; road safety; bridges and other structures; footbridges and subways; maintenance of monuments and historic structures in the highway; drainage; materials; highway inspections; consultation with parish and town councils; winter maintenance	**3** There will be severe impacts on the higwhay network a a result of flooding. This will put huge prressure on authority resources	**3** There is already evidence of this happening and it will worsen as climate change impacts develop	9	**2** The LAs have some level of responsibility over the maintenance and operation of their drainage systems	**18**	**R3**
	Scour to structures	Maintenance of street furniture; street lighting; bridges and other structures; footbridges and subways; maintenance of monuments and historic structures in the highway; earthworks; materials; flooding; drainage; highway inspections; materials; carriageway surface treatment; carriageway resurfacing; carriageway patching and minor repair	**2** This will have effects on the maintenance needs of structures and will put pressure on the 3CAP region's financial and workforce resources	**2** There is already some evidence of this and it is likely to increase in magnitude as climate change develops	4	**3** The LAs are responsible for the maintenance and operation of the structures within their highway network	**12**	**O2**
	Damage to pavement surface layers	Carriageway patching and minor repair; carriageway resurfacing, overlay and reconstruction; carriageway surface treatment; skidding resistance (SCRIM) policy; highway inspections; materials; flooding; drainage; winter maintenance	**2** This will put pressure on the highway network and increase the need for maintenance work	**2** There is beginning to be some evidence of the imapct of heavy rainfall and flooding of pavement condition	4	**3** The LAs are responsible for the maintenance and operation of their highway network	**12**	**O3**
	Top soil run-off	Conservation; cultivation licences; edge cuting back (siding); grass cutting; maintenance of soft landscaped areas; tree and hedge maintenance; tree planting; verge maintenance; weed treatment; safety fencing; flooding; drainage; earthworks; mud or dung on the highway; highway inspections; consultation with parish and town councils; biodiversity; winter maintenance; carriageway surface treatment; carriageway resurfacing; materials	**2** This may lead to increased financial and resource implictions for the highway network authorities	**2** There is already some evidence of this and it is likely to increase in magnitude as climate change develops	4	**1** The LAs have little influence over the top soil run-off from the land around their highways	**4**	**B5**
	Tree root damage	Conservation; cultivation licences; edge cuting back (siding); grass cutting; maintenance of soft landscaped areas; tree and hedge maintenance; tree planting; verge maintenance; weed treatment; safety fencing; flooding; drainage; earthworks; carriageway patching and minor repairs; carriageway resurfacing; carriageway surface treatment; highway inspections; consultation with parish and town councils; bridges and other structures; biodiversity; materials	**2** This may have some effect on trees on the soft estate	**1** Unknown probability	2	**2** The LAs have responsibility for the maintenance and management of trees on land under their control	**4**	**B6**
	Landslips	Conservation; cultivation licences maintenance of soft landscaped areas; verge maintenance; tree planting; tree and hedge maintenance; safety fencing; emergencies; emergency road closures and diversions; flooding; hazards on the highway; road traffic accidents; temporary signs; vehicle-activated interactive road signs; bridges and other structures; drainage; earthworks; mud or dung on the highway; highway inspections, biodiversity; highway patching and minor repair; materials	**2** This will have some irregular and unpredicatable impacts on the emergency department within the 3CAP authorities	**2** There is some evidence of this already but the future probability is difficult to predict	4	**2** The LAs have responsibility for the safety and maintenance of their land around the highway network	**8**	**Y1**
	Embankment erosion	Conservation; cultivation licences; edge cuting back (siding); grass cutting; maintenance of soft landscaped areas; tree and hedge maintenance; tree planting; verge maintenance; weed treatment; safety fencing; flooding; drainage; bridges and other structures; earthworks; mud or dung on the highway; highway inspections; consultation with parish and town councils; biodiversity; carriageway patching and minor repairs; carriageway surface treatment; carriageway resurfacing; materials	**2** This will put pressure on the highway authorities and increase the need for embankment monitoring and maintenance work	**2** There is some evidence of this already and it is likely to increased as climate change develops	4	**2** The LAs have responsibility for the safety and maintenance of their land around the highway network	**8**	**Y2**
	Subsidence and heave on the highway	Carriageway patching and minor repairs; carriageway surface treatment; carriageway resurfacing, overlay and construction; edge cutting back (siding); tree and hedge maintenance; flooding, drainage, materials; bridges and other structures; earthworks; highway inspections; winter maintenance	**2** This will lead to increased financial and resource implictions for the highway network authorities	**2** There is some evidence of this already and it is likely to increased as climate change develops	4	**3** The LAs are responsible for the maintenance and operation of their highway network	**12**	**O4**

Key

(red)	Very high risk
(orange)	High risk
(yellow)	Medium risk
(light orange)	Low risk

Table 7: Risk and Probability Assessment – Stronger Winds and More Storminess

Climate Change Type	Effect	Policies and Standards affected	Impact (I)	Probability (P)	Score (I x P)	Local Authority Influence	Overall Risk	Effect Code
Stronger winds and more storminess	Scour and damage to structures	Maintenance of street furniture; street lighting; bridges and other structures; footbridges and subways; maintenance of monuments and historic structures in the highway; earthworks; materials; flooding; drainage; highway inspections; severe weather warnings; carriageway resurfacing; carriageway surface treatment	2 This will have significant effects on the maintenance needs of structures and will put pressure on the 3CAP region's financial and workforce resources	2 There is already some evidence of this and it is likely to increase in magnitude as climate change develops	4	3 The LAs are responsible for the maintenance and operation of the structures within their highway network	12	O5
	Severe damage to light-weight structures	Maintenance of street furniture; street lighting; tree and hedge maintenance; bridges and other structures; footbridges and subways; maintenance of monuments and historic structures in the highway; earthworks; materials; flooding; drainage; emergencies, emergency road closures and diversions, hazards on the highway; highway inspections; carriageway resurfacing; carriageway patching and minor repair; carriageway surface treatment	2 This will have significant effects on the maintenance needs of structures and the safety of the network. It will put pressure on the 3CAP region's financial and workforce resources	2 There is already some evidence of this and it is likely to increase in magnitude as climate change develops	4	3 The LAs are responsible for the maintenance and operation of the structures within their highway network	12	O6
	Top soil and embankment erosion	Conservation; cultivation licences; edge cutting back (siding); grass cutting; maintenance of soft landscaped areas; tree and hedge maintenance; tree planting; verge maintenance; weed treatment; safety fencing; flooding; drainage; bridges and other structures; earthworks; mud or dung on the highway; highway inspections; consultation with parish and town councils; biodiversity; winter; carriageway patching and minor repairs; carriageway surface treatment; carriageway resurfacing maintenance; materials	2 This will put pressure on and increase the need for embankment monitoring and maintenance work	2 There is some evidence of this already and it is likely to increased as climate change develops	4	2 The LAs have responsibility for the safety and maintenance of their land around the highway network	8	Y3
	Tree damage	Conservation; cultivation licences; edge cutting back (siding); maintenance of soft landscaped areas; tree and hedge maintenance; tree planting; verge maintenance; weed treatment; safety fencing; flooding; drainage; earthworks; carriageway patching and minor repairs; highway inspections; consultation with parish and town councils; biodiversity; winter maintenance; bridges and other structures; materials	2 This may have some effect on the safety of the highway network and may lead to the obstruction of structures	2 This may as climate change develops and there are more storms and extreme weather events	4	2 The LAs have responsibility for the maintenance and management of trees on land under their control	8	Y4
	Increased leaf-fall	Conservation; cutivation licences; grass cutting; edge cutting back (siding); maintenance of soft landscaped areas; tree and hedge maintenance; tree planting; verge maintenance; skid resistant surfacing; skidding resistant (SCRIM) policy; early life skidding resistance; hazards on the highway; drainage; highway inspections; consultation with parish and town councils; biodiversity; winter maintenance; bridges and other structures; materials	2 This may have some effect on the safety of the highway network and may lead to the obstruction of drainage	2 This may as climate change develops and there are more storms and extreme weather events	4	1 The LAs have limited control over leaf-drop and only manage the trees on their land	4	B7
	Increased accidents on the network	Safety fencing; high skid resistance surfacing; skidding resistance (SCRIM) policy; early life skidding resistance; tree and hedge maintenance; emergencies; emergency road closures and diversions; highway patching and minor repair; flooding; hazards on the highway; road traffic accidents; vehicle-activated interactive road signs; road safety; speed limits; health and safety; highway inspections; severe weather warnings; winter maintenance; materials	2 This will have some irregular and unpredicatable impacts on the emergency department within the 3CAP authorities	1 This may as climate change develops and there are more storms and extreme weather events	2	2 The LAs have responsibility for the safety of their highway network	4	B8

Key

(red)	Very high risk
(orange)	High risk
(yellow)	Medium risk
(peach)	Low risk

Table 8: Risk and Probability Assessment – Warmer Winters

Climate Change Type	Effect	Policies and Standards affected	Impact (I)	Probability (P)	Score (I x P)	Local Authority Influence	Overall Risk	Effect Code
Warmer winters	Less disruption by snow and ice	Winter maintenance; highway inspections; consultation with parish and town councils; emergencies; emergency road closures and diversions; hazards on the highway; severe weather warnings; temporary signs; vehicle-activated interactive road signs; materials; carriageway resurfacing; carriageway surface treatment; carriageway patching and minor repair; grass cutting; tree and hedge maintenance	2 Less requirement for salting and snow and ice removal. Financial and resource savings	2 There is likely to be less requirement for winter maintenance as climate change develops. However, the probability and magnitude is difficult to predict	4	3 The LAs are responsible for all aspects of winter maintenance work on their network	12	O7

Key

(red)	Very high risk
(orange)	High risk
(yellow)	Medium risk
(peach)	Low risk

From the risk and probability assessment, it is possible to rank those climate change risks that are expected to have the most impact on the highway network and its associated policies and standards. As each of the effects have been given a total risk score up to a maximum of 27, based on impact, probability and local authority influence, the risks can be prioritised by ranking them in order of overall risk score, as shown in Table 9. This forms the Climate Change Adaptation Risk Register for the 3CAP region's highway network.

Table 9: Climate Change Adaptation Risk Register

Effect	Climate Change Type	Overall Risk Score	Effect Code
Pavement failure from prolonged high temperatures	Hotter and drier summers	18	R1
Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate	Hotter and drier summers	18	R2
Lack of capacity in the drainage system and flooding of the highway network	More intense rainfall	18	R3
Surface damage to structures	Hotter and drier summers	12	O1
Scour to structures	More intense rainfall	12	O2
Damage to pavement surface layers	More intense rainfall	12	O3
Subsidence and heave on the highway	More intense rainfall	12	O4
Scour and damage to structures	Stronger winds and more storminess	12	O5
Severe damage to light-weight structures	Stronger winds and more storminess	12	O6
Less disruption by snow and ice	Warmer winters	12	O7
Landslips	More intense rainfall	8	Y1
Embankment Erosion	More intense rainfall	8	Y2
Top-soil and embankment erosion	Stronger winds and more storminess	8	Y3
Tree damage	Stronger winds and more storminess	8	Y4
Plant and animal species changing, shifting patterns of migration and plants flowering earlier	Hotter and drier summers	2	B1

Increased recreation and leisure based travel in the summer months	Hotter and drier summers	2	B2
Modal shift. Increased number of cars and bikes on the road as people move away from public transport in hot weather	Hotter and drier summers	4	B3
Fire risk on the soft estate	Hotter and drier summers	3	B4
Top soil run-off	More intense rainfall	4	B5
Tree root damage	More intense rainfall	4	B6
Increased leaf-fall	Stronger winds and more storminess	4	B7
Increased accidents on the network	Stronger winds and more storminess	4	B8

Table 9 shows the hierarchy of risks from climate change on the highway network and serves to achieve the objective of Task 3 of this project. The top three identified risks are:

- Pavement failure from prolonged high temperatures;
- Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate; and
- Lack of capacity in the drainage system and flooding of the highway network.

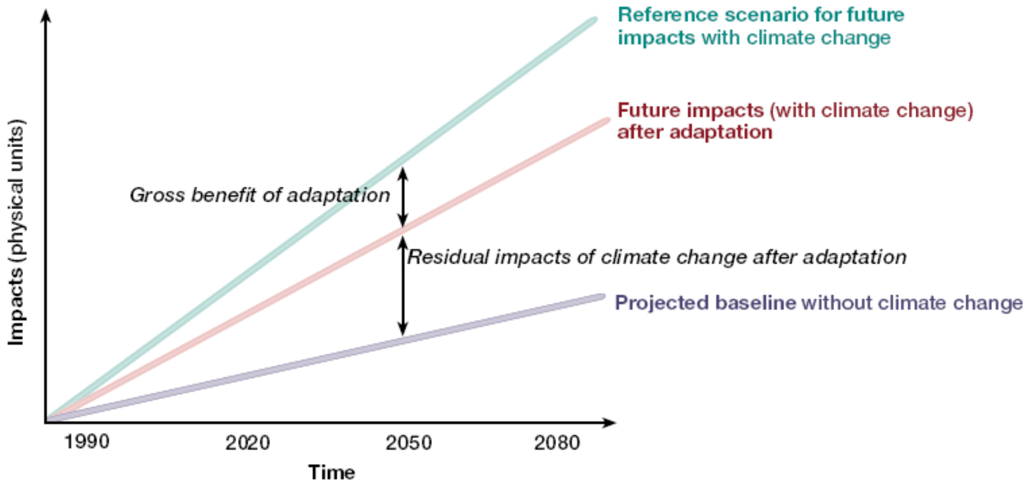
The risks shown in Table 9 have been used to assess and prioritise the adaptation responses developed in the adaptation plan.

5. ADAPTATION RESPONSE DEVELOPMENT AND EVALUATION

In order to ensure that the effects of climate change on 3CAP's highway network are minimised, adaptation of existing policies, standards and strategies needs to be carried out. From the results of the risk and probability assessment, climate change effects have been ranked into a hierarchy of probability and impact (Ref. Table 9). This hierarchy has been used as the basis of the development of adaptation responses and their subsequent evaluation. The following sections give an overview of the processes of adaptation option appraisal, multi-criteria analysis (MCA), evaluation criteria development and weighting, development of adaptation responses and evaluation of the responses using a MCA technique.

5.1 BACKGROUND OF ADAPTATION OPTION APPRAISAL

UKCIP costing guidelines found in 'Costing the impacts of climate change in the UK: Overview of guidelines' [Metroeconomica, 2004], provide guidance for decision-makers to develop adaptation responses to climate change risks or opportunities. Responses are developed to reduce the negative, or enhance the positive impacts of climate change risks. Reduction or enhancement of the risk can be classed as the 'effectiveness' of the adaptation response, or the 'gross benefits' of the adaptation. As shown in Figure 4, the gross benefit of adaptation is the estimated impact of climate change in the absence of adaptation measures, minus the estimated impacts with adaptation.



[Metroeconomica, 2004]

Figure 4: The benefits of adaptation to climate change

This information allows decision makers to assess whether the gross benefit of an adaptation response is greater than the actual cost of the response. This in turn allows for the decision-maker to either accept or reject the adaptation response, or to rank the responses in order of magnitude of benefit.

Decision / evaluation criteria should be established to evaluate the adaptation options available (an 'options appraisal'). Once climate risks have been quantified and the costs of adaptation responses have been valued, a **cost-benefit analysis (CBA)** can be carried out. According to UKCIP guidance, a CBA is:

> *'…designed to show whether the total advantages (benefits) of a project or policy intervention – e.g. an adaptation option – exceed the disadvantages (costs). This essentially involves calculating in monetary terms all of the costs and benefits, including terms for which the market does not provide an observable measure of value, accruing*

> *to all affected parties. The affected parties should include not only the policy/programme/project participants and consumers, but also third parties who are affected. Basically, an adaptation project represents a good investment if the aggregate benefits exceed the aggregate costs'*
>
> [Metroeconomica, 2004: p12]

However, many of the impacts of climate change cannot be measured in monetary terms and so these should be assessed using a form of a **multi-criteria analysis (MCA).** As described in UKCIP costing guidance, a MCA:

> *'…has been developed to account for the fact that some effects cannot be measured, or cannot be costed. Moreover, economic efficiency may not be sole criterion in climate adaptation decisions. Other objectives, including flexibility, avoiding irreversibility, equity, risk and uncertainty, political sensitivity, etc. are important. MCA essentially involves defining a framework to integrate different decision criteria in a quantitative analysis without assigning monetary values to all factors. HM Treasury refer to MCA as 'weighting and scoring'*
>
> [Metroeconomica, 2004].

The MCA method has been applied within this project. Further detail on the MCA process and its implementation is found in Section 5.2.

5.1.1 Uncertainty

Due to the relative uncertainty about the magnitude and impacts of climate change in the future, developing adaptation responses can be complex as it is difficult to predict the true magnitude of the effects of changes to the climate. As a result, the range of adaptation responses that can be implemented under this uncertainty can be categorised into the groups below. By categorising responses at the decision making stage, the potential range of adaptation methods can be ranked and prioritised in order of magnitude, certainty and impact.

Optimistic	-	The option *may* produce the best adaptation outcome
Precautionary	-	The option associated with the most favourable of the least favourable possible outcomes
Least Regret	-	The option associated with the lowest lost opportunities or regret
No-Regret	-	The best adaptation option under all possible outcomes

Furthermore, according to UKCIP, when anticipating future climate trends, mistakes can be made in decision making. Uncertainty over the impacts and effects of climate change will lead to mistakes and errors being made at times with regards to adaptation responses. The types and levels of potential decision making mistakes are shown in Table10.

Table 10: Typical climate change adaptation decision errors

Consequence of poor decision	Description of cause of poor decision
Under-adaptation – 1	Where adaptation to climate change is or should be an essential component of the decision, but is either ignored, or insufficient action are taken to adapt.
Under-adaptation – 2	Where non-climate factors are perceived as having greater importance to the decision than climate change factors, the result may be that insufficient weight is attached to the need for adaptation. This may lead to under-adaptation.
Over-adaptation – 1	Actions taken where climate change is considered to be a significant factor on the decision to be taken, but where it will have or should have little or no influence on that decision.
Over-adaptation – 2	Actions taken where non-climate factors that should have a significant influence on the decision are ignored or given insufficient weight compared to climate change factors. This may tend to lead to over-adaptation.
Maladaptation	Actions taken that reduce the options or ability of decision-makers now or in the future to manage the impacts of climate change. Such actions are sometimes described as reducing climate headroom.

[Connell and Willows, 2003]

It is important to ensure that these decision errors are considered during the development and assessment of adaptation responses. By conducting the exercise using a multi-criteria analysis technique and incorporating the findings from the literature review, individual meetings with the 3CAP counties and project team and the Workshop, these concerns were minimised.

5.2 MULTI-CRITERIA ANALYSIS (MCA)

As discussed in Section 5.1, economic efficiency cannot always be used exclusively as the evaluation criteria when assessing climate change adaptation responses. Techniques such as cost-benefit analysis (CBA) work well as a decision-making tool when costs and benefits can be valued in monetary terms. However, many environmental and social impacts can not be valued in this way. Many climate change impacts cannot be valued in monetary terms and so other criteria should be considered, such as; flexibility, political sensitivity, public acceptance, sustainability and environmental impact. According to UKCIP guidance [Metroeconomica, 2004] multi-criteria analysis (MCA), or 'weighting and scoring', techniques are different to typical CBA methods as they:

- Do not restrict the decision-making process to economic efficiency criteria:
- Allow for climate impacts to be measured in units other then monetary ones; and
- Do not require the use of economic valuation to accommodate climate impacts in the decision-making process, but may still include it.

MCA allows for a comparative assessment of alternative methods of interventions to be carried out. The form of analysis is designed to allow for several criteria to be taken into account simultaneously and for decision-makers to be integral to all stages of the process. UKCIP guidance splits the process of MCA into four steps as shown in Figure 5.

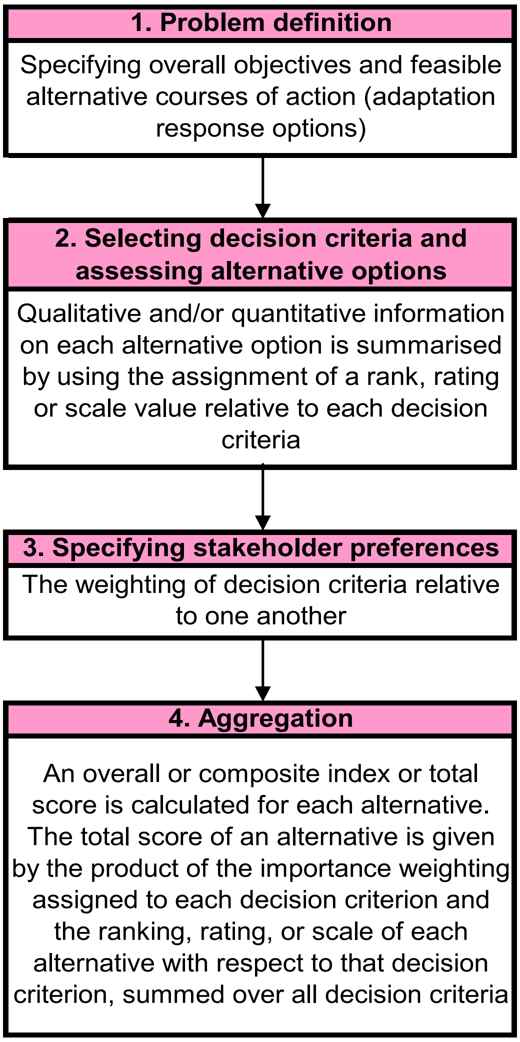


Figure 5: The MCA process [Metroeconomica, 2004]

A MCA allows for the integration of different objectives in a quantitative analysis without needing to assign monetary values to the impacts. Other units can be used to systematically compare adaptation responses. Compared to decisions made simply by informal judgement and personal opinion, MCAs offer a number of advantages, including:

- They are open and explicit;
- The objectives and criteria that are chosen by the decision-making group are open to analysis and change if it is deemed necessary;
- The scores and weights selected are established according to established techniques;
- The measurement of performance can be carried out by experts or the decision-making body themselves;
- It can provide an important communication tool between the decision-makers and the wider community; and
- The use of scores and weights mean that it can be easily audited.

[DTLR, 2002]

However, as auditable monetary values are not applied, there is the risk that a MCA analyses can be subjected to bias and personal opinion which may influence the evaluation criteria applied and lead to unrealistic weighting of the criteria being carried forward to the evaluation stage. It is important that subjectivity and professional knowledge and judgement are used throughout the MCA process.

5.3 EVALUATION CRITERIA DEVELOPMENT

In order to assess the range of adaptation responses developed, a single list of evaluation criteria has been established. This list is derived from the findings from all previous tasks and specifically from delegate input from the Task 4 Workshop. Using the criteria to evaluate the adaptation responses allows a MCA to be carried out. This will assess the climate impacts and the possible adaptation responses in non-monetary terms and will facilitate the decision-making process. The choice of evaluation criteria, their definition and their relative weighting are central to the process of MCA.

The criteria needs to be as exhaustive as possible and should represent the views and concerns of the decision-makers and those that the final decision will affect. The criteria should contribute to the achievement of the objectives set out in original project and organisational aims. The evaluation criteria to be applied to the suggested adaptation responses consist of thirteen aspects, identified by the Task 4 Workshop delegates, as detailed in Figure 6:

1) **Cost – capital:** what will be the initial cost for implementing the response? Will new staff, machinery or other resources be needed?
2) **Cost – whole-life:** what will the whole-life cost of the adaptation be? Will the cost be continuous or is it likely to increase/ decrease over time?
3) **Technical feasibility:** is the adaptation response technically feasible with the available technology? Will it require the investigation of alternative techniques or technologies?
4) **Practicality:** is the adaptation response practical? Can it be carried out in accordance with existing county council practices and principles?
5) **Politically acceptable:** is the adaptation response politically acceptable? Does it comply with existing legislation and government strategy? Will it attract political criticism or scrutiny?
6) **Publically acceptable:** is the adaptation response publically acceptable? Does it address public concerns and priorities? Will it attract public criticism or scrutiny?
7) **Future-proof:** will the adaptation response meet future needs? Will there be an end-of-life cost scenario? Is the response adaptable to changes in demand, impact and resource availability?
8) **Environmental impact:** what is the environmental impact of the adaptation response? Will the response lead to adverse environmental effects (to air, water, land etc)? Will the response contradict county council objectives for reducing carbon emissions and reducing waste?
9) **Level of county council control / responsibility:** how much influence and control do the county council have over the impact area? Will the council be able to effectively be able to implement and manage the adaptation response without outside influence and interference? Do the council need the approval and assistance of outside organisations or regulatory bodies to be able to implement the adaptation?
10) **Sustainability of the response:** is the adaptation response sustainable? Can the response be embedded into existing council policies and standards and be implemented in a sustainable and long-term method??
11) **Risk of no action:** what is the risk associated with doing nothing? Will the end cost of doing nothing be greater than the cost of implementing the adaptation response?
12) **Scale / impact of the response:** what will be the overall impact of the adaptation response? Will the magnitude of the effect make the additional cost and resource

implications worthwhile? Will it be possible to audit the adaptation's level of success?

13) **Resources / skills / knowledge available to implement the adaptation:** do the councils have the resources available to implement the adaptation response immediately with the existing skills and knowledge in their authority?

Figure 6: Adaptation Response Evaluation Criteria

5.3.1 Weighting the criteria

In order to be able to apply these criteria to the adaptation responses, they need to be ranked in order of importance (as discussed in Section 5.2). Using a scale to rank the evaluation criteria allows for a relative assessment of the responses to be conducted and an aggregate evaluation score to be established for each adaptation option. Looking at the evaluation criteria in this way allows for a realistic representation of the most effective responses to be made and allows for the decision-makers to have an ongoing input into adaptation development.

A combination of professional judgement, feedback from delegates at the Task 4 Workshop and project stakeholders has been applied to rank the criteria accordingly. This ranking system will be referred to in the final stages of the decision-making process.

Table 11 shows the evaluation criteria ranked according to perceived county council relevance and importance. Weighting has been allocated out of a total 100 points. As the difference in importance between the evaluation criteria is minimal in many cases, the criteria were given scores of either 10, 7.5 or 5 so not to produce significant gaps between the levels of ranking.

Table 11: Weighting of the evaluation criteria

Evaluation Criteria	Weighting
Cost – capital	10 %
Cost – whole-life	10 %
Technical feasibility	10 %
Risk of no action	10 %
Environmental impact	10 %
Sustainability of the response	7.5 %
Practicality	7.5 %
Level of county council control/ responsibility	7.5 %
Scale/ impact of the response	7.5 %
Politically acceptable	5 %
Publically acceptable	5 %
Resources/ skills/ knowledge available to implement the adaptation	5 %
Future-proof	5 %
TOTAL	**100 %**

5.4 DEVELOPING THE ADAPTATION RESPONSES

From the development of the 3CAP region's Climate Change Adaptation Risk Register (see Section 4.2), the climate change effects have been ranked in order of risk and probability.

Very High (Red)

- Pavement failure from prolonged high temperatures (hotter and drier summers) – **R1**
- Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate (hotter and drier summers) – **R2**
- Lack of capacity in the drainage system and flooding of the highway network (more intense rainfall) – **R3**

High (Orange)

- Surface damage to structures (hotter and drier summers) – **O1**
- Scour to structures (more intense rainfall) – **O2**

- Damage to pavement surface layers (more intense rainfall) – **O3**
- Subsidence and heave on the highway (more intense rainfall) – **O4**
- Scour and damage to structures (stronger winds and more storminess) – **O5**
- Severe damage to light-weight structures (stronger winds and more storminess) – **O6**
- Less disruption by snow and ice (warmer winters) – **O7**

Medium (Yellow)

- Landslips (more intense rainfall) – Y1
- Embankment erosion (more intense rainfall) – Y2
- Top-soil and embankment erosion (stronger winds and more storminess) – Y3
- Tree damage (stronger winds and more storminess) – Y4

Low (Beige)

- Plant and animal species changing, shifting patterns of migration and plants flowering earlier (hotter and drier summers) – B1
- Increased recreation and leisure based travel in the summer months (hotter and drier summers) – B2
- Modal shift. Increased number of cars and bikes on the road as people move away from public transport in hot temperatures (hotter and drier summers) – B3
- Fire risk on the soft estate (hotter and drier summers) – B4
- Top soil run-off (more intense rainfall) – B5
- Tree root damage (more intense rainfall) – B6
- Increased leaf-fall (stronger winds and more storminess) – B7
- Increased accidents on the network (stronger winds and more storminess) – B8

From this Climate Change Adaptation Risk Register, it is now possible to undertake an assessment of the most effective adaptation responses to be implemented by the 3CAP counties to help adapt to the effects of climate change.

The first stage of this process is to individually consider which of the main policies and standards are likely to be affected by climate change, as shown in Section 4.2, Table 3. The policies and standards chosen to be assessed in detail are:

1. Bridges and other structures;
2. Drainage;
3. Grass cutting;
4. Materials;
5. Resurfacing;
6. Tree and hedge maintenance; and
7. Winter maintenance.

These seven policy areas have been selected as they are likely to be the most significantly affected by climate change and offer the greatest opportunities for adaptation. Other relevant policies such as street lighting have not been assessed as potential actions tend to be more related to reducing the effects of climate change, rather than adapting to the impacts themselves.

Each of these policies/standards have been placed in a table (Ref. Table 3) along with the climate change types that will affect them (hotter and drier summers, more intense rainfall, stronger winds and more storminess, and warmer winters). Each of the identified risks are also considered and placed in their order of hierarchy so that the adaptation responses developed can correspond with the risks. This ensures that the adaptation responses developed are strongly related to the risks and will maximise the effectiveness and practicality of the response.

The adaptation responses developed have been gathered from a combination of sources, including: the Task 1 Literature Review, Task 2 Individual Meetings, Task 4 Workshop, feedback from the project team, common sense and also from further research into the subject. The adaptation responses selected are those that can be directly implemented by the county councils and will impact upon the existing policies and standards directly. Those which are influenced by higher bodies and which could only be implemented through changes in national practices, standards and specifications have not been included in the assessment.

5.5 EVALUATION OF ADAPTATION REPONSES METHODOLOGY

In order to assess the adaptation responses in a fair, efficient and methodical way, a scoring system had to be devised. This is used alongside the criteria weighting (see Table 11) to obtain a final score for each of the criteria. For this to be done, each of the thirteen criteria has been assigned scores from 1 to 3 (e.g. for whole-life cost a score of 1 = high whole-life cost, whereas a score of 3 = a low whole-life cost). This method will mean that those adaptation responses with the highest scores at the end of the evaluation will be the response that are likely to be the most realistic, effective successful at helping the highway network to adapt to climate change. Table 12 shows the scoring system for each of the thirteen evaluation criteria applied to the adaptation responses.

Table 12: Evaluation criteria scoring system

Evaluation Criteria	Scoring System	Notes
Cost – capital	1-3	1 = high capital cost, 3 = low capital cost
Cost – whole-life	1-3	1 = high whole-life cost, 3 = low whole-life cost
Technical feasibility	1-3	1 = not technically feasible, 3 = high technical feasibility
Risk of no action	1-3	1 = low risk associated with doing nothing, 3 = high risk associated with doing nothing
Environmental impact	1-3	1 = significant adverse environmental impact, 3 = no significant adverse environmental impacts or significant beneficial environmental impacts
Sustainability of the response	1-3	1 = low level of sustainability, 3 = highly sustainable
Practicality	1-3	1 = not practical, 3 = highly practical
Level of county council control/ responsibility	1-3	1 = no or little county council control, 3 = full county council control
Scale/ impact of the response	1-3	1 = the adaptation response will have minimum impact, 3 = the adaptation response will have significant impact
Politically acceptable	1-3	1 = not politically acceptable, 3 = politically favourable
Publically acceptable	1-3	1 = not publically acceptable, 3 = publically favourable
Resources/ skills/ knowledge available to implement the adaptation	1-3	1 = lack of resources/ skills / knowledge, 3 = readily available resources/ skills/ knowledge
Future-proof	1-3	1 = unlikely to be future-proof, 3 = high likelihood of being future-proof

To calculate the overall preference score for each adaptation option, the score for each evaluation criterion is multiplied by the weighting assigned to that criterion (see Table 11). This is replicated for each of the evaluation criteria and the scores are then all added together to obtain the final score for the option. This allows for the adaptation responses to be ranked in order of preference and expected effectiveness. The formula for this calculation is:

$$S_i = s_{i1}w_1 + s_{i2}w_2 + \ldots + s_{in}w_n = \sum_{j=1}^{n} s_j w_{ji}$$

where:
S = total score for the adaptation response
s_{in} = score for a particular criteria
w_n = weighting assigned to the particular criteria

In other words, the particular adaptation response's score for each criteria is multiplied by the weighting for that particular criteria and then the scores are added together to get the overall score for the adaption response option. It is important that the criteria are mutually preference independent, and that the score assigned to each option is not affected by the scores given to the other criteria [DTLR, 2002]. Table 13 shows an example of the process carried out to calculate the total score for two particular adaptation responses; (1) increasing the frequency of grass cutting, (2) changing the vegetation on the soft estate to slower growing species, in response to the need to adapt to the lengthened growing season as a result of warmer temperatures and more rainfall.

Table 13: Calculating the overall scores for two adaptation responses using multi-criteria analysis (MCA)

		Possible Adaptation Responses	
	Criteria Weighting (out of 100%)	**1. Increase the frequency of grass cutting)**	**Change the species of vegetation**
Evaluation Criteria		**Score 1-3**	**Score 1-3**
Cost – capital	10 %	**2**	**1**
Cost – whole-life	10 %	**2**	**3**
Technical feasibility	10 %	**3**	**3**
Risk of no action	10 %	**2**	**2**
Environmental impact	10 %	**2**	**2**
Sustainability of the response	7.5 %	**3**	**2**
Practicality	7.5 %	**2**	**1**
Level of county council control/ responsibility	7.5 %	**3**	**2**
Scale/ impact of the response	7.5 %	**2**	**1**
Politically acceptable	5 %	**3**	**2**
Publically acceptable	5 %	**3**	**2**
Resources/ skills/ knowledge available to implement the adaptation	5 %	**2**	**1**
Future-proof	5 %	**2**	**1**
TOTAL SCORE	100%	**2.35 (or 78%)**	**1.85 (or 62%)**

From carrying out this method of MCA, it shows that the adaptation response to increase the frequency of grass cutting gets a total score, out of a maximum total score of 3, of 2.35 (or 78% effectiveness), while the option to change the species of plants to slower growing species gets a score of 1.85 (or 62% effectiveness). This shows that the first option to increase the frequency of grass cutting is preferable when considered against the selected thirteen evaluation criteria using the MCA process.

This process has been carried out in Section 6 for the seven policies and standards identified earlier (Ref. Section 5.4) as being likely to be the most significantly affected by climate change.

6. POLICY REVIEW AND ADAPTATION RESPONSE EVALUATION

Table 3 identifies the 3CAP policies and standards which are likely to be affected by the four key climate change types identified by this project. Table 9 identifies and ranks the various effects (e.g. pavement failure from prolonged high temperatures, ref. effect code R1), and Section 5.4 considers this information to identify the top seven 3CAP policies and standards worthy of adaptation. The development and evaluation of potential adaptation responses are featured in Sections 6.1 to 6.7 for the seven priority areas. Each section includes an introduction which comprises of information extracted from the reviews carried out of the selected 3CAP policy documents, followed by specific information related to the individual counties (Derbyshire, Leicestershire and Nottinghamshire), where appropriate. Therefore, information contained within the following sections relate to the most recent policies and standards and should be reviewed in the event of any changes or updates made to these documents.

6.1 BRIDGES AND OTHER STRUCTURES

6.1.1 3CAP Policies and Standards for Bridges and other Structures

The maintenance of bridges and other structures on the highway is carried out by the relevant Highway Authority to prevent deterioration of structural fabric, to maintain the stock of structures in a safe condition and to strengthen or reconstruct where necessary. Inspections are typically undertaken to:

- Prevent deterioration of the structural fabric leading to the point where expensive repair work is needed or the structure's life is reduced below the normal expectancy (for example new road bridges should have a typical life expectancy of 120 years);
- Carry out any routine maintenance required by the details of the design and function of the structure such as metal parapets, drainage pipes, expansion joints, fixed joints, bearings and removal of graffiti etc. to ensure structural deterioration is not caused; and
- Assess the need for the strengthening or reconstruction of structures taking into account current vehicle weight regulations, the road hierarchy and the acceptability and enforcement of weight restrictions.

Each county council has an established policy for the frequency with which bridges and other structures are inspected and undergo routine maintenance work. These are summarised below.

<u>Derbyshire County Council Inspection Regime</u>

Derbyshire County Council's current inspection regime for bridges and culverts is as follows:

1. The frequency of inspection will depend upon the form of construction, age, general condition and other special considerations but should not normally be less than once per year. Foundation inspections should be included with those of the structure and where applicable should include underwater inspections.
2. More frequent inspections will be required for bridges and culverts in areas of mining subsidence and those crossing rivers liable to sudden flooding. Bridges crossing heavily trafficked waterways must be inspected frequently (daily if necessary, though by non-technical staff) to check for signs of collisions by vessels. The moving parts of bridges (e.g. expansion joints and bearings) may need to be inspected two or three times a year depending on the range of movement and type of construction. Moving bridges and major structures deserve a special inspection and maintenance programme which will depend on the size and complexity of the structure.
3. Bridge inspections should as far as possible be carried out by an engineer experienced in bridge work. Where technicians are employed on these inspections they should be provided with detailed schedules to ensure adequacy and consistency of inspections. Old and known weak bridges and culverts should always be inspected by a bridge engineer. So too should all cases of serious damage or deterioration.

In addition to the normal cycle of inspections, occasional Special Inspections are carried out when a structural problem is received, to ensure that the highway is in safe condition for its users. Bridges will be inspected and maintained in an appropriate manner to conserve the County's historic and architectural structures. Consent will be sought from the appropriate regulatory body before work commences where it involves a listed structure. Due consideration will be given for the protection of protected species, e.g. bats and otters in the maintenance of bridges and structures.

When the need for maintenance of a structure is identified during an inspection, a priority number is calculated using an established formula and the repair included on a list of outstanding work. Annual programmes of structure maintenance works are prepared from this list. In addition a programme of routine maintenance is developed from inspections carried out in previous years comprising removal of graffiti and vegetation, and clearing of structure drainage systems.

Leicestershire County Council Inspection Regime

Highway bridges are subject to periodic inspection to determine their condition and to record any defects present. The regime is as shown in Table 14.

Table 14: Leicestershire County Council Structures Inspection Regime

Type	Frequency	Assets Inspected
General Inspections	Every 2 years	All bridges
Principal Inspections	Every 6 years	Bridges on A or B roads or lorry routes
	Every 10 years	All other bridges
Diving Inspections	Ad hoc	Bridges which have substructures in deep, often fast-flowing watercourses
Special Inspections	Ad hoc	All structures as necessary

In addition to condition inspections, a programme of strength assessments commenced in the early 1990s in Leicestershire to determine whether bridges achieved the required live load capacity of 40/44T. Where bridges failed to provide this capacity, strengthening work was usually carried out, although some structures on non-critical routes were subject to a permanent weight limit in lieu of strengthening. A review of existing strength assessments and bridges that have not been previously assessed is carried out at the following intervals:

- A minimum of 12 years, to coincide with principal inspections; and/or
- Whenever there is a significant change in bridge condition.

Currently, Leicestershire County Council's work programme is determined using the data in the bridge management system, and priority is given to the following:

- Structures with low BCICRIT values, i.e. those with structural defects which have a direct impact on their load-carrying capacity;
- Structures with safety-related defects; and
- Structures with defects which, if not remedied, are likely to lead to more serious problems, for example failed waterproofing systems which will permit water ingress, leading to corrosion of the foundation, supporting sections and any reinforcements.

Currently, maintenance works are identified in an annual programme, although major schemes are planned up to two years ahead. In future editions of the Leicestershire County Council's Transport Asset Management Plan (TAMP) this will be extended to a five year programme, to assist with scheme delivery and overall financial planning.

Nottinghamshire County Council Inspection Regime

As outlined in Nottinghamshire County Council's Highway Network Management Plan (HNMP), in order to maintain the overall required standard of bridges and other structures, it is necessary to:

1. Assess the strength and other characteristics of all structures against current national standards, together with any known intended improvements to these standards. **Frequency**: The strength assessment will be reviewed at every principal inspection and reassessed if there is any significant deterioration in the structure.
2. Improve identified sub-standard structures within a reasonable time period or to impose a weight restriction (traffic order) or other suitable method if this cannot be achieved. In some cases a structure may need an immediate temporary weight restriction. **Frequency**: As necessary.
3. Carry out routine inspections of all structures, including parapets. **Frequency**:
   - General Inspections (remote visual) – All structures – Every 2 years
   - Principal Inspections (inspected within touching distance) – NCC owned railway and major river bridges – Every 6 years
   - Other bridges – Every 10 - 12 years if risk assessment allows, otherwise every 6 years
   - Culverts and subways – Every 10 - 12 years if risk assessment allows, otherwise every 6 years
   - Underwater Inspections – Relevant structures – Every 3 years and after major flooding events
4. Carry out steady state maintenance work and other works identified during routine inspections to prevent deterioration of the bridge stock. **Frequency**: Ad-hoc.

Nottinghamshire County Council's maintenance activities are carried out on a cyclic basis. They are usually carried out annually with timings based on historical experience. Steady state maintenance is carried out to maintain the condition of the structure by protecting it from deterioration or by slowing down the rate of deterioration. Maintenance work carried out can include:

- Vegetation removal – typically carried out as a works package before the start of the bird nesting season;
- De-silting culverts, clearing grilles and cleaning out drainage systems – typically carried out before winter (partially carried out by District Councils and Drainage Boards);
- Work packages for masonry and concrete repair work are issued every year using defect information stored on the bridges database. This type of work forms a significant part of steady state maintenance as the majority (approximately 90%) of Nottinghamshire County Council's bridge stock is either masonry or concrete. There is usually more outstanding work stored on the database and identified each year than the available budget can meet. Repair work is prioritised using current Bridge Condition Index (BCI) scores however road hierarchy, location and access are also taken into consideration;
- A small annual bridge painting contract is let every year for painting small items such as steel parapets; and
- The county also has 10 major steel structures and a major maintenance bridge painting contract is arranged every one or two years.

A parapet protection and improvement study has been carried out by Nottinghamshire County Council to identify work for bridges on A and B classified roads. It is planned to undertake a similar exercise for bridges on C and unclassified roads.

Other upgrading includes provision of bridge waterproofing systems. There are over 40 concrete bridges in Nottinghamshire with no or failing waterproof systems. There are also masonry arch bridges with arch barrels suffering freeze thaw damage by water penetration through the fill. Concrete saddle and waterproofing is an effective option for slowing down deterioration and extending the serviceable life. A bridge waterproofing programme is being developed.

Bridge Condition Index

During routine inspections, a Bridge Condition Index (BCI) is determined for each individual bridge, based on its condition at the time of the inspection. The BCI system is a nationally developed method, endorsed by the County Surveyors' Society (CSS), with two BCI values calculated for each bridge:

- BCICRIT – the value when only the critical load-carrying elements are considered; and
- BCIAV – the value when every element of the bridge is considered.

As a guide, the BCI values represent the following:-

- 100 – 95: Very good condition
- 94 – 85: Good condition
- 84 – 65: Fair Condition
- 64 – 40: Poor condition
- 39 – 0: Very poor condition

Bridge Condition Indices (BCI_{CRIT} and BCI_{AV}) are monitored on an annual basis. An average value for the whole bridge stock, known as the Bridge Stock Condition Index ($BSCI_{CRIT}$), is also calculated based on the individual BCI_{CRIT} values, as is weighted by area.

Leicestershire County Council has set aims for their bridge stock to meet particular BCI levels. These are shown below. Similar aims have been set by Derbyshire County Council and Nottinghamshire County Council.

BCI_{CRIT} aim	No more than 10% of bridge spans will have a BCI_{CRIT} value below 75
$BCSI_{CRIT}$ aim	The bridge stock will have a minimum $BSCI_{CRIT}$ value of 86
Strength assessment aim	All bridges will be capable of carrying European standard 40/44T vehicles (except where weight limits have been imposed)
Bridge inspections aim	All bridges will be inspected on a 2-year cycle

The BCI results obtained from inspections can be used to establish a programme of maintenance and strengthening works. The results can also be used to assess whether weight restrictions on a particular bridge are required to reduce the risk of premature deterioration or excessive structural damage.

6.1.2 Design Manual for Roads and Bridges (DMRB)

The Highways Agency's Design Manual for Roads and Bridges (DMRB) contains guidance and design standards for bridges and related structures on the highway. A number of these existing standards will be influenced be climate change and are expected to be reassessed following the release of the UKCIP09 predictions. These will have an influence on the design, maintenance and management activities of the 3CAP councils.

- **BA 59/94: The design of highway bridges for hydraulic action -** bridge design for scour (this standard also requires design for erosion, hydraulic forces on piers and decks, and loads from flood debris and ice;
- **BD 63/07: Inspection of highway structures** - requires the regular 2-yearly bridge inspections to also include examination for evidence of scour and bank erosion and, following flooding, probing of any foundations under water;
- **BA 74/06: Assessment of scour at highway bridges** – provides a method for the quantitative assessment of scour at existing structures; and
- **BD 37/01**: **Loads for highway bridges** – bridge design for wind loads and thermal effects.

6.1.3 Risk Assessment Results

From the Risk and Probability Assessment carried out (Section 4.2), it has been identified that the existing policies and standards for bridges and other structures will be affected by three of the main climate change types investigated; 'hotter and drier summers', 'more intense rainfall', and 'stronger winds and more storminess'. The specific climate change effects that will affect bridges and other structures are shown in the Risk Assessment (Section 4.2).

6.1.4 Adaptation Responses and Evaluation

In order to ensure that bridges and other structures on the highway can withstand the effects of climate change, a number of adaptation responses have been established. These being:

B1. Increase the number and frequency of maintenance works carried out to increase the BCI average and critical values;

B2. Carry out a risk assessment to identify which structures are most at risk from climate change;

B3. Ensure that all strengthening and repair work that is currently outstanding for failed or below standard bridges is carried out;

B4. Ensure that all data (new and historical) is transferred into a single system to make assessments of maintenance and repair priorities and needs more effective;

B5. Carry out a culvert assessment programme using the CSS national Bridge Condition Indicator System (as carried out for bridges);

B6. Evaluate the Depreciated Replacement Cost (DRC) for all highway structures to allow for an assessment of the impact of spending to be made;

B7. Carry out a programme of culvert replacement for those that are beyond repair;

B8. Introduce an inspection programme for retaining walls;

B9. Apply plant and wildlife resistant substances to structures to discourage intrusion;

B10. Develop a bridge waterproofing programme for concrete bridges with no or failing waterproofing, and for masonry arch bridges susceptible to freeze thaw damage through water penetration;

B11. Carry out a programme of improvement to safety barriers and parapets as identified from a Risk Assessment;

B12. Carry out flood studies with the help of other agencies and organisations (the Environment Agency etc);

B13. Slow down and manage the velocity of water flows;

B14. Review the county council's existing policies and standards on weight restrictions;

B15. Carry out wind modelling on major structures;

B16. Increase the use of warning signs on high bridges and roads to warn against the dangers during high winds; and

B17. Fell trees that pose a risk to structures during periods of high winds and storms.

These seventeen adaptation responses have undergone evaluation using the 13 no. established evaluation criteria, as per the example in Section 5.5. The results of this evaluation are shown in Table 15.

Table 15: Adaptation Response Evaluation – Bridges and other Structures

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Link to effects	Score (out of 3)	Links to other council plans, strategies and operations
Bridges and Other Structures	Hotter and drier summers More intense rainfall Stronger winds and more storminess	R2. Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate R3. Lack of capacity in the drainage system and flooding of the highway network O1. Surface damage to structures O2 and O5. Scour to structures O4. Subsidence and heave on the highway O6. Severe damage to light-weight structures Y1. Landslips Y2 and Y3. Top soil and embankment erosion Y4. Tree damage B2. Increased recreation and leisure based travel in the summer months B6. Tree root damage B7. Increased leaf-fall	B1. Increase the number and frequency of maintenance works carried out to increase the BCI average and critical values	All	2.85	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B2. Carry out a risk assessment to identify which structures are most at risk from the effects of climate change	All	2.775	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B3. Ensure that all strengthening and repair work that is outstanding for failed or below standard bridges is carried out	All	2.6	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B4. Ensure that all data (new and historical) is transferred into a single system to make assessments of maintenance and repair priorities and needs more effective	All	2.55	Urban Design, Planning, Assets
			B5. Carry out a culvert assessment programme using the CSS National Bridge Condition Indicator System (as carried out for bridges)	All	2.2	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B6. Evaluate the Depreciated Replacement Cost (DRC) for all highway structures to allow for an assessment of the impact of spending to be made	All	2.3	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B7. Carry out a programme of culvert replacement for those that are beyond repair	All	2.125	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B8. Introduce an inspection programme for retaining walls	R2, R3, O1, O2, O4, O5, O6, Y1, Y2, Y3, Y4	2.125	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B9. Apply plant and wildlife resistant substances to structures to discourage intrusion	R2	1.9	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B10. Develop a bridge waterproofing programme for concrete bridges with no or failing waterproofing, and for masonry arch bridges susceptible to freeze thaw damage through water penetration	R3, O1, O2, O5, O6, Y1, Y2, Y3, B7	2.1	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B11. Carry out a programme of improvement to safety barriers and parapets as identified from a Risk Assessment	R3, O1, O2, O5, O6, Y1, Y2, Y3, B2	2.075	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B12. Carry out flood studies with the help of other agencies and organisations (the EA etc)	R3, O2, O5, Y2, Y3	2.625	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity
			B13. Slow down and manage the velocity of water flows	R3, O2, O5, Y2, Y3	1.45	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			B14. Review the county council's existing policies and standards on weight restrictions	O1, O2, O4, O5, O6, B2	2.2	Urban Design, Planning, Assets
			B15. Carry out wind modelling on major structures	O6	2.025	Environmental Services, Urban Design, Planning, Assets
			B16. Increase the use of warning signs on high bridges and roads to warn against the dangers during high winds	O6	1.9	Environmental Services, Urban Design, Planning, Assets, Waste
			B17. Fell trees that pose a risk to structures during periods of high winds and storms	Y4, B6	1.725	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste

Scores

>2.5	Very high
2.25 - 2.5	High
2 - 2.25	Medium
1.75 - 2	Low
< 1.75	Very low

From the evaluation of the suggested adaptation responses, it can be seen that five responses have scored 'high' or 'very high' and so are likely to be the most realistic and effective if applied, these being B1, B2, B3, B4 and B12. Full calculation tables can be found in Appendix 3.

6.2 DRAINAGE

6.2.1 3CAP Policies and Standards for Drainage

Drainage systems are provided to ensure that surface water is effectively removed from the carriageway, footways and cycleways as quickly as possible in order to avoid ponding and flooding which cause inconvenience and danger to the public. Slow draining surface water may also cause structural damage to the road foundation. Section 100 of the Highway Act 1980 describes the duties of a Highway Authority with regard to drainage of highways. Where the highway is adversely affected by water flowing from an adjacent property or land, the Authority may serve notice under Section 151 or 163 of the Highways Act 1980 to the owners of the property or land instructing them to address this.

Typically, drainage systems for the sole purpose of accepting surface water run-off from the highway are the responsibility of the Highway Authority unless Water Companies have specifically adopted them. Highway drainage systems are installed to capture surface water run-off to alleviate flooding and protect the fabric of the road. County Councils have a number of responsibilities relating to drainage within their region, these include that they shall:

- Prioritise any necessary structural maintenance through specific schemes or other repairs through general maintenance; and
- Arrange for cyclic cleansing and the correct disposal of waste to be carried out at reasonable frequency.

Cross-footway channels and drains that are used to convey roof water from properties, from down-pipes, into the carriageway channel, is the responsibility of the owner(s) of the down-pipe. Should defects be noted during any inspection regime then these are brought to the attention of the property owner(s) who are required to undertake the necessary repairs.

As set out in Derbyshire County Council's Highway Network Management Plan, the condition of highway drainage systems can contribute to the key objectives:

- **Safety** – Accumulations of water on carriageways, footways and cycleways;
- **Serviceability** – Accumulations of water on carriageways, footways and cycleways; and
- **Sustainability** – Polluted effluent from clearing of highway drainage affecting watercourses and inadequate drainage of the highway structure will reduce effective life and increase maintenance liability.

Drainage systems do not deteriorate in the same predictable way as carriageways. Need is assessed by carrying out inspections or by recording reports of flooding and accumulations of ice that cannot be dealt with by cleansing. Drainage maintenance and repair schemes can be described against the following criteria:

- **Type and Scale of Flooding** – Carriageway, footway, adjacent dwelling and adjacent fields;
- **Effect on Population** – Number of householders, pedestrians and motorists affected and degree of inconvenience;
- **Flooding Frequency** – Average number of times per year flooding occurs or warning signs are erected; and
- **Benefits of Remedial Work** – Reduced routine maintenance liability, reduced winter maintenance liability and benefit to carriageway structure.

Typically, no planned maintenance is carried out to open and piped drainage and so problems are often identified by reports of flooding. Very few records of open or piped drainage exist and though records are kept of new systems it is unlikely to be cost effective to survey existing systems for record purposes. For most open ditches on the highway, the responsibility for maintenance rests with the adjoining landowner.

No one system is specified for drainage but the general presumption is that drainage of surface water from principal roads should be as rapid as possible and wherever possible encouraged to drain into the ground. A trapped gulley system into a dedicated positive carrier highway drain or public surface water sewer will be the most likely system to be employed in urban areas. Use of combined drainage and kerb systems will be accepted where carriageway gradients are slack and to assist more rapid dispersal of surface water.

As detailed in Nottinghamshire County Council's Highway Network Management Plan, drainage defects are typically identified during footway or carriageway safety or service inspections. Inspections of drainage elements should record defects which include:

- Worn ironwork which constitutes a skidding hazard to pedal and motor cyclist in wet conditions;
- Cracked or broken items, which may be in danger of collapse/failure;
- Ditches, culverts, grips or gullies which require cleaning/emptying;
- Cracked or blocked headwalls or outfalls;
- Areas of standing water sufficient to cause a hazard; and
- Obstructions to the effective inflow of water to the drainage system.

Furthermore, areas and locations susceptible to flooding problems should be identified and an appropriate list maintained. Remedial works should be carried out within the available budget and have regard to the following considerations:

- **Location of flooding** – carriageway, footway, cycleway, adjacent dwelling or adjacent land;
- **Effects** – inconvenience to highway users and householder/property owners;
- **Frequency and amount** – number of times per year flooding occurs and the intensity of the rainfall with the length of time it persists; and
- **Benefits or works** – whether causing accidents, structural damage, winter liability or loss of amenity value.

The first priority when dealing with any flooding incident is usually to address and remedy any significant safety hazard or flooding of property. Instances of flooding will be dealt with when they occur, including the erection of temporary 'Flood' warning signs.

Within Nottinghamshire the design of highway drainage schemes should normally allow for the following storm return periods (a similar policy is in operation by Derbyshire County Council and Leicestershire County Council):

- Normal – 1 in 1
- Large Gradients – 1 in 2
- Areas prone to flooding – 1 in 5
- Time of entry – 4 minutes

Highway drainage systems are provided and maintained to ensure that flooding or standing water does not cause a serious safety hazard on the highway and to ensure that the surface water does not remain within the road foundation or on carriageways, footways or cycleways. The frequency of cleaning highway drainage systems depends upon their location in relation to industrial sites and trees. Depending on these factors, there may be a need to vary the cleaning frequency. Table 16 shows the drainage inspection and maintenance regimes currently being implemented by the individual 3CAP councils.

Table 16: Drainage inspection and maintenance regimes

Activity	Derbyshire CC	Leicestershire CC	Nottinghamshire CC
Gully emptying	Minimum frequency of once annually for all roads. Higher in other areas (dependent on local conditions and the presence of dirty industries). Reduced frequency in some rural areas.	Frequencies vary depending on location and flooding risk	Every 12 months. Those prone to blockage should be identified and cleaned as necessary
Grip clearing	Natural and concrete grips cleared once per year on a scheduled basis. Scheduled to commence after the last grass cut and completed before the worst effects of winter begin	Cleaned once per year	Concrete and earth grips cleared every 12 months and as required following inspection
Highway ditches and piped drainage	No information	No information	Inspected every 10 years and cleaned/jetted as required
Culverts, manholes, catchpits, SuDS, Soakaways inspections	No information	Inspected twice annually (average)	Inspected every 2 years. Cleaned/jetted as required
Drainage inspections	Checked twice annually (before and after winter). Additional inspections made in areas where leave tend to accumulate in autumn. All principal and trunk roads also inspected once annually during periods of heavy rain (to ensure that they can withstand one-year storm conditions)	No information	No information
Design of drainage systems	No information	No information	The design of highway drainage schemes should normally allow for the following storm returns: Normal – 1 in 1 Large gradients – 1 in 2 Areas prone to flooding – 1 on 5 Time of entry – 4 minutes

6.2.2 Regional Highway Design Guide

Reference must be made to the Regional Highway Design Guide's requirements for drainage for new developments. Derbyshire County Council has recently resolved to work with Leicestershire County Council and Leicester City Councils in order to produce regional design guidance in respect of highways and transport infrastructure associated with new development. In the interim existing Leicestershire guidance found in the document 'Highways, transportation and development (Htd) [2007] has been adopted as the source for advice within the areas covered by the individual authorities

With regards to drainage issues, the guide states that new developments should include satisfactory arrangements for draining the adoptable highway. All highway drains should be located within the land being adopted. Only in exceptional circumstances will they be permitted in land that is to remain private.

Alternative drainage systems, such as SuDs, flow attenuation (reduction) or retention systems (including oversized pipes) and so on, on a site-by-site basis. Where there are valid reasons for providing systems like these, and where they would present extra maintenance liability over a piped system, it is the requirement that commuted sums are paid.

Generally, drainage of other non-adopted areas into any highway system is not accepted. The drainage of most other areas of development are matters for water companies and should be designed in line with the water companies' specifications and requirements.

Typically, drainage systems should be designed not to flood any part of the highways or site in a 1 in 30 year return period design storm or any other return period that is set in any latest version of 'Sewers for Adoption'

6.2.3 SuDS/ Soakaways Policies and Standards

Each of the three 3CAP counties has a particular policy for the application of Sustainable Drainage Systems (SuDS) and Soakaways within their regions. These policies are very similar and generally discourage their use (particularly on large-scale non-residential developments) on the grounds of unknown maintenance costs and liabilities.

Derbyshire County Council SuDS and Soakaway Policy:

Where a proposed residential development has received planning consent, the County Council requires a submission of detailed designs for the new estate roads and the drainage system serving them. Soakaways can be considered if the developer can prove that all other reasonable options for the disposal of surface water from the road have been thoroughly investigated. The County Highway Authority must be satisfied that the ground conditions will permit satisfactory percolation, that the capacity, design and location of the chambers is acceptable, and that the Authority's additional maintenance liability is offset by the payment of a commuted sum.

Leicestershire County Council SuDS and Soakaway Policy:

Where SuDS are proposed for highway drainage, discussions with all relevant parties must be held at an early stage (before any planning application) to agree ownership and responsibility for the facility. The design of the system and future maintenance arrangements must be satisfactory. If SuDS and non-standard drain elements, including above and below ground flow attenuation systems and pollution control devices, a commuted sum must be paid to cover future maintenance.

Nottinghamshire County Council SuDS and Soakaway Policy:

On residential developments, the use of sustainable drainage systems (SuDS) is encouraged in principle where the proposed surface water run-off is expected to be greater than that which occurs naturally from the catchment. However, careful consideration must be given to suitability of the ground conditions and particular attention given to the avoidance of possible damage to buildings, structures and highways.

Soakaways are not preferred as part of a highway surface water management system as their traditional use had been to take roof drainage or small paved areas, however, they are permissible in certain circumstances. Soakaways may be sited within any part of the adoptable highway subject to structural calculations being provided to show that anticipated loading on the system can be tolerated without detriment. It is unlikely that soakaways will be allowed for other than parts of small residential developments.

The consent of the Environment Agency will be required to discharge surface water from a soakaway system. In some areas the EA will promote the use of soakaways to alleviate falling water tables. The location of the soakaway must not affect the structural integrity of the highway, or adjacent buildings or structures (soakaways are usually sited at least 5m away from buildings or structures). The effects downstream should be assessed, where water logging should also be avoided. The provision of a soakaway system requires the specific approval of the Local Highway Manager. A comprehensive plan of the proposed surface water management system shall be supplied together with detailed calculations for each soakaway or soakaway system.

A soakaway system should have a design life of 50 year, which shall be certified by the developer. A commuted sum equal to the estimated cost of the complete replacement of the soakaway system shall be deposited with the County Council by the developer following satisfactory completion of the installation.

6.2.4 Risk Assessment Results

From the Risk and Probability Assessment carried out (Section 4.2), it has been identified that the existing policies and standards for drainage will be affected by three of the main climate change types investigated; 'hotter and drier summers', 'more intense rainfall', and 'stronger winds and more storminess'. The specific climate change effects that will affect drainage are shown in the Risk Assessment (Section 4.2).

6.2.5 Adaptation Responses and Evaluation

In order to ensure that drainage on the highway can withstand the effects of climate change, a number of adaptation responses have been established. Due to the nature of uncertainly surrounding the responsibilities for maintenance and repair of drainage assets, and the fact that responses to the recently published Pitt Report are still outstanding, adaptation responses that could directly be implemented by the 3CAP region and do not rely on extensive outside influence and input have been developed. These being:

D1. Improve the knowledge of drainage assets;

D2. Undertake a risk assessment to determine vulnerable areas and establish a prioritised scheme for maintenance;

D3. Change to an ad-hoc gully emptying strategy based on demand and need;

D4. Increase the frequency of highway network drainage inspections;

D5. Increase the gully emptying frequency;

D6. Increase highway budgets for drainage maintenance;

D7. Provide sealed edges to pavements to prevent silted drains;

D8. Invest in asset management and location reviews;

D9. Carry out drainage condition surveys;

D10. Make enforcement on landowners easier;

D11. Improve flood protection;

D12. Define alternative routes and ensure that they are adequate for if flooding occurs;

D13. Increase the use of SuDS and clarify responsibilities and ownership;

D14. Capture and store water (tanks, containers etc); and

D15. Build more temporary buildings and structures.

These fifteen adaptation responses have undergone evaluation using the 13 no. established evaluation criteria, as per the example in Section 5.5. The results of this evaluation are shown in Table 17.

Table 17: Adaptation Response Evaluation – Drainage

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Links to effects	Score (out of 3)	Links to other council plans, strategies and operations
Drainage	More intense rainfall Stronger winds and more storminess	R2. Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate R3. Lack of capacity in the drainage system and flooding of the highway network O2 and O5. Scour to structures O3. Damage to pavement surface layers O4. Subsidence and heave on the highway O6. Severe damage to light-weight structures Y1. Landslips Y2 and Y3. Embankment erosion Y4. Tree damage B5. Top soil run-off B6. Tree route damage B7. Increased leaf-fall	D1. Improve the knowledge of drainage assets	All	2.625	Environmental Services, Urban Design, Planning, Assets
			D2. Undertake a risk assessment to determine vulnerable areas and establish a prioritised scheme for maintenance	All	2.575	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			D3. Change to an ad-hoc gully emptying strategy based on demand and need	All	2.4	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			D4. Increase the frequency of highway network drainage inspections	All	2.275	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			D5. Increase gully emptying frequency	All	2.15	Environmental Services, Urban Design, Planning, Assets, Biodiversity, Waste
			D6. Increase highway budgets for drainage maintenance	All	2	Environmental Services, Urban Design, Planning, Assets
			D7. Provide sealed edges to pavements to prevent silted drains	All	1.925	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			D8. Invest in asset management and location reviews	R3, O6	2.4	Environmental Services, Urban Design, Planning, Assets, Waste
			D9. Carry out drainage condition surveys	R3	2.375	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			D10. Make enforcement on landowners easier	R2, R3, Y1, Y2, Y3, Y4, B5, B6, B7	2.15	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity
			D11. Improve flood protection	R3, O2, O3, O4, O5, O6, Y1, Y2, Y3	2.025	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			D12. Define alternative routes and ensure that they are adequate for if flooding occurs	R3, O3, O4, O6, Y1, Y2, Y3, Y4	2.025	Environmental Services, Urban Design, Planning, Assets, Waste
			D13. Increase the use of SUDS and clarify responsibilities and ownership	R3	1.675	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			D14. Capture and store water (tanks, containers etc)	R3, O2, O3, O4, O5, O6, Y1, Y2, Y3, B5, B6	1.525	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			D15. Build more temporary buildings and structures	O6	1.55	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste

Scores

(red)	>2.5	Very high
(orange)	2.25 - 2.5	High
(yellow)	2 - 2.25	Medium
(peach)	1.75 - 2	Low
(white)	< 1.75	Very low

From the evaluation of the suggested adaptation responses, it can be seen that six responses have scored 'high' or 'very high' and so are likely to be the most realistic and effective if applied, these being D1, D2, D3, D4, D8 and D9. Full calculation tables can be found in Appendix 3.

6.3 GRASS CUTTING

6.3.1 3CAP Policies and Standards for Grass Cutting

Typically, grass cutting is carried out to standards which are designed to ensure that, in normal weather conditions, growth does not present a road safety hazard to road users. The approach set out in the relevant highway network policies and standards is established with the aim of maintaining a balance between the need for road safety and the need to preserve the natural habitat within road side verges in terms of both flora and fauna.

As identified in Derbyshire County Council's HNMP, the condition of roadside grass and landscaped areas can contribute to the key objectives:

Safety:
- Obstruction to user visibility.

Serviceability:
- Potential for service interruption; and
- Quality of user experience.

Sustainability:
- Landscape conservation;
- Mitigation of climate change effects; and
- Support for habitat and biodiversity.

Although the main purpose of grass cutting is safety, there is often a public expectation that grass will be cut for amenity reasons, which is a District Council function. Some District Councils and Parish Councils increase the standard and frequency of grass cutting within the highway using their own funds. The Highway Authorities should produce and annually update plans showing exceptions to the frequencies set out in the council's policies and standards. These exceptions are typically based on safety, appearance and the budget available for extra work.

Frequencies for grass cutting are varied depending on whether the area is classified as rural or urban. For grass cutting purposes an urban road is classified as a section of road subject to a speed limit of 40mph or less and a rural road is classified as having a speed limit exceeding 40mph. However, there may be some circumstances where this classification will need to be varied for a particular road section due to local conditions or justification for a more or less frequent cutting frequency.

The frequency with which each of the individual 3CAP counties carries out grass cutting activities is shown Table 18.

Table 18: Grass cutting frequencies

	Derbyshire County Council	**Leicestershire County Council**	**Nottinghamshire County Council**
Urban areas	• Visibility splays, traffic islands, raised roundabouts and grass adjoining highways in built-up areas with numerous accesses: cut **5 times** per year on strategic and main distributor roads. **4 times** per year on other roads • Grass areas adjoining highways on all other roads: cut 2 swath widths **5 times** per year on strategic and main distributor roads; **4 times** per year on other roads • Grass areas adjoining footways, horse riding and cycle tracks: cut a single swath **5 times** per year on both sides on strategic and main distributor roads, **5 times** per year on other roads • Newly seeded areas: **one full cut** in the first season • Areas with serious noxious (injurious) weeds: **one cut** to be arranged where necessary or chemical treatment as recommended by DEFRA	• Grass cutting, urban roads: **9 times** per year • Grass cutting, visibility splays: as per rural grass cutting plus additional cutting depending on the growth rate • Grass cutting, obstacles: grass around obstacles, such as trees, lamp columns and posts to be cut to same height as surrounding area	• Vision splays, traffic islands, raised roundabouts and grass adjoining highways in built-up areas with numerous accesses: minimum **4 times** per year or as required to maintain visibility • Grass areas adjoining highways on all other areas: **4 times** per year • Grass areas adjoining footways and cycle tracks: **4 times** per year • Newly seeded areas: during the first 3 years cut as necessary to allow satisfactory establishment • Areas with injurious weeds: remove as necessary in accordance with Section 5.1.9. of the HNMP
Rural areas	• At visibility splays; junctions; gaps in central reserves; inside of bends; where there is considerable pedestrian traffic e.g. schoolchildren; at Public Rights of Way; at lay-bys and at locations where there is restricted visibility causing an exceptional hazard to motorists or pedestrians: **4 cuts** per year for strategic, main and secondary roads, **2 cuts** per year for link and local roads • At traffic signs and bollards to ensure adequate stopping sight distance: **3 cuts** per year for strategic, main and secondary roads, **2 cuts** per year for link and local roads • Embankments and cutting slopes: not normally cut • Areas incorporating access to ducts, drainage systems etc: not normally cut • Adjacent to the carriageway and at sites other than those above: single swath **2 cuts** per year for strategic, main and secondary roads, single swath **1 cut** per year for link and local roads	• Grass cutting, rural roads: 2 single swath width cuts per year. 1 full width cut per year towards the end of the growing season	• Rural roads without footways (vision splays): full width cut of vision splay minimum **2 times** per year or as required to maintain visibility • Rural roads without footways (all other grassed areas adjoining the highway): single width swath cut **2 times** per year. Every third year the final cut of the season should be full width • Rural roads with footways (vision splays): full width cut of vision splay minimum **2 times** per year or as required to maintain visibility • Rural roads with footways (all other grassed areas adjoining the highway): full width cut between the footway and road edge, single width swath cut at rear of footway **2 times** per year. Every third year the final cut of the season should be full width • Rural roads with footways (areas with injurious weeds): remove as necessary in accordance with Section 5.1.9. in the HNMP

6.3.2 Risk Assessment Results

From the Risk and Probability Assessment carried out (Section 4.2), it has been identified that the existing policies and standards for grass cutting and verge maintenance will be affected by all four of the main climate change types investigated; 'hotter and drier summers', 'more intense rainfall', 'stronger winds and more storminess' and 'warmer winters'. The specific climate change effects that will affect grass cutting are shown in the Risk Assessment (Section 4.2).

6.3.3 Adaptation Responses and Evaluation

In order to ensure that grass verges on the highway can withstand the effects of climate change, two adaptation responses have been established. These being:

GC1. Increase the frequency of grass cutting;

GC2. Treat grass with growth retardant and/or fertiliser to produce slower growing and/or better quality grass; and

GC3. Change the species of grasses/ plants on the soft estate to slower growing species.

These two adaptation responses have undergone evaluation using the 13 no. established evaluation criteria, as per the example in Section 5.5. The results of this evaluation are shown in Table 19.

Table 19: Adaptation Response Evaluation – Grass Cutting

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Link to effects	Score	Links to other council plans, strategies and operations
Grass Cutting	Hotter and drier summers More intense rainfall Stronger winds and more storminess Warmer winters	R2. Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate Y2, Y3 and B5. Top soil and embankment erosion O7. Less disruption by snow and ice B1. Plant and animal species changing, shifting patterns of migration and plants flowering earlier B4. Fires on the soft estate B6. Tree root damage B7. Increased leaf-fall	GC1. Increase the frequency of grass cutting	All	2.6	Environmental Services, Urban Design, Ecology, Parks, Trees and Woodland, Planning
			GC2. Treat grass with growth retardant and/or fertiliser to produce slower growing and/or better quality grass	All	2.6	Environmental Services, Urban Design, Ecology, Parks, Trees and Woodland, Planning
			GC3. Change the species of trees/ grasses/ plants on the soft estate to slower growing species	All	2.15	Environmental Services, Urban Design, Ecology, Parks, Trees and Woodland, Planning

Scores

Score	Rating
>2.5	Very high
2.25 - 2.5	High
2 - 2.25	Medium
1.75 - 2	Low
< 1.75	Very low

From the evaluation of the suggested adaptation responses, it can be seen that response GC1: Increase the frequency of grass cutting, and GC2: Treat grass with growth retardant and/or fertiliser to produce slower growing and/or better quality grass, have scored more highly than the alternative response to change the species of trees, grasses and plants to slower growing varieties. This suggests that these responses will therefore be more effective and realistic is applied. Full calculation tables can be found in Appendix 3.

6.4 MATERIALS

6.4.1 3CAP Policies and Standards for Materials

There is a wide variety of materials which can be considered for the design and maintenance of the highway network. Whilst some technical specifications, or aspects thereof, will be mandatory, there is often an opportunity for significant discretion on the application of standards to particular circumstances. This is important, for if too high a specification is set for materials and treatment standards; this will not only increase cost, but may reduce the potential for sustainability, for example by excluding the use of a locally sourced material. Within all schemes, consideration should be given to encourage reduction, re-use and recycling of materials and minimise landfill requirements. In the context of Best Value, seeking the right balance of materials and treatments to be used in particular circumstances is not merely a technical or financial issue, it is one of sustainability also.

Highway Pavement Materials

The uppermost materials in the council's highway pavements are most commonly aggregates bound with asphalt. The important mechanical properties with respect to pavement life are the stiffness of the material, which relates to load spreading and this changes with both temperature and traffic speeds; the fatigue performance, i.e. resistance to cracking; and the deformation characteristics, i.e. resistance to wheelpath rutting.

Asphalt-bound materials in common usage by Leicestershire County Council include:

- Hot Rolled Asphalt (HRA) surface course with 20mm pre-coated chippings, used in heavily trafficked and high speed rural areas; with 14mm pre-coated chippings used in 30mph urban areas which are noise sensitive;
- Asphalt Concrete (AC) surface course used in lightly trafficked rural areas;
- Stone Mastic Asphalt (SMA) surface course used as an alternative; and
- Heavy Duty Macadam (HDM) with a 50pen binder or HRA with a 50pen binder is used as binder and base layers.

Derbyshire County Council most commonly use AC (a Dense Bituminous Macadam) or SMA surface course on their carriageways – with limited use also of HRA or a Thin Surface Course System (TSCS); but SMA has been seen to crack above settled areas (poor/wet foundation) as it is less able to flex. On the existing footways, localised patching and a general application of slurry seal is used during maintenance, unless the patching is sufficiently extensive to consider an AC surface course inlay. Many proprietary materials are not sufficiently well understood to allow their consideration.

Nottinghamshire County Council provided their Specification for surface course material: Hot Rolled Asphalt (HRA), 50pen, in accordance with BS594-2003 [Note: BS594:1 (HRA mixture design) was replaced by EN 13108 in January 2008; and BS594:2 (HRA laying standards) was replaced by BS 594987], with a 45% stone content, and 14mm nominal stone size for surface course laid 40-50mm in thickness or 10mm nominal stone size for surface course laid 25-40mm in thickness. Nottinghamshire County Council also raised a number of material issues and possible adaptations, as follows:

- Rising crude oil prices may lead to consideration of the lighter bitumen binders (i.e. higher penetration binder grades, e.g. 125pen), which would increase the susceptibility to permanent deformation in hotter temperatures;
- There is a need to consider the crack susceptibility of pavements in the light of long dry summers resulting in shrinkage of the soil subgrade;
- Consider revising the grading of the typical Type 1 subbase to ensure a more free-draining material; and.
- There has always been a need to ensure that the pavement is free draining, and this must be borne in mind when considering the new planning requirements for attenuating runoff.

Highway Structures Materials

In addition to the pavement materials, highway structures materials should be considered in the light of climate change. Overall it is considered that there would be no significant short term effects on highway structures due to climate change. There would have to be very significant increases in the following key climate change types [Ref. Table 3] to require short term adaptation responses in highways structures and individual elements and materials therein:

- ***Hotter Drier Summers***

  The design of bridges for thermal effects is dealt with in BD 37/01 and is for a thermal event return period of 120 years. Load effects from temperature are developed from maps of the UK showing isotherms for both maximum and minimum shade air temperature. For example structures located in Chesterfield in Derbyshire, would be designed for a maximum shade air temperature of 36^0C and a minimum of -18^0C.

  Changes in temperature due to climate change would have to be very large to cause any serious problems in bridges and would probably concern serviceability rather than structural integrity issues. Probably most at risk would be deck movement joints which are selected to deal with a certain range of movements due to thermal expansion and contraction. Hence should significant changes occur in these thermal effects then larger movement capability joints would have to be selected in design and replacement. A similar situation may exist with movement plates on structural bearings.

- ***More Intense Rainfall (i.e. flooding)***

  Scour of bridge foundations is probably the most onerous effect resulting from increased flows in watercourses and flooding outside of the watercourse. Bridges are currently designed for scour in accordance with BA 59/94. This Standard also requires design for erosion, hydraulic forces on piers and decks and loads from flood debris and ice.

  Standard BD 63/07 requires the regular 2-yearly bridge inspections to also include for examination for evidence of scour or bank erosion and, following flooding, probing of foundations located under water. In addition there must be a regular programme of underwater inspections carried out by specialist diving contractors.

  Standard BA 74/06 provides a method for quantitative assessment of scour at existing structures.

  Possibly future design for river bridge foundations outside of the watercourse may have to consider a potential level of flooding beyond that currently experienced and if deemed necessary include appropriate scour protection measures as though it were a foundation within the river.

  Scour and erosion are currently recognised issues at river bridges and are dealt with well by existing arrangements for design and inspection. These measures would pick up any deterioration resulting from climate change effects.

  It is difficult to imagine 'surface damage to structures' occurring as a result of climate change – structure design is very robust and includes such items as impact of 30 tonne HGV's on piers.

- ***Stronger Winds and more Storminess***

  Only lightweight structures are sensitive to wind loading and possibly at risk from increased wind due to climate change. Such structures would be steel footbridges, steel sign gantries, large road signs and lighting columns.

  Design wind loads are derived from BD 37/01 which includes a probability factor of 1.05 to be applied to wind loads to account for a return period of 120 years. This would seem to be fairly conservative and should allow for wind effects well beyond currently experienced norms. Loads in BD 37/01 are developed from basic wind speed shown on a map of the UK. For example structures located in Chesterfield in Derbyshire, would be designed using a basic wind speed of 22 m/s i.e. 50 mph, gusting up to about 75 mph.

An indirect and positive effect of the climate change type Warmer Winters [Ref. Table 3] might be a reduced application of de-icing salts on roads over bridges in response to a reduced risk of ice forming on the region's roads. This would mitigate one of the worst enemies of reinforced concrete and steel – corrosion from chlorides.

Highway Verge Flora

Tree populations located on highways are in the front line of environmental change due to their situation; often isolated, under water deficits or nutrient fluxes, subject to physical damage, storm damage and to pollution. Whilst the anticipated elevated CO_2 levels and temperatures mediate an increase in the growth season and promote an estimated possible 30-50% increase in growth of young trees, the higher average temperatures and changes in precipitation patterns are expected to promote summer drought conditions. Forest research indicates that such drought conditions pose significant threats to tree health and survival [Nisbet, 2002].

Research conducted by Lonsdale & Gibbs [2007] suggests that climate change effects, combined with the increased CO_2 fertilisation effect, could result in an increase in pest and disease incidence. Increased severity of pest and disease attack and enhanced wood decay are accompanying processes, and increased incidence of established pest and disease organisms (and their vectors) is becoming evident.

It is also probable that the defensive mechanisms of trees within roadside environments will be challenged by previously benign organisms, as it is known that some wood decay saprophytic fungi can also be weakly parasitic. More specifically, weak pathogens that exist on dead and decaying wood within trees can become parasitic when the tree declines in health and vigour [Redfern & Hendry, 2007]. Consequently, it appears that the health and structural integrity of mature trees could be compromised by climate change related stresses. The occurrence and spread of more exotic pathogens has also begun to be documented within the UK.

6.4.2 Risk Assessment Results

From the Risk and Probability Assessment carried out (Section 4.2), it has been identified that the existing policies and standards for highway pavement, structures and verge (flora) materials will predominantly be affected by three of the four main climate change types investigated; 'hotter and drier summers', 'more intense rainfall' and 'stronger winds and more storminess'; (with some potential positive benefits of 'warmer winters', i.e. extended growing season for a healthy verge estate and possible reduced use of de-icing salts, discussed in section 6.4.1). The specific climate change effects that will affect these policies and standards are shown in the Risk Assessment (Section 4.2: Tables 5-7).

6.4.3 Adaptation Responses and Evaluation

In order to ensure that the highway network materials can withstand the effects of climate change, a number of adaptation responses have been established. These being:

Highway Pavement Materials

- M1. Monitor ground water levels – in order to assess the adequacy of the current drainage provision;
- M2. Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat (e.g. un-sheltered roads suffering deformation and cracking; and tree-lined roads and footways suffering soil shrinkage damage, where materials susceptible to heave could be removed and replaced);
- M3. Sanding of asphalt surfaces in summer – to prevent loss of skid resistance, using the winter gritting equipment; and treatment of 'fatting up' areas with hot fine aggregate;

M4. Increased maintenance to seal all faces/joints/cracks to prevent water ingress - all pavements are vulnerable to water in terms of stripping of the binder, scouring/erosion/polishing, and softening/removal of the support;

M5. Review existing materials specifications – General;

M6. Use performance related specifications which promote properties which resist the negative effects of climate change;

M7. Specification: Consider using high modulus base/binder materials and rut resistant surface course material (including asphaltic concrete mixtures with a polymer modified binder, stone mastic asphalt mixtures with cellulose fibres and grouted macadam). Remove rut-prone Hot Rolled Asphalt surface course during routine resurfacing operations;

M8. Closer control: During construction ensure compaction of pavement layers (density, air voids monitoring etc, for reduced permeability) and adequate curing – to ensure durable pavement materials;

M9. Specification: Consider the application of bond coats to reduce voids at layer interfaces – to ensure a durable pavement;

M10. Specification: Consider using hydraulically bound layers with a low coefficient of expansion coarse aggregate and/or smaller slab sizes by induced cracking;

M11. Specification: Consider using light coloured aggregate, reflective aggregate, modified colour asphalt, and/or concrete ('white-topping') surface course to increase solar reflectance;

M12. Specification: Consider using aggregates less prone to stripping, anti-stripping agents (e.g. hydrated lime), and/or more viscous binders to reduce stripping;

M13. Consider increasing the permeability of the surface course (where appropriate) to reduce the run-off and adjust road crossfall/alignment to prevent water ponding;

M14. Restrict or redirect heavy traffic during prolonged periods of hot and dry conditions; and

M15. Develop a long-term programme to locate and assess the adequacy and condition of the current drainage provision, and ensure it is well maintained.

Highway Structures Materials

M16. Specification: Amend BA 59/94 bridge design for scour; and/or amend BD 63/07 regular 2-yearly bridge inspections; and/or amend BA 74/06 method for quantitative assessment of scour at existing structures; and/or amend BD 37/01 design wind loads; and/or amend BD 37/01 bridge design for thermal effects; and

M17. Assess lightweight structures for sensitivity to wind loading.

Highway Verge Flora

M18. Identify where soil comprises clay with a high plasticity index and avoid planting/removing forest trees from within at least 15m from the road edge;

M19. Specification: Appropriate planting - avoid planting fast growing trees like poplars; 'thirsty' (broad leaf) trees should not be planted near the carriageway; shrubs should not be planted within 3m of the carriageway and trees not within 5m of the carriageway; ensure that new plantings are composed of trees and shrubs suited to those local conditions; consider any new trends in diseases and pests associated with specific tree species and avoid another "Dutch elm disease scenario" where predictable; climax tree species such as oak and lime are not be suitable for planting close to a carriageway; vigorous species such as willow and poplar should not be located close to trunk roads given incumbent high maintenance needs and vulnerability to cracking in high winds as they mature; consider utilizing areas more distant from the carriageway for landscaping and biodiversity gain;

M20. Tree maintenance regimes should be established, to control the size of each tree and its water requirement; and

M21. Avoid creating tree wind-throw risks when undertaking works such as copse or tree-line thinning, removing hedgerows or earth works.

These twenty-one adaptation responses have undergone evaluation using the 13 no. established evaluation criteria, as per the example in Section 5.5. The results of this evaluation are shown in Tables 20 to 22.

Table 20: Adaptation Response Evaluation – Highway Pavement Materials

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Link to effects	Score (out of 3)	Links to other council plans, strategies and operations
Materials (Highway Pavements)	Hotter and drier summers More intense rainfall Stronger winds and more storminess	R1. Pavement failure from prolonged high temperature R3. Lack of capacity in the drainage system and flooding of the highway network O3. Damage to pavement surface layers O4. Subsidence and heave on the highway Y1. Landslips Y2 and Y3. Embankment erosion B2. Increased recreation and leisure based travel in the summer months B3. Modal shift. Increased number of cars and bikes on the road as people move away from public transport in high temperatures B5. Top soil run-off B6. Tree root damage B7. Increased leaf-fall B8. Increased accidents on the network	M1. Monitor ground water levels – in order to assess the adequacy of the current drainage provision	R3, O3, O4, Y1, Y2, Y3, B5, B8	1.8	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity
			M2. Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat	R1, O3, O4, B2, B3,	2.55	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity
			M3. Sanding of asphalt surfaces in summer – to prevent loss of skid resistance	R1, O3, O4, B2, B3, B8	1.975	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			M4. Increased maintenance to seal all faces/joints/cracks to prevent water ingress	R3, O3, O4, B5	2.15	Environmental Services, Assets, Ecology, Biodiversity, Waste
			M5. Review existing materials specifications - General	All	2.225	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			M6. Use performance related specifications which promote properties which resist the adverse effects of climate change	All	2.375	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			M7. Specification: Consider using high modulus base/binder materials and rut resistant surface course material	R3, O3, O4	2.55	Environmental Services, Ecology, Biodiversity, Waste
			M8. Closer control: During construction ensure compaction of pavement layers and adequate curing	All	1.75	Environmental Services, Ecology, Biodiversity, Waste
			M9. Specification: Consider the application of bond coats to reduce voids at layer interfaces	R3, O3, O4	2.125	Environmental Services, Ecology, Biodiversity, Waste
			M10. Specification: Consider using hydraulically bound layers with a low coefficient of expansion coarse aggregate and/or smaller slab sizes by induced cracking	R1, O3, O4	1.7	Environmental Services, Ecology, Biodiversity, Waste
			M11. Specification: Consider using light coloured/reflective aggregate and/or modified colour asphalt in the surface course to increase solar reflectance	R1, O3, B2, B3, B8	2.175	Environmental Services, Ecology, Biodiversity, Waste
			M12. Specification: Consider using aggregates less prone to stripping, anti-stripping agents (e.g. hydrated lime), and/or more viscous binders to reduce stripping.	R3, O3, O4, Y1,Y2, Y3, B5	1.8	Environmental Services, Ecology, Biodiversity, Waste
			M13. Consider increasing the permeability of the surface course to reduce the run-off and adjust road crossfall/alignment to prevent water ponding	R3, O3, O4, Y1, Y2, Y3, B5, B7, B8	1.525	Environmental Services, Ecology, Biodiversity, Waste
			M14. Restrict or redirect heavy traffic during prolonged periods of hot and dry conditions	R1, O3, B2, B3, B8	1.65	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity
			M15. Develop a long-term programme to locate and assess the adequacy and condition of the current drainage provision, and ensure it is well maintained.	R3, O3, O4	2.475	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity

Table 21: Adaptation Response Evaluation – Highway Structures Materials

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Link to effects	Score (out of 3)	Links to other council plans, strategies and operations
Materials (Highway Structures)	Hotter and drier summers More intense rainfall Stronger winds and more storminess	O1. Surface damage to structures O2 and O5. Scour to structures O6. Severe damage to light-weight structures Y1. Landslips Y2 and Y3. Embankment erosion	M16. Specification: Amend BA 59/94 bridge design for scour; and/or BD 63/07 regular 2-yearly bridge inspections; and/or BA 74/06 method for quantitative assessment of scour at existing structures; and/or BD 37/01 design wind loads; and/or BD 37/01 bridge design for thermal effects	All	1.7	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			M17. Assess lightweight structures for sensitivity to wind loading	O6	2.125	Assets

Table 22: Adaptation Response Evaluation – Highway Verge Materials (Flora)

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Link to effects	Score (out of 3)	Links to other council plans, strategies and operations
Materials (Highway Verge - Flora)	Hotter and drier summers More intense rainfall Stronger winds and more storminess	R2. Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate Y4. Tree damage B2. Plant and animal species changing, shifting patterns of migration and plants flowering earlier B4. Fire risk on the soft estate B6. Tree root damage B7. Increased leaf-fall	M18. Identify where soil comprises clay with a high plasticity index and avoid planting/removing forest trees from within at least 15m from the road edge	All	1.575	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity
			M19. Specification: Appropriate planting - tree types and locations	All	2.375	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			M20. Tree maintenance regimes should be established, to control the size of each tree and its water requirement	All	2.175	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity
			M21. Avoid creating tree wind-throw risks when undertaking works such as copse or tree line thinning, removing hedgerows or earth works.	Y4	2.375	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste

Scores

(red)	>2.5	Very high
(orange)	2.25 - 2.5	High
(yellow)	2 - 2.25	Medium
(light orange)	1.75 - 2	Low
(white)	< 1.75	Very low

From the evaluation of the suggested adaptation responses, it can be seen that seven responses have scored 'high' or 'very high' and so are likely to be the most realistic and effective if applied, these being highway pavement materials responses M2, M5, M6, M7 and M15; and highway verge (flora) materials responses M19 and M21. Full calculation tables can be found in Appendix 3.

The most realistic highway pavement materials adaptation responses include inspection and inventory regarding the parts of the network most susceptible to high temperatures or with inadequate drainage provision; and a move towards more climate change resistant material options and performance assessment.

The low scoring adaptation responses for highway structures materials reflects the very prescriptive design, inspection and maintenance requirements, mostly contained in the Highways Agency's Design Manual for Roads and Bridges. Structures design is to (ultimate and serviceability) limit state and fairly conservative, generally to extremes well beyond normal scenarios. More significant effects due to climate change over a very long period of time would be addressed during the regular updates of these documents by the code authors. In the meantime it is believed that short term climate change effects would be covered by the existing conservative criteria.

Tree populations located on highways are often isolated, under water deficits or nutrient fluxes, subject to physical damage, storm damage and to pollution. It is expected that climate change impact to trees in the highway soft estate will be more pronounced than in sheltered more natural woodlands.

6.5 RESURFACING

6.5.1 3CAP Policies and Standards for Resurfacing

Carriageway patching and minor repairs are undertaken to ensure that surfaces are maintained in a safe condition, taking into account the need to protect and retain historic surfaces and features. In conservation areas traditional natural materials are usually replaced on a 'like for like' basis, e.g. stone kerbs will be replaced with stone kerbs to match. In areas where patching or surface treatment is not appropriate, resurfacing or overlay is used to strengthen the running surface, reduce surface irregularity and improve skid-resistance. Resurfacing or full reconstruction of the carriageway is usually carried out where it would be uneconomic and/or unacceptably inconvenient to the road user to undertake repeated repairs to the carriageway.

Resurfacing or overlay can be carried out as a treatment to restore carriageway condition or as a preventative measure. Intervention at the right time can avoid more expensive reconstruction having to be carried out. The materials used are usually bituminous. Concrete surfacing materials should not be used without the prior approval of the appropriate decision-maker within the council.

Surface treatment is carried out to give an appropriate riding/walking surface, to seal against water penetration, to arrest deterioration and to restore adequate skidding resistance. The need to protect and enhance the local environment is taken into account when specifying types of historic surfaces and choice of surface to complement landscape character.

Various condition surveys are carried out by the Highway Authority on different sections of the network in order to assess need and prioritise work within the available resources. The condition surveys used presently throughout the 3CAP region are:

- **Detailed Visual Inspection (DVI)**: Involve the visual inspection and recording and inspection of deterioration of various characteristics of structure, kerbing and footways. ;
- **Coarse Visual Inspection (CVI)**: Intended to satisfy one of the visual condition survey requirements of UKPMS, to enable authorities to cover large parts of the network on a regular basis. The surveys are normally carried out from slow moving vehicles and identify and categorise lengths of features having generally consistent defects rather than identifying individual defects;
- **Deflectograph**: The technique measures deflection of the road under an imposed load and produces pavement residual life information from which appropriate treatments can be derived;
- **SCRIM (Sideways Force Co-efficient Routine Investigation Machine / Griptester**: Measures skid-resistance of the carriageway surface. The surveys are typically carried out on all A and B roads on a rolling programme and other roads in response to accident statistics;
- **SCANNER (TTS) Surveys**: These automated condition surveys collect and report data on any defects that exist in the road. This allows for maintenance programmes to be developed and prioritised; and
- **NRMCS (National Road Maintenance Condition Survey)**: These surveys look at the condition of public roads, footways, kerbs and verges in the UK. They are typically based around SCANNER surveying techniques.

The frequency that carriageway condition assessment is carried out, as detailed in the relevant policy and standard documents for Derbyshire and Leicestershire County Councils, are shown in Tables 23 and 24.

Table 23: Derbyshire County Council's Carriageway Condition Assessment Frequency

Hierarchy		Frequency	
Carriageway Type	**Category**	**CVI**	**DVI**
Strategic Routes	2	Every year (surveyed in alternative directions year on year as routes)	In addition to CVI inspections, SCRIM/Griptester surveys (plus a pilot on other roads) are carried out (typically on a 3-year rolling programme) to identify costs and implications and to investigate surface condition on sites identified from the accident database. Deflectograph surveys are on all roads periodically.
Main Distributor	3(a)	Every year (surveyed in alternative directions year on year as routes)	Deflectograph surveys are carried out on some roads, typically on a 3-year rolling programme.
Secondary Distributor	3(b)	Every two years (surveyed in a single direction as routes each time)	Deflectograph surveys are carried out periodically on problem areas.
Link Road	4(a)	Every two years (surveyed in a single direction on specified areas)	Every two years (walked survey including District). Sites identified as required in the year from the CVI Surveys identified.
Local Access Road	4(b)	Every two years (surveyed in a single direction on specified areas)	Every two years (walked survey including District). Sites identified as required in the year from the CVI Surveys identified.

Table 24: Leicestershire County Council's Carriageway Condition Assessment Frequency

Road Type	Principal (A Roads)	Non Principal Classified (B & C Roads)	Unclassified (All Other Roads)
UKpms CVI Surveys	20% of network surveyed annually	50% of network surveyed annually (may reduce to 20% in 2005)	20% of network surveyed annually
SCANNER (TTS) Surveys	100% of network surveyed annually in one direction	100% of network surveyed annually in one direction	Not surveyed
Deflectograph Surveys	20% of A and B road network surveyed annually	20% of A and B road network surveyed annually	Not surveyed
NRMCS Surveys	50 sites	110 sites	90 sites
Griptester Surveys	33% of network surveyed annually	Site specific surveys only	Not surveyed

<u>**Nottinghamshire County Council Carriageway Condition Assessment Frequency**</u>

- **DVI –** The poorest roads in each district are highlighted and a list of sites in priority order and a works programme are produced;
- **CVI –** Large parts of the network are covered on a regular basis;
- **Deflectograph –** Currently carried out on all A roads on a 3-year rolling programme; and

- **SCRIM –** Currently carried out on all A and B roads on a 3-year rolling programme and other roads in response to accident statistics.

Surface dressing

Surface dressing is an established process, in which the existing carriageway or footway surface is coated with a layer of propriety adhesive (binder) over which stone chippings are spread and rolled to bind them to the carriageway or footway surface. This nationally recognised process is a cost-effective measure taken to maintain and extend the life of the carriageway or footway and, from a safety aspect, as an aid to accident reduction. The main benefits are:

- To improve the surface texture and resistance to skidding;
- To seal the surface against water penetration;
- To arrest disintegration of the existing surface; and
- To add a specific colour to the surface.

Surface dressing is a rapid process, which when carried out competently in suitable weather conditions, gives economical and effective results. The process is carried out to prevent water penetration, arrest surface deterioration and to reduce the likelihood of accidents caused by lack of adequate skidding resistance. Typically, to ensure that the correct conditions exist for surface dressing, it is only carried out between May and September. The bitumen will set even if the road is damp.

Hot rolled asphalt incorporating precoated chippings of high polished stone value shall generally be used as a surfacing material on principal and heavily trafficked roads only. The use of concrete as a road surfacing material except in bus bays and lay-bys shall only be adopted with written approval of appropriate individual with the councils. Consideration should be given to the use of newly developed materials as these are developed with appropriate trials and approvals required prior to usage.

6.5.2 Risk Assessment Results

From the Risk and Probability Assessment carried out (Section 4.2), it has been identified that the existing policies and standards for resurfacing, overlay, reconstruction and surfacing dressing will be affected by all four of the main climate change types investigated; 'hotter and drier summers', 'more intense rainfall', 'stronger winds and more storminess' and 'warmer winters'. The specific climate change effects that will affect these policies and standards are shown in the Risk Assessment (Section 4.2).

6.5.3 Adaptation Responses and Evaluation

In order to ensure that carriageway surfacing can withstand the effects of climate change, a number of adaptation responses have been established. These being:

S1. Undertake a risk assessment to identify the most vulnerable areas of the network and develop priority actions to be carried out;

S2. Implement a targeted programme of improvement;

S3. Increase the frequency of carriageway surface inspections;

S4. Implement a cyclic programme of carriageway resurfacing and maintenance (rather than on demand);

S5. Consider tree felling to reduce the soil moisture deficit in summer;

S6. Use chamfered edges to reduce the risk of spalling during expansion in hot weather;

S7. Review local experience of the durability of surface dressing and consider whether other measures may be more appropriate;

S8. Use polymer modified binders that are less prone to binder stripping and other materials with a greater 'stiffness';

S9. Sand/ dust bituminous surfaces in summer;

S10. Trial reinforcement of the carriageway to reduce subsidence;

S11. Induce transverse cracks to pavements during resurfacing and repair activities to reduce the risk of cracking in high temperatures;

S12. Restrict the periods where resurfacing activities are carried out (i.e. not during high temperatures);

S13. Increase gully emptying and inspection frequency;

S14. Increase verge maintenance and grass cutting frequencies to reduce the risk of 'root invasion' and vegetation ingress on the highway;

S15. Revise the parameters for the design storm to reduce the risks and effects of flooding; and

S16. Introduce surface/ sub-surface drainage during maintenance works where they do not exist at present.

These sixteen adaptation responses have undergone evaluation using the 13 no. established evaluation criteria, as per the example in Section 5.5. The results of this evaluation are shown in Table 25.

Table 25: Adaptation Response Evaluation – Carriageway Resurfacing/ Carriageway Surface Treatment/ Carriageway Patching and Minor Repair

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Links to effects	Score (out of 3)	Links to other council plans, strategies and operations
Carriageway Resurfacing / Carriageway Surface Treatment / Carriageway Patching and Minor Repair	Hotter and drier summers More intense rainfall Stronger winds and more storminess Less disruption by snow and ice	R1. Pavement failure from prolonged high temperatures R2. Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate R3. Lack of capacity in the drainage system and flooding of the highway network O1. Surface damage to structures O2 and O5. Scour to structures O3. Damage to pavement surface layers O4. Subsidence and heave on the highway O6. Severe damage to light-weight structures O7. Less disruption by snow and ice Y1. Landslips Y2 and Y3. Embankment erosion Y4. Tree damage B2. Increased recreation and leisure based travel in the summer months B3. Modal shift. Increased number of cars and bikes on the road as people move away from public transport in hot temperatures B5. Top soil run-off B6. Tree root damage B8. Increased accidents on the network	S1. Undertake a risk assessment to identify the most vulnerable areas of the network and develop priority actions to be carried out	All	2.525	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S2. Implement a targetted programme of improvement	All	2.175	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S3. Increase the frequency of carriageway surface inspections	All	2.225	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S4. Implement a cyclic programme of carriageway resurfacing and maintenance (rather than on demand)	All	2.1	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S5. Consider tree felling to reduce the soil moisture deficit in summer	R1, R2, O3, O4, Y1, Y2, Y3, Y4, B5, B6	1.65	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S6. Use chamfered edges to reduce the risk of spalling during expansion in hot weather	R1, O3, O4, Y2, Y3, B5, B6	2	Environmental Services, Urban Design, Planning, Ecology, Biodiversity
			S7. Review local experience of the durability of surface dressing and consider whether other measures may be more appropriate	R1, O3, O4, O7, B2, B3, B5, B6	2.475	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S8. Use polymer modified binders that are less prone to binder stripping and other materials with a greater 'stiffness'	R1, R3, O3, O4, B6	2.05	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S9. Sand/dust bituminous surfaces in summer	R1, O3, O4, B2, B3	2.05	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S10. Trial reinforcement of the carriageway to reduce subsidence	R1, O3, O4, B6	1.725	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S11. Induce transverse cracks to pavements during resurfacing and repair activities to reduce the risk of cracking in high temperatures	R1, O3, O4	1.75	Environmental Services, Urban Design, Planning, Assets, Waste
			S12. Restrict the periods where resurfacing activities are carried out (not during high temperatures)	R1, O3, O4	2.15	Environmental Services, Urban Design, Planning, Ecology, Biodiversity, Waste
			S13. Increase gully emptying and inspection frequency	R2, R3, O2, O3, O4, O5, Y1, Y2, Y3, B5, B6, B8	2.15	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S14. Increase verge maintenance and grass cutting frequencies to reduce the risk of 'root invasion' and vegetation ingress on the highway	R2, R3, O3, O4, Y2, Y3, Y4, B5, B6, B8	2.35	Environmental Services, Urban Design, Planning, Ecology, Biodiversity, Waste
			S15. Revise the parameters for the design storm to reduce the risks and effects of flooding	R3, O1, O2, O3, O4, O5, Y1, Y2, Y3, Y4, B5, B6	1.75	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			S16. Introduce surface/sub-surface drainage during maintenance works where they do not exist at present	R3, O1, O2, O3, O4, O5, Y1, Y2, Y3, B5, B6	1.7	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste

Scores

(red)	>2.5	Very high
(orange)	2.25 - 2.5	High
(yellow)	2 - 2.25	Medium
(light orange)	1.75 - 2	Low
(white)	< 1.75	Very low

From the evaluation of the suggested adaptation responses, it can be seen that four responses have scored 'high' or 'very high' and so are likely to be the most realistic and effective if applied, these being S1, S3, S7, and S14. Full calculation tables can be found in Appendix 3.

6.6 TREE AND HEDGE MAINTENANCE

6.6.1 3CAP Policies and Standards for Tree and Hedge Maintenance

Although the area of law relating to trees growing in the highway is unclear, overall responsibility for all trees growing in the highway rests with the Highway Authority. Where trees are planted in the highway by a third party, with the consent of the Highway Authority, the Authority will seek to indemnify against any claims in respect of injury, damage or loss arising out of the planting or presence of the tree in the highway. According to National Code Recommendations; highway safety inspections should include highway trees, including those outside, but within falling distance of the highway. Authorities should include some basic arboricultural guidance in training for highway inspectors. With this guidance, Authorities should develop a policy for the installation management, removal and replacement of highway trees.

The controlling Highway Authority should only carry out work for safety reasons and limited essential work within available budgets and with regard to the care and protection of the tree. The Highway Authority will not carry out works for aesthetic purposes. Trees within the highway will be maintained in a safe and healthy condition. Trees that cause obstructions to signs, street lighting, free movement of vehicles or are likely to cause damage to the highway or vehicles will be managed by tree surgery or removal.

The Highway Authority recognises landscape, cultural or ecological importance of veteran trees, due to their age, size or character. In carrying out work for safety reasons special care will be taken to ensure the long-term viability of veteran trees. Local Planning Authorities are empowered under the Town and Country Planning Act 1990, to make Tree Preservation Orders (TPOs) for the protection of trees and woodlands in the interests of amenity. Conservation Areas, designated by Local Planning Authorities, are areas of special architectural or historical interest, the character or appearance of which it is desirable to preserve or enhance. The Town and Country Planning Act 1990 makes special provision for trees in Conservation Areas that are not the subject of TPOs, which is effectively a blanket TPO for all such trees.

When trees on private property are thought to be dangerous, the Highway Authority will advise the owner of its concern and request that prompt action is taken to make the trees safe. The Highway Authority will seek co-operation from landowners in dealing with trees and hedges that overhang the highway and impede visibility and safe passage of traffic and/or pedestrians. Owners of land containing trees which could cause a hazard to the adjacent highway will be instructed to take appropriate action.

The Highway Authority's management of trees will be carried out with the aim of enhancing the value of the trees or recognising the needs of highway safety. Costs will be charged to the owners where appropriate. Any works required to trees to prevent damage to overhead cables are the responsibility of the utility concerned. Careful positioning of signs and street lights in relation to existing trees and making allowances for signs and street lights when designing schemes can help reduce the necessity for maintenance work.

As identified in Derbyshire County Council's policy and standard document, there are four main types of tree maintenance procedures carried out by County Council. These processes are similar for Leicestershire County Council and Nottinghamshire County Council.

1. Emergency works – Dangerous trees

In any situation where there is, in the opinion of the Highway Authority, a clear and imminent danger to users of the highway, emergency action to remedy the situation will be taken as a matter of urgency based on the 24 hour response system for all highway emergency issues.

2. General works to highway trees – Minor works

Defined as works of a limited nature, usually undertaken to provide head clearance to pedestrians, horses, cyclists and vehicles, or to clear obstruction of signs and accesses. Also to remove basal growth when this impedes footways, access and/or visibility. The Authority without consultation will directly carry out these works.

3. General works to highway trees – Intermediate works
Works of a more substantial nature undertaken to trees outside of Conservation Areas and without Tree Preservation Orders (TPO). These works consist of removal of dead, damaged or crossing branches in a manner that retains the balance and form of the tree.

4. Major works
Works to mature trees, trees in conservation areas, and/or with TPO designation may entail major surgery, removal of a substantial feature, or in very exceptional cases, removal of a live tree. In the event of major works to a tree with a TPO, or the necessary removal of a major live tree, a report will be obtained from an Arboricultural Consultant who is registered in the Arboricultural Association's Directory. In all cases where the felling of a tree is the only option, the planting of a suitably located replacement tree, subject to safety considerations, will be undertaken after consultations with the Department's Area Network Manager and Landscape Officer together with a representative of the District or Local Council.

Derbyshire County Council's Standards for Tree and Hedge Maintenance

Table 26 shows Derbyshire County Council's current standards for tree and hedge maintenance activities.

Table 26: Derbyshire County Council Tree and Hedge Maintenance Standards

Item	Standard	Notes
• **Hedges and trees in Highway Authority ownership**	Training and pruning where required on strategic and main distributor roads. Reactive and emergency works only on other roads	Work should only be undertaken on safety grounds following inspection reports or complaints
• **Hedges and trees in other ownership**	Owners requested to trim and prune where required	To provide visibility and prevent obstruction (following inspection reports or complaints)
• **Dangerous trees in Highway Authority ownership**	Pruning or felling arranged when required	On safety grounds following inspection by qualified tree specialist. Replacements planted if possible
• **Dangerous trees in other ownership**	Owners asked to fell when required	On safety grounds following inspection
• **Newly planted areas and existing / established areas of shrubs and trees**	Standards being produced	

Derbyshire County Council as the Highways Authority must control the overgrowth of shrubs and trees that spread from hedgerows onto verges causing a highway safety issue. The County Council aims to limit verge scrub flailing to the period September to February inclusive (due to the EC Nesting Birds Directive and the Wildlife and Countryside Act 1981). The authority will not undertake work between April and July, unless there are immediate road safety issues. The Council also aims to extend this period to include March to August, unless unforeseen operational or highways safety requirements prevent it from doing so.

Leicestershire County Council Standards for Tree and Hedge Maintenance

Tree and hedge maintenance is not included in Leicestershire County Council's Highway Maintenance Policy and Strategy. Brief information is available on the nature of the maintenance and inspections activities carried out on Leicestershire's tree and hedge stock.

Currently all trees both on the public highway and adjoining it receive a cursory inspection by the Highway inspector at the same time as the carriageway is inspected. Any defect noted is passed on to the County Council's Forestry Team, to enable a detailed inspection to be undertaken by a suitably qualified person. A tree management strategy (for all LCC trees, not just highways) is currently in preparation. It is proposed that the LCC tree strategy be included in the maintenance document by reference once it has been approved by Members.

Except in an emergency incident, tree surgery shall only be undertaken within the dormant season outside the bird nesting season. All mature trees shall be checked for bat roosts in any cavities, before any arboricultural works are carried out.

Nottinghamshire County Council's Standards for Tree and Hedge Maintenance

Table 27 shows Nottinghamshire County Council's current standards for tree and hedge maintenance.

Table 27: Nottinghamshire County Council Tree and Hedge Maintenance Standards

Item	Standard	Notes
• **Hedges and trees within the highway**	Prune as required	Works undertaken on safety grounds following complaints or inspection
• **Hedges and trees in private ownership**	Owners requested to prune as required	Mainly to restore visibility and prevent obstruction
• **Dangerous trees within the highway**	Fell as required	Works undertaken on safety grounds following inspection by qualified arboriculturalist
• **Dangerous trees in private ownership**	Owners requested to fell as required. Followed by legal action if necessary	Following inspection by qualified arboriculturalist

Trees felled within the highway should be replaced with trees of the same species unless there are arboricultural or engineering reasons to the contrary. Routine works to trees should be carried out with regard to the Wildlife and Countryside Act 1981. This particularly refers to the protection of nesting birds and bat roosts. The bird nesting season is normally considered to be from mid-February to late August. It is an offence to disturb any nesting wild birds under the Wildlife and Countryside Act 1981.

In the case of privately owned trees, the landowner should be advised of the nature of the problem and given notice to undertake any remedial actions considered necessary. Section 154 of the Highways Act 1980 outlines the procedure for Highways Authorities to deal with hedges, trees and shrubs growing on adjacent land and also allows for the recharging of any reasonable costs incurred.

All works carried out in the vicinity of trees will be done with regard to the National Joint Utilities Group (NJUG 10) code of practice 'Guidelines for the planning, installation and maintenance of utility services in proximity to trees' and BS5837: 1991 'Guide for trees in relation to construction' and with due consideration to the County Council 'Tree Conservation and Maintenance Policy' document.

6.6.2 Risk Assessment Results

From the Risk and Probability Assessment carried out (Section 4.2), it has been identified that the existing policies and standards for tree and hedge maintenance will be affected by all four of the main climate change types investigated; 'hotter and drier summers', 'more intense rainfall', 'stronger winds and more storminess' and 'warmer winters'. The specific climate change effects that will affect tree and hedge maintenance are shown in the Risk Assessment (Section 4.2).

6.6.3 Adaptation Responses and Evaluation

In order to ensure that trees and hedges on the highway can withstand the effects of climate change, a number of adaptation responses have been established. These being:

T1. Improve the knowledge of existing tree stock;

T2. Undertake a risk assessment to determine vulnerable trees and establish a priorities scheme for maintenance;

T3. Increase the frequency of tree and hedge inspections;

T4. Increase the budget available for tree and hedge maintenance;

T5. Carry out a programme of tree condition surveys;

T6. Increase the frequency of tree training and pruning;

T7. Make enforcements on landowners easier;

T8. Make enforcements on utility companies easier;

T9. Fell trees that are deemed to be a threat to highway structures or a threat to road safety;

T10. Develop a tree management strategy for implementation across the county councils (to include all trees, not just those on or near the highway);

T11. Replace felled trees with slower growing varieties, rather than those of the same species; and

T12. Review the species choice for new trees to ensure the most appropriate species is selected.

These eleven adaptation responses have undergone evaluation using the 13 no. established evaluation criteria, as per the example in Section 5.5. The results of this evaluation are shown in Table 28.

Table 28: Adaptation Risk Evaluation – Tree and Hedge Maintenance

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Links to effects	Score (out of 3)	Links to other council plans, strategies and operations
Tree and Hedge Maintenance	Hotter and drier summers More intense rainfall Stronger winds and more storminess	R2. Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate O4. Subsidence and heave on the highway O6. Severe damage to light-weight structures O7. Less disruption by snow and ice Y1. Landslips Y2 and Y3. Embankment erosion Y4. Tree damage B1. Plant and animal species chnaging, shifting patterns of migration and plants flowering earlier B4. Fire risk on the soft estate B5. Top soil run-off B6. Tree root damage B7. Increased leaf-fall B8. Increased accidents on the network	T1. Improve the knowledge of existing tree stock	All	2.275	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T2. Undertake a risk assessment to determine vulnerable trees and establish a prioritised scheme for maintenance	All	2.3	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T3. Increase the frequency of tree and hedge inspections	All	2.05	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T4. Increase the budget available for tree and hedge maintenance	All	2.2	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T5. Carry out a programme of tree condition surveys	All	2.075	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T6. Increase the frequency of tree training and pruning	All	2	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T7. Make enforcements on landowners easier	All	1.975	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T8. Make enforcements on utility companies easier	All	1.925	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T9. Fell trees that are deemed to be a threat to highway structures or a threat to road safety	All	1.85	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T10. Develop a tree management strategy for implemetation across the county councils (to include all trees, not just those on or near to the highway)	All	2.375	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T11. Replace felled trees with slower growing varieties, rather than of the same species	All	1.975	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			T12. Review the species choice for new trees to enusre the most appropriate species is selected	All	2.325	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste

Scores

(red)	>2.5	Very high
(orange)	2.25 - 2.5	High
(yellow)	2 - 2.25	Medium
(peach)	1.75 - 2	Low
(white)	< 1.75	Very low

From the evaluation of the suggested adaptation responses, it can be seen that four responses have scored 'high' and so are likely to be the most realistic and effective if applied, these being T1, T2 and T10. Full calculation tables can be found in Appendix 3.

6.7 WINTER SERVICE

6.7.1 3CAP Policies and Standards for Winter Service

The statutory basis for winter service varies in different parts of the UK. In England and Wales, Section 41 of the Highways Act 1980 imposes a duty on highway authorities to maintain highways maintainable at public expense. There is a duty on highway authorities to ensure, so far as is reasonably practicable, that safe passage along a highway is not endangered by snow or ice. There is also, in Section 150 of the Highways Act 1980, a duty upon highway authorities to remove any obstruction of the highway resulting from accumulation of snow or from the falling down of banks on the side of the highway, or from any other cause.

County councils have certain duties under the Highways Act 1980 to maintain the highway, these being:

- Section 41: Imposes a duty to maintain a highway at public expense;
- Section 41 (1A): A Highway Authority has a duty to ensure, so far as reasonably practicable, that safe passage along the highway is not endangered by snow or ice;
- Section 150 (1): A Highway Authority shall remove any accumulation of snow from the highway if it is causing an obstruction;
- Section 150 (2): This gives a magistrates court the power to enforce the removal of an obstruction; and
- Section 150 (4a): A Highway Authority may take any reasonable steps (including the placing of lights, signs and fences) for warning users of the highway of the obstruction.

Also, according to the ideal contained in 'Well-maintained Highways: Code of Practice for Highways Maintenance Management (2005)', winter service contributes significantly to the following highway maintenance objectives:

- **Safety** – users needs vary in parts of the county but safety is a prime consideration for the winter service;
- **Serviceability** – maintaining availability and reliability of the highway network is a key objective for the winter service and one where user judgements of performance will be immediate rather than long term; and
- **Sustainability** – low temperatures and the formation of ice can cause serious damage to the fabric of running surfaces and the winter service can therefore make an important contribution to whole life costs.

Typically, there are three distinct elements to the winter service, each of which are undertaken according to pre-defined conditions and circumstances:

1. Pre-treatment (precautionary salting);
2. Post-treatment (salting following the formation of ice); and
3. Clearance of snow.

<u>**Derbyshire County Council Winter Service Policy**</u>

Derbyshire County Council's pre-treatment salting routes generally comprise all strategic routes, and main distributors together with certain secondary distributors and other roads. In order to minimise the adverse effects on the environment the amount of salt used will be the minimum possible consistent with achieving adequate treatment. The storage of salt will be managed on a 'just in time' principle and with adequate environmental controls.

A hierarchy of salting routes is maintained, regularly reviewed and published by the council. Treatment of ice and snow on carriageways is carried out where conditions require. Priority is given in accordance with the road hierarchy followed by providing at least one access to all communities. Treatment to prescribed town centre footways is undertaken in periods of persistent ice or snow and carried out in priority order.

Weather conditions can vary significantly across Derbyshire. Road conditions can also vary considerably and be influenced by local topography, humidity, wind-speed and residual salinity. Some of the conditions that need to be responded to are as follows:

- Temperatures falling to zero with varying cloud cover conditions, humidity and residual salinity on the roads;
- Frost or light snow forecast on dry roads;
- Frost forecast after rain;
- Freezing conditions with rain;
- Ice already formed on road surfaces;
- Rapid fails in temperature due to changing cloud conditions;
- Considerable variations in temperature, humidity and wind speed; and
- Heavy snow falls.

Derbyshire County Council's winter service is normally provided within the period 1st October to 30th April inclusive. This Winter Service Operational Plan is reviewed annually at the end of each winter and updated as necessary prior to the start of the next winter season to provide the most cost effective and efficient service. Derbyshire County Council have a decision making matrix for precautionary salting. This specifies whether salting is carried out before frost, wet patches are salted before frost, salting is carried out after the rain stops, or no action is taken. This is dependent on temperature (expected to fall below zero or not) and predicted precipitation and road conditions.

Particular attention is given to the possibility of water running across the highway, e.g. off adjacent fields and verges after heavy rains, washing off silt previously deposited. Such locations are closely monitored and may require treating in the evening and morning and possibly at other times.

Currently, Derbyshire County Council is one of the top spending Authorities in the country on winter service by precautionary salting (in excess of the Audit Commission guidelines of 25-30% of the network). This reduces the amount of revenue budget available for other general and routine highway maintenance works. Also, due to nature of the highway network within Derbyshire and the location of depots each current route includes an amount of "dead mileage" which is the amount of miles travelled without salt spread within a route. Currently the total distance of treated road as a percentage of the total route travelled (route efficiency) is approximately 60% (40% "dead mileage"). The Code of Practice for maintenance management recommends a target route efficiency of 75% and route redesign should be considered when less than 65%.

<u>Leicestershire County Council's Winter Service Policy</u>

As stated in Leicestershire County Council's Winter Service standards, the need to carry out winter service operations is caused by predicted or actual adverse weather conditions. The local topography, temperature, humidity, precipitation, wind speed and salinity influence actual conditions and likely duration.

The objectives of the winter maintenance services are to:

- Ensure as far as reasonably practicable the safe movement of vehicles and pedestrians on the highway network;
- Minimise delays, accidents and damage to the highway resulting from ice and snow; and
- Undertake the winter service effectively and efficiently.

Normal precautionary salting is carried out on 45% of Leicestershire County Council's road network. Each route is a combination of Priority 1 and 2 roads. Priority 1 Roads (P1) comprise Main Distributor roads, commuter roads and major bus routes. Priority 2 Roads (P2) comprise Secondary Distributor and Locally Important roads in the carriageway hierarchy and at least one route in to all villages as far as reasonably practicable. Routes with steep hills at junctions or a school on the road.

Nottinghamshire County Council's Winter Service Policy

Nottinghamshire County Council's winter maintenance operations give priority to a strategic network of 'Priority 1 Routes'. The intention is always to complete the treatment of Priority 1 Routes in advance of ice forming on road surfaces whilst accepting that in some circumstances, such as late changes in weather forecasts, this will not always be possible. In severe weather, treatment shall be extended to Priority 2 Routes as resources allow once Priority 1 Routes are in a satisfactory and passable condition. Priority 3 Routes shall be treated once all Priority 1 and Priority 2 Routes are in a satisfactory condition and passable.

The objective of the Nottinghamshire County Council's Winter Service Operational Plan is to complete precautionary salting before ice starts to form and actions must be made with this aim in mind. Provision should be made in any system so that salting is done when required, not necessarily when it is convenient.

There are generally two identifiable operational periods for precautionary salting within Nottinghamshire:

- **Period 1**: This occurs at the beginning and end of winter, when occasional light frost may require treatment if associated with damp road surfaces. This may be dealt with by a call-out of gritters by the Duty Winter Maintenance Controller following receipt of a frost warning; and
- **Period 2**: This occurs from early November until late March, or as decided considering the prevailing weather conditions. During this period a Night Shift will operate.

Nottinghamshire County Council has a similar decision making matrix for precautionary salting to DCC. Similar to Derbyshire County Council, Nottinghamshire County Council gives particular attention to the possibility of water running across carriageways e.g. off adjacent fields after heavy rains, washing off salt previously deposited. Such locations are kept under scrutiny and may require treating in the evening and morning, and possibly on other occasions.

6.7.2 Risk Assessment Results

From the Risk and Probability Assessment carried out (Section 4.2), it has been identified that the existing policies and standards for winter maintenance activities will be affected by three of the main climate change types investigated; 'more intense rainfall', 'stronger winds and more storminess' and 'warmer winters'. The specific climate change effects that will affect winter maintenance are shown in the Risk Assessment (Section 4.2).

6.7.3 Adaptation Responses and Evaluation

In order to ensure that winter maintenance activities can withstand the effects of climate change, a number of adaptation responses have been established. These being:

W1. Carry out risk assessment surveys of the region to establish which routes are highest risk for ice formation;

W2. Re-assess and re-classify priority routes based on future climate change predictions;

W3. Move to using gritting materials that are more resistant to thaw and surface water run-off (move from crushed rock salt to pre-wetted salting methods etc);

W4. Increase the capacity to carry out reactive salting to react more rapidly and effectively to changing weather predictions and uncertainty;

W5. Establish more monitoring stations and/or invest in new monitoring technologies that enable more accurate readings and predictions to be made; and

W6. Invest in new gritting vehicles that are able to carry out salting more rapidly and efficiently.

These six adaptation responses have undergone evaluation using the 13 no. established evaluation criteria, as per the example in Section 5.5. The results of this evaluation are shown in Table 29.

Table 29: Adaptation Response Evaluation – Winter Service

Policy / Standard	Climate Change Type	Effect (from hierarchy developed from Risk Assessment)	Adaptation Response	Link to effects	Score (out of 3)	Links to other council plans, strategies and operations
Winter Maintenance	More intense rainfall Stronger winds and more storminess Warmer winters	R3. Lack of capacity in the drainage system and flooding of the highway network O3. Damage to pavement surface layer O4. Subsidence and heave on the highway O7. Less disruption by snow and ice Y3 and B5. Top soil run-off and embankment erosion Y4. Tree damage B7. Increased leaf-fall B8. Increased accidents on the network	W1. Carry out risk assessment surveys of the region to establish which routes are highest risk for ice formation	All	2.65	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			W2. Re-assess and re-classify priority routes based on future climate change predictions	All	2.625	Environmental Services, Urban Design, Planning, Assets; Ecology
			W3. Move to using gritting materials that are more resistant to thaw and surface-water run-off (move from crushed rock salt to pre-wetted salting methods etc)	All	1.975	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			W4. Increase the capacity to carry out reactive salting to react more rapidly and effectively to changing weather predictions and uncertainty	O7	2.05	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity
			W5. Establish more monitoring stations and/or invest in new monitoring technologies that enable more accurate readings and predictions to be made	O7	1.775	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste
			W6. Invest in new gritters that are able carry out salting more rapidly and efficiently	O7	1.75	Environmental Services, Urban Design, Planning, Assets, Ecology, Biodiversity, Waste

Scores

(red)	>2.5	Very high
(orange)	2.25 - 2.5	High
(yellow)	2 - 2.25	Medium
(light orange)	1.75 - 2	Low
(white)	< 1.75	Very low

From the evaluation of the suggested adaptation responses, it can be seen that two responses have scored 'very high' and so are likely to be the most realistic and effective if applied, these being W1 and W2. Full calculation tables can be found in Appendix 3.

7. RECOMMENDATIONS FROM THE REVIEW

By carrying out a risk and probability assessment and a subsequent multi-criteria analysis (MCA), thirty-one adaptation responses have shown to be the most realistic and effective at adapting 3CAP's highway network to the effects of climate change. A hierarchy of the most effective adaptation responses can be seen in Table 30. For the full range of adaptation responses evaluated (90 no.) and their scores, see Section 6.

Table 30: Most effective adaptation responses for the 3CAP region

Policy/ Standard Type	Adaptation Response	Score (out of 3)
Bridges and other Structures	B1. Increase the number and frequency of maintenance works carried out to increase the BCI average and critical values	2.85
	B2. Carry out a risk assessment to identify which structures are most at risk from the effects of climate change	2.775
	B12. Carry out flood studies with the help of other agencies and organisations	2.625
	B3. Ensure that all strengthening and repair work that is outstanding for failed or below standard bridges is carried out	2.6
	B4. Ensure that all data (new and historical) is transferred into a single system to make assessments of maintenance and repair priorities and needs more effective	2.55
	B6. Evaluate the Depreciated Replacement Cost (DRC) for all highway structures to allow for an assessment of the impact of spending to be made	2.3
Drainage	D1. Improve the knowledge of drainage assets	2.625
	D2. Undertake a risk assessment to determine vulnerable areas and establish a prioritised scheme for maintenance	2.575
	D3. Change to an ad-hoc gully emptying strategy based on demand and need	2.4
	D8. Invest in asset management and location reviews	2.4
	D9. Carry out drainage condition surveys	2.375
	D4. Increase the frequency of highway network drainage inspections	2.275
Grass Cutting	GC1. Increase the frequency of grass cutting	2.6
	GC2. Treat grass with growth retardant and/or fertiliser to produce slower growing and/or better quality grass	2.6
Materials	M2. Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat	2.55
	M7. Specification: Consider using high modulus base/binder materials and rut resistant surface course material	2.55
	M15. Develop a long-term programme to locate and assess the adequacy and condition of the current drainage provision, and ensure it is well maintained	2.475
	M6. Use performance related specifications which promote properties which resist the adverse effects of climate change	2.375
	M19. Specification: Appropriate planting – tree types and locations	2.375
	M21. Avoid creating wind-throw risks when undertaking works such as copse or tree line thinning, removing hedgerows or earthworks	2.375
	M5. Review existing materials specifications - general	2.225
Resurfacing	S1. Undertake a risk assessment to identify the most vulnerable areas of the network and develop priority actions to be carried out	2.525
	S7. Review local experience of the durability of surface dressing and consider whether other measures may be more appropriate	2.475
	S14. Increase verge maintenance and grass cutting frequencies to reduce the risk of 'root invasion' and vegetation ingress on the	2.35

	highway	
	S3. Increase the frequency of carriageway surface inspections	2.225
Tree and Hedge Maintenance	T10. Develop a tree management strategy for implementation across the county councils (to include all trees, not just those on or near the highway)	2.375
	T12. Review the species choice for new trees to ensure the most appropriate species is selected	2.325
	T2. Undertake a risk assessment to determine vulnerable trees and establish a prioritised scheme for maintenance	2.3
	T1. Improve the knowledge of existing tree stock	2.275
Winter Service	W1. Carry out risk assessment surveys of the region to establish which routes are highest risk for ice formation	2.65
	W2. Re-assess and re-classify priority routes based on future climate change predictions	2.625

From Table 30 the 3CAP region can identify the most effective ways in which they can start to work towards adapting their policies, standards, operations and strategies to the effects of current and final climate change. This is in line with the requirements of National Indicator 188, Levels 1 and 2.

Many of the responses identified as potentially being the most effective involve the undertaking of a risk assessment and/or asset review. This indicates that by ensuring that the three counties have a clear indication of the location, condition and vulnerabilities of their assets (whether it be structures, the highway pavement itself, or the surrounding soft estate), a more targeted programme of action and improvement can be developed. In order to adapt to the effects of climate change, the 3CAP councils must be aware of the level at which different parts of their network are vulnerable and most in need of attention. By taking action now and identifying the work that needs to be carried out (monitoring, maintenance, strengthening, reconstruction etc), the network will be more resilient to the effects of the changing climate and it will reduce the cost and inconvenience caused by any necessary emergency or reactive work in the future.

By applying a structured evaluation technique the responses have been assessed against relevant criteria and scored according to their overall likely effectiveness and probability of success. This has also allowed for the most realistic responses to be identified in terms of resource demand, public and government acceptance, scale, risk, impact, sustainability and practicality.

The three councils are now in a position to identify their targets and timescales for implementing the identified adaptation responses and for realigning their policies and standards in the face of future climate change. This will move them towards achieving Levels 3 and 4 of National Indicator 188: Adapting to Climate Change.

- **Level 3:** The authority has developed an adaptation action plan to deliver necessary steps to achieve the existing objectives set out in council strategies, plans, investment decisions and partnership arrangements in light of projected climate change.

- **Level 4:** The authority has implemented an adaptation action plan, and a process for monitoring and review to ensure progress with each measure.

Full details about the requirements for NI 188 can be found in Appendix 1.

Chapter 8 gives details on the feedback obtained from the 3CAP councils on the report and the finalised adaptation responses and associated timeline for action that has derived from this feedback. Assessed against a climate change timeline for the East Midlands, this moves the 3CAP towards Level 3 of NI 188 and provides a timescale for action to adapt for the effects of climate change.

8. 3CAP REVIEW AND TIMESCALE FOR ACTION

Following the completion of Chapters 1 to 7, the report was submitted to the 3CAP representatives for review and comment. This review was conducted by the three project partners from Derbyshire, Leicestershire and Nottinghamshire County Councils and also from representatives form the council departments involved in the areas of operation considered in the review (bridges and other structures, drainage, grass cutting, materials, resurfacing, tree and hedge maintenance and winter service), as well as representatives from ecology and biodiversity departments.

The comments and feedback from the review have now been used to form the final action plan for the 3CAP region for adapting their highway network policies and standards to climate change. Finalised adaptation responses have been developed and analysed against a climate change timeline for the 3CAP region (see Appendix 2). This forms the climate change adaptation timeline for the 3CAP region and moves the county councils to meet **Level 3 of NI 188** (i.e each authority has developed an adaptation action plan to deliver necessary steps to achieve the existing objectives set out in council strategies, plans, investment decisions and partnership arrangements in light of projected climate change).

The sections below detail the feedback from 3CAP review for the selected areas of policy review. Confirmed adaptation responses and associated timescales are shown in Table 31.

8.1 3CAP ADAPTATION PLAN RESPONSE

8.1.1 Bridges and other Structures

From 3CAP review of the study, and from Table 30 in particular, four adaptation responses for bridges and other structures have been identified and confirmed as being suitable for action by Derbyshire, Leicestershire and Nottinghamshire County Councils. Each of these will require immediate action by the 3CAP councils;

- **AR1**. Carry out a risk assessment to identify which structures are most at risk from climate change. Identify the nature and frequency of changes that are needed to the inspection and maintenance regimes of bridges and other structures (adapted from response B2 in Table 30);
- **AR2.** Increase the number and frequency of maintenance works carried out to increase the BCI values for bridges assessed as liable to risks from climate change. Ensure that all strengthening and repair work that is outstanding for failed or below standard bridges is carried out (from responses B1 and B3 in Table 30);
- **AR3**. Carry out flood studies with the help of other agencies and organisations (from response B12 in Table 30); and
- **AR4**. Ensure that all data (new and historical) is transferred into a single system to make assessments of maintenance and repair priorities, and needs, more effective (from response B4 in Table 30).

Response B6 in Table 30 (evaluate the Depreciated Replacement Cost (DRC) for all highway structures to allow for an assessment of the impact of spending to be made) has not been chosen as a confirmed adaptation response by 3CAP as it was deemed to be beyond the scope and will be likely to be carried out during asset management works.

In addition to the findings from the study, it has been identified that there is the risk that stronger winds will increase the potential of lighting column collapse. The existing standard practice of attaching road traffic signage to columns should be reviewed as this increased wind loading could be evidenced as a contributory cause of any collapse.

Hotter summers may also impact on the reliability of some traffic signal equipment. There is now a wider utilisation of LED signals but a problem associated with this type of light source is the dissipation of heat build-up in the units. This has resulted in some premature failures which the industry is addressing. The potential for hotter summers needs to be a consideration in manufacturer's designs and the Local Authority's choice of equipment.

8.1.2 Drainage

There is recognition that increased rainfall is the most significant risk to highways, as evidenced by recent events. Sections of highway will be prone to flooding for which it may be too costly or impossible to implement flood protection measures (usually the responsibility of the Environment Agency). These areas at risk need to be identified and included in the asset management system so that assets on these sections can be managed and maintained to reflect the conditions.

From 3CAP review of the study, and from Table 30 in particular, two adaptation responses for drainage have been identified and confirmed as being suitable for action by Derbyshire, Leicestershire and Nottinghamshire County Councils. Both of these will require immediate action by the 3CAP councils;

- **AR5**. Invest in asset management and location reviews, carry out drainage surveys and improve the knowledge of drainage assets, hydraulic capacity and ownership, and carry out flood studies with the help of other agencies and organisations (adapted from responses D8, D9, D1 and B12 in Table 30); and
- **AR6.** Undertake a risk assessment to determine vulnerable areas and establish a prioritised scheme for maintenance (from response D2 in Table 30).

Although both of these responses will require immediate action, there needs to be some reference as to when the effects are likely to occur. The climate change timeline for the 3CAP region (see Appendix 2) predicts an increase in winter rainfall of almost 5% by the 2020s and of over 10% by the 2050s. This increase in winter rainfall, combined with the prediction for more intense rainfall events and storms will have an impact upon county council drainage assets.

Responses D3 (change to an ad-hoc gully emptying strategy based on demand and need) and D4 (increase the frequency of highway network drainage inspections) from Table 30 have not been chosen as confirmed adaptation responses by 3CAP as it has been identified that a 'blanket' approach to increasing the frequency of gully empting and maintenance is not necessarily the most effective method for improving the drainage asset conditions and increasing the resilience to the effects of climate change. Instead, a risk based approach is more appropriate, with the frequency of gully cleansing reflecting the attributed risk.

Changing to an ad-hoc gully emptying strategy based on demand and need is a good idea. However, this can only be achieved once knowledge of county council drainage assets has been improved and a hierarchy if need and risk has been developed.

From the review, it is predicted that the number of flooding events are not likely to increase significantly due to climate change. However it is expected that:

- The intensity and impact of flooding events are likely to increase;
- Locations that are not currently defined as 'hot-spots', i.e. prone to flooding during periods or heavy or prolonged rainfall, may become vulnerable;
- Existing flooding 'hot-spots' will become more at risk during periods of heavy or prolonged rainfall;
- If no action was taken to adapt drainage to the effects of climate change, whilst the frequency of flooding may not increase, the impact will and the number of locations affected is also likely to increase.

There are concerns that a lack of existing data on occurrences of extreme rainfall restricts the ability to make predictions for the likelihood of such events occurring in the future and also that a lack of clarity over drainage asset ownership and responsibility, and also of hydraulic capacity, currently makes drainage maintenance and management complex. Carrying out the two adaptation response above will help to reduce these concerns and clarify drainage asset needs and responsibilities.

8.1.3 Grass cutting

From 3CAP review of the study, and from Table 30 in particular, two adaptation responses for grass cutting have been identified and confirmed as being suitable for action by Derbyshire, Leicestershire and Nottinghamshire County Councils. Each of these will require time-scaled action by the 3CAP councils;

- **AR7**. Increase the frequency of grass cutting and the length of the grass cutting season (from response GC1 in Table 30); and
- **AR8**. Treat grass with growth retardant and/or fertiliser to produce slower growing and/or better quality grass (from response GC2 in Table 30).

Increased annual temperatures and higher levels of precipitation in the winter will lead to increased annual grass growth and growing season. A response to this would be to increase the frequency with grass cutting activities are carried out and also to increase the grass cutting season (currently typically carried out March to October) (GC1). However, hotter and drier summers would mean that growth in the hottest summer months (June to August) will be reduced thus reducing the need for grass cutting activities to be carried out during these months.

An alternative approach would be to treat grass with a growth retardant (GC2). This method has been used previously by West Sussex Council. This adaptation response would work out at approximately the same cost as increasing the grass cutting frequency (to achieve the same effect). This process is also commonly carried out in parks to reduce grass and vegetation growth but has not yet been widely used for roadside verge maintenance. Fertiliser can also be used within the spray to produce a better quality and shorter grass (as seen in West Sussex).

Therefore, two conflicting adaptation responses have been identified and confirmed as suitable for application by the 3CAP councils (GC1 and GC2). The two responses could be carried out separately or in conjunction with each other and it will be up to the individual councils to identify which response is most effective ad realistic within their capacities and areas of operation. Cost and environmental issues, as will as public and government acceptance will also need addressing to identify the most appropriate response. .

Currently, the 3CAP councils typically carry out grass cutting activities from March until October. However, from the climate change timeline for temperature and precipitation (see Appendix 2), it is predicted that:

- The grass cutting season will need to begin in February but will still conclude in October by 2020;
- The grass cutting season will need to begin in January and will conclude in November by 2050; and
- Grass cutting will need to be carried out year-round by 2080. However, due to predicted higher summer temperatures, the requirement carry out grass cutting and verge maintenance activities is likely to reduce during the key summer months (June to August) due to slower growth.

It is predicted that changes to grass cutting frequencies and season length are not likely to be required within the next five years and so existing contracts do not need revising. However, at the next stage of contracting and planning for grass cutting activities, a review of the frequency and season length will be necessary.

It has also been identified that hotter and drier summers will also lead to an increased risk of fires on the verges and losses of natural habitats. It may be prudent to look at measures to introduce other species which could help protect verges and wildlife. These issues will also need addressing and considering as the effects of climate change increase.

8.1.4 Materials

From 3CAP review of the study, and from Table 30 in particular, two adaptation responses for materials have been identified and confirmed as being suitable for action by Derbyshire, Leicestershire and Nottinghamshire County Councils. Each of these will require immediate action by the 3CAP councils;

- **AR9**. Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat (from response M1 in Table 30); and
- **AR10**. Review current material specifications to assess their suitability for resistance to the effects of climate change. Consider changing to end specifications which address the adverse effects of climate change (adapted from responses M7, M6, M19 and M5 in Table 30).

These two responses for inspection and inventory, and for material specification review, move towards a more climate change resistant highway network.

Responses M15 (develop a long-term programme to locate and assess the adequacy and condition of the current drainage provision, and ensure it is well maintained) and M21 (avoid creating wind-throw risks when undertaking works such as copse or tree-line thinning, removing hedgerows or earthworks) from Table 30 have not been chosen as confirmed adaptation responses by 3CAP as they will be covered by responses D1 and D2 for drainage, and T1 for tree and hedge maintenance respectively.

The 3CAP are to carry out review of the current highway network specifications and polices in 2009. This will help to assign policies and standards within the three councils and identify which specifications require amendment in the light of climate change predictions (relates to response M2). This review of specifications is due for completion by the end of 2009 and its findings should be applied within future material choices and construction and maintenance activities.

8.1.5 Resurfacing

From 3CAP review of the study, and from Table 30 in particular, five adaptation responses for resurfacing have been identified and confirmed as being suitable for action by Derbyshire, Leicestershire and Nottinghamshire County Councils. These have been identified as requiring either immediate or time-scaled action by the 3CAP councils;

- **AR11.** Undertake a risk assessment to identify the most vulnerable areas of the network and develop priority actions to be carried out. Implement a targeted programme of improvement (from response S1 in Table 30);
- **AR12**. Ensure asset management plans take account of adaptations required for climate change in resurfacing programmes (new response developed through 3CAP consultation after review);
- **AR13**. Review new material and treatment choices and specify appropriate replacements (adapted from response S7 in Table 30);
- **AR14**. Use polymer modified binders that are less prone to binder stripping and other materials with a greater 'stiffness' (from response S8 in Table 25); and
- **AR15**. Increase verge maintenance and grass cutting frequencies to reduce the risk of 'root invasion' and vegetation ingress on the highway (from response S14 in Table 30).

Response S3 (increase the frequency of carriageway inspections) from Table 30 has not been chosen as confirmed adaptation responses by 3CAP as it has been identified that, although it will be more effective to be pro-active than reactive with resurfacing activities, a risk-assessed and structured cyclic programme of carriageway resurfacing and maintenance is more effective than simply increasing frequency across all parts of the network.

Concern has been raised about the level of understanding about surfacing materials and which materials are suitable for specific locations. This, and clearer understanding about how different surfacing materials are prone to the effects of climate change, needs developing.

As with the recommendations put forward in the materials section, a review of the surfacing materials currently used within the 3CAP region should be conducted. More suitable replacements and alternatives should be specified where necessary. For example, the use of polymer modified binders which are less prone to binder stripping will be more resistant to the effects of climate change (specifically, high temperatures and intense rainfall). Materials with higher 'stiffness' values will also be more resilient and should be considered for use.

From the climate change timeline for the 3CAP region (see Appendix 2) it is predicted that the highway network will become increasing prone to stripping given high temperatures and increased extreme rainfall events by 2020. Therefore, a review of the materials currently used for resurfacing activities should be carried you immediately, with any changes to the specifications implemented by 2020.

8.1.6 Tree and Hedge Maintenance

From 3CAP review of the study, and from Table 30 in particular, two adaptation responses for tree and hedge maintenance have been identified and confirmed as being suitable for action by Derbyshire, Leicestershire and Nottinghamshire County Councils. Both of these have been identified for requiring immediate (or as soon as feasibly possible) action by the 3CAP councils;

- **AR16**. Improve the knowledge of existing tree stock. Undertake a risk assessment to determine vulnerable trees and establish a prioritised scheme for maintenance. Increase the frequency of tree and hedge inspections and maintenance (adapted from responses T1, T2 and T10 in Table 30 and response T3 in Table 28); and
- **AR17**. Review the species choice for new trees to ensure the most appropriate species is selected (from response T12 in Table 30).

Concern has been raised about the increased occurrences of strong winds and storms (particularly in winter) leading to tree damage and early leafing becoming a more significant safety issue on the roads. Also, as experienced in recent summers, an increase in summer high winds has increased the risk associated with collapsing tree branches. Trees full of foliage are more susceptible to collapse or lose branches due to the associated increased wind loading and so specific maintenance activities should be focused on high-risk trees. Also, it will be important to ensure that highways activities do not open up new tree wind-throw opportunities when undertaking works such as corpse or tree-line thinning, removing hedgerows or earthworks.

The correct choice of tree species is important. A review of the most appropriate tree species should be conducted before any new planting is carried out. Appropriate species should be selected on a site-by-site basis. Recommendations include;

- Climax tree species such as oak and lime are not suitable for planting close to the carriageway;
- Vigorous species such as willow and poplar should not be located close to trunk roads, as a result of the growth characteristics of these is incumbent high maintenance needs and vulnerability to cracking in high winds as they mature;
- Utilising areas further away from the carriageway for landscaping and biodiversity gain should be investigated;
- Where soil is clay with a high plasticity index avoid planting/removing forest trees from within at least 15m from the road edge and fast growing trees such as Poplars should be avoided altogether; and
- 'Thirsty' (broad leaf) trees should not be plated near to the carriageway. Shrubs should not be plated within 3m of the carriageway and trees not within 5m of it. Large trees should be placed at least 7.5m away from the edge of the carriageway [Highways Agency, 2008].

It should be ensured that new plantings are composed of trees and shrubs suited to those conditions. Landscaping schemes need to take account of any new trends in diseases and pests associated with specific tree species and avoid another 'Dutch Elm' scenario where predictable.

8.1.7 Winter Service

Four adaptation responses for winter service have been identified and confirmed as being suitable for action by Derbyshire, Leicestershire and Nottinghamshire County Councils. These have been identified as requiring either immediate or time-scaled action by the 3CAP councils;

- **AR18**. Carry out risk assessment surveys to establish which routes have the highest risk of ice formation (from response W1 in Table 30);
- **AR19**. Re-assess and re-classify priority routes based on future climate change predictions (from response W2 in Table 30);
- **AR20**. Review established resources for winter service provision and consider if changes need to be made (new response developed through 3CAP consultation after review); and
- **AR21**. Provide a more flexible and responsive winter service (new response developed through 3CAP consultation after review).

The climate change timeline for the 3CAP region (see Appendix 2) predicts that there will be a 23.5% reduction in annual snowfall by the 2020s. This indicates that a more flexible provision of winter service will be required by then. The timeline also predicts that there will be 47.1% less snowfall by the 2050s and 82.4% less by the 2080s. This is likely to lead to internal pressure to reduce expenditure on winter service as winters become warmer and snow and ice become less frequent as a result of climate change. This also indicates that a dedicated nightshift may not be required by the 2050s and it is recommended that this is reviewed by 2020.

It has also been identified that decreasing levels of snow and ice as a result of climate change will mean that a review of the number and location of monitoring stations will need to be carried out by 2020. Thermal mapping and domains may need to be changed as a result of shifting weather patterns and some areas (specifically low-lying areas) may need to be removed from gritting routes.

8.2 3CAP ADAPTATION ACTION PLAN AND TIMELINE

Taking the adaptation responses identified as being the most effective for the 3CAP region (see Table 30), and applying the feedback from the review carried out by the 3CAP representatives, a finalised list of climate change adaptation responses have been compiled and are shown in Table 31. This table clarifies the responses and applies a timescale for action for the three councils.

Table 31: Adaptation responses and timescales for the 3CAP region

Policy/Standard Type	Adaptation Response Number	Adaptation Response Details	Timescale
Bridges and other Structures	**AR1**	Carry out a risk assessment to identify which structures are most at risk from climate change. Identify the nature and frequency of changes that are needed to the inspection and maintenance regimes of bridges and other structures [adapted from response B2 in Table 30]	**Immediate**
	AR2	Increase the number and frequency of maintenance works carried out to increase the BCI values for bridges assessed as liable to risks from climate change. Ensure that all strengthening and repair work that is outstanding for failed or below standard bridges is carried out [from responses B1 and B3 in Table 30]	**Immediate**
	AR3	Carry out flood studies with the help of other agencies and organisations [from response B12 in Table 30]	**Immediate**
	AR4	Ensure that all data (new and historical) is transferred into a single system to make assessments of maintenance and repair priorities, and needs, more effective [from response B4 in Table 30]	**Immediate**
Drainage	**AR5**	Invest in asset management and location reviews, carry out drainage surveys, improve the knowledge of drainage assets, hydraulic capacity and ownership and carry out flood studies with the help of other agencies and organisations [adapted from responses D8, D9, D1 and B12 in Table 30]	**Immediate**
	AR6	Undertake a risk assessment to determine vulnerable areas and establish a prioritised scheme for maintenance [from response D2 in Table 30]	**Immediate**
Grass cutting	**AR7**	Increase the frequency of grass cutting and the length of the grass cutting season [from response GC1 in Table 30]	Grass cutting/ retardant treating to be extended to Feb to Oct by 2020, to Jan to Nov by 2050 and year-round by 2080 (with less growth in the summer)
	AR8	Treat grass with growth retardant and/or fertiliser to produce slower growing and/or better quality grass [from response GC2 in Table 30]	
Materials	**AR9**	Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat [from response M1 in Table 30]	**Immediate**

Materials	**AR10**	Review current material specifications to assess their suitability for resistance to the effects of climate change. Consider changing to end performance specifications which address the adverse effects of climate change [adapted from responses M7, M6, M19 and M5 in Table 30]	**Immediate (by the end of 2009)**
Resurfacing	**AR11**	Undertake a risk assessment to identify the most vulnerable areas of the network and develop priority actions to be carried out. Implement a targeted programme of improvement [from response S1 in Table 30]	**Immediate**
	AR12	Ensure asset management plans take account of adaptations required for climate change in resurfacing programmes (new response developed through 3CAP consultation after review)	As soon as feasibly possible
	AR13	Review new material and treatment choices and specify appropriate replacements [adapted from response S7 in Table 30]	**Immediate**
	AR14	Use polymer modified binders that are less prone to binder stripping and other materials with a greater 'stiffness' [from response S8 in Table 25]	By 2020
	AR15	Increase verge maintenance and grass cutting frequencies to reduce the risk of 'root invasion' and vegetation ingress on the highway [from response S14 in Table 30]	See GC1 and GC2 for timescales
Tree and Hedge Maintenance	**AR16**	Improve the knowledge of existing tree stock. Undertake a risk assessment to determine vulnerable trees and establish a prioritised scheme for maintenance. Increase the frequency of tree and hedge inspections and maintenance [adapted from responses T1, T2 and T10 in Table 30 and response T3 in Table 28]	**Immediate**
	AR17	Review the species choice for new trees to ensure the most appropriate species is selected [from response T12 in Table 30]	As soon as feasibly possible
Winter Service	**AR18**	Carry out risk assessment surveys to establish which routes have the highest risk of ice formation [from response W1 in Table 30]	**Immediate**
	AR19	Re-assess and re-classify priority routes based on future climate change predictions [from response W2 in Table 30]	By 2020
	AR20	Review established resources for winter service provision and consider if changes need to be made [new response developed through 3CAP consultation after review]	By 2020
	AR21	Provide a more flexible and responsive winter service [new response developed through 3CAP consultation after review]	By 2020

In order to meet the strategic objectives set out in their policy documents (such as; Highway Network Management Plans, Transport Asset Management Plans, Winter Service Plans), the 3CAP region need to ensure that their policies and standards are adapted to deal with the future effects of climate change. Aligning 3CAP's policies and standards will provide another method for the three councils to ensure that they are prepared for the effects and will make maintenance, repair and inspection activities more efficient and consistent across the region. This will lead to capital and whole-life resource savings for Derbyshire, Leicestershire and Nottinghamshire County Councils and an increasing synergy of operations across the region.

By working together to align and co-ordinate maintenance activities and changes to existing policies and standards, the 3CAP region will be able to plan for and adapt to climate change more effectively than if they work separately as Derbyshire, Leicestershire and Nottinghamshire County Councils.

The three councils are now in a position to implement the identified adaptation responses and for realigning their policies and standards in the face of future climate change. This will move them towards achieving Level 4 of National Indicator 188: Adapting to Climate Change (see Appendix 1 for full NI 188 details).

This chapter has given details on the feedback obtained from the 3CAP councils on the report and Table 31 gives finalised adaptation responses and associated timelines for action that has derived from this feedback. Assessed against a climate change timeline for the East Midlands, this moves the 3CAP towards Level 3 of NI 188 and provides a timescale for action to adapt for the effects of climate change.

The findings from this study, and specifically the adaptation responses shown in Table 31, should be considered and applied during the preparation of any new asset management and lifecycle plan documents. This will ensure that the 3CAP councils are implementing the adaptation actions effectively and that they are integrated firmly within all council policies and plans.

8.3 FUTURE CONSIDERATIONS

The UK Climate Impacts Programme are to release a new series of climate change predictions in Spring 2009 (delayed from the original release date of late 2008). These UKCIP09 scenarios will include a new weather generator that which will allow for more accurate weather projections to be made for specific regions (such as the 3CAP region) for rolling 30 year periods, starting at 2010. These updated projections will also provide:

- **Probabilistic climate change predictions**: Information on modelled future climate change for all 25 x 25km UK land grid squares, provided in probabilistic terms;
- **Weather generator projections**: Information on modelled statistics of future daily climate for each 5 x 5km UK land grid square
- **Marine projections**: Information on modelled future climate changes above and below the surface of sea areas around the UK
- **Historical climate information**: Information on present UK climate and recent trends, based on observations

A revised version of UKCIP's report 'The climate of the UK and recent trends' will also be released in early 2009. This report will consider how climate change is going to affect the UK and the current and future risks posed to individuals, landscapes, organisations and the economy.

A review of the findings of this report will need considering in the light of these more detailed predictions and reports when they are released by UKCIP later in 2009.

9. ADDITIONAL FINAL CONSIDERATIONS

A number of recently published policy and research reports will have a direct impact on the effects of climate change on county council policies and standards and the efforts that local authorities are able to make to adapt to these effects. These recent developments and newly implemented policies and initiatives will need to be considered when any changes to existing highway network policies and standards are made as they may include newly defined local authority responsibilities or roles within the decision making process. They also contain a number of new objectives and aims set by the UK Government that local authorities must or should aim to meet. These additional considerations include, but are not limited to, those summarised below in Sections 9.1 to 9.5.

9.1 THE PITT REPORT

In June 2008, a report by the Cabinet Office was released which looked at the flooding that occurred in the UK during the summer of 2007. This report, 'The Pitt Review: Learning lessons from the 2007 floods', summarises the flooding that took place and looks at methods of planning for and forecasting flooding, responses to flooding, the recovery process, and methods of reducing the risk of flooding and its impacts [Pitt, 2008]. The review uses evidence from public experience and opinion throughout the document and direct quotes from those affected are featured throughout.

The Pitt Review presents recommendations for improved action and response in the future and also information on how these recommendations can be delivered. Attention is specifically paid to aspects of; leadership in central government, oversight at the local level, and scrutiny at the regional and local level. Although the government has yet to formally respond to these findings and recommendations, action is already being taken across the UK, including significant work within the East Midlands.

9.2 THE REGIONAL HIGHWAY DESIGN GUIDE

Derbyshire County Council has resolved to work with Leicestershire County Council and Leicester City Councils in order to produce regional design guidance in respect of highways and transport infrastructure associated with new development. In the interim, Leicestershire County Council's guidance within 'Highways, transportation and development' (Htd) [2007] has been adopted as the source for advice within the areas covered by Derbyshire, Leicestershire and Leicester City Councils.

The Htd was adopted as Leicestershire County Council policy in December 2007 and was adopted as Leicester City Council policy document with effect from 1st January 2008. Derbyshire County Council adopted this document as interim guidance with effect 31st January 2008.

This guide provides guidance on preparing development proposals; design, materials and construction information and standards; and guidelines to be followed when working on existing highways. This document represents the attempt to harmonise local authority activities and legislation and should be considered in all policy and standard assessment, formation or change.

9.3 PLANNING POLICY STATEMENTS (PPS)

Planning Policy Statements (PPS) set out the Government's national policies on spatial planning. These documents are published by the Department for Communities and Local Government (DCLG). Specifically, PPS1 sets out the overarching planning policies on the delivery of sustainable development through the planning system. PPS: Planning and Climate Change is a supplement to PPS1 and sets out how planning should contribute to reducing greenhouse gas emissions and stabilising climate change, and take into account the unavoidable consequences [DCLG, 2007].

Tackling climate change is a key Government priority for the planning system and so policies within PPS1 should be reflected in Regional Spatial Strategies and by planning authorities in Local Development Documents.

As set out in PPS1, the key planning objectives for regional planning bodies relating to climate change are:

- Make a full contribution to delivering the Government's Climate Change Programme and energy policies, and in doing so contribute to global sustainability;
- In providing for the new homes, jobs, services and infrastructure needed for communities, and in renewing and shaping the places where they live and work, secure the highest viable resource and energy efficiency and reduction in emissions;
- Deliver patterns of urban growth and sustainable rural developments that help secure the fullest possible use of sustainable transport for moving freight, public transport, cycling and walking; and, which overall, reduce the need to travel, especially by car;
- Secure new development and shape places that minimise vulnerability, and provide resilience, to climate change; and in ways that are consistent with social cohesion and inclusion;
- Conserve and enhance biodiversity, recognising that the distribution of habitats and species will be affected by climate change;
- Reflect the development needs and interests of communities and enable them to contribute to tackling climate change; and
- Respond to the concerns of business and encourage competitiveness and technological innovation in mitigating and adapting to climate change.

PPS: Planning and Climate Change also outlines how regional planning bodies should apply a number of principles when making decisions about their spatial strategies. These include:

- The proposed provision for new development, its spatial distribution, location and design should be planned to limit carbon dioxide emissions;
- New development should be planned to make good use of opportunities for decentralised and renewable or low carbon energy;
- New development should be planned to minimise future vulnerability in a changing climate;
- Climate change considerations should be integrated into all spatial planning concerns;
- Mitigation and adaptation should not be considered independently of each other, and new developments should be planned with both in mind;
- Sustainability appraisal (incorporating strategic environmental assessment) should be applied to shape planning strategies and policies that support the Key Planning Objectives; and
- Appropriate indicators should be selected for monitoring and reporting on in regional planning bodies' and planning authorities' annual monitoring reports. Such monitoring should be the basis on which regional planning bodies and planning authorities periodically review and roll forward their planning strategies.

Regional planning bodies should actively work with all stakeholders in their region to develop realistic and responsible approaches to addressing climate change. Climate change should be central to Regional Spatial Strategies and should be addressed alongside economic, social and environmental concerns when forming the strategies. Amongst other things, it is stated that regional planning bodies should help to bring forward adaptation options for existing developments in vulnerable areas [DCLG, 2007]. This can be related to the different elements of highways, to include, drainage, structures and the soft estate.

As also mentioned in PPS1, priority should be given to sustainable drainage systems, such as SuDS, paying attention to the potential contribution to be gained to water harvesting from impermeable surfaces and encourage layouts that accommodate waste water recycling. This is also discussed in PPS25: Development and Flood Risk.

9.4 FLOODS AND WATER BILL FOR ENGLAND

Defra has recently announced the introduction of a new Floods and Water Bill for England that will help counties to be better prepared for flooding [IEMA, 2008]. It is proposed that the Environment Agency (EA) will be given the strategic overview for all flooding issues throughout England. Under this overview, local authorities will take responsibility for surface water flooding in their area. The EA will support local authorities to develop surface water management plans that will identify who has the responsibility within their area for the issue. The Bill will also propose that local authorities are given powers to ensure that landowners and organisations within their area fulfil their obligations to maintain drainage on their land. Defra is aiming to consult on the draft Bill in Spring 2009 [IEMA, 2008].

This Floods and Water Bill will have a significant impact on the role of local authorities in flood preparation and drainage maintenance in their areas. The Bill should be consulted upon its publication.

9.5 ADAPTING TO CLIMATE CHANGE PROGRAMME

The Government has established the **Adapting to Climate Change (ACC) Programme** with the aim of bringing together the work already being carried out by the public sector on climate change adaptation in England. Led by the Department for the Environment, Food and Rural Affairs (Defra), this work will be built upon to develop the Government's climate change adaptation methods in the future. By providing tools and regulating structures, the Government is helping public bodies and other organisations to understand climate change risks and develop adaptation plans to allow their networks or activities to become resilient to climate change [Defra, 2008].

According to the guidance set out in Defra's ACC Programme, adaptation is:

> *'Any adjustment in natural or human systems in response to actual or expected stimuli or their effects, which moderates harm or exploits beneficial opportunities.'*

[Defra, 2008; p9]

Adapting to climate change must not have negative impacts of any mitigation measures implemented (i.e. measures to reduce the causes of climate change, such as reducing greenhouse gas emissions). For example, a response to an increased growing season could be to increase the frequency with which local authority highway teams carry out mowing and maintenance of their soft estate (as adaptation response ref. GC1). This would likely lead to an increase in carbon emissions and so this must be taken into account when developing and assessing adaptation responses. Adaptation responses need to be sustainable and aid mitigation.

The UK's Climate Change Bill came into force by the end of 2008. This Act will introduce a legally binding framework for the UK to cut CO2 emissions and implement methods to adapt to the effects of climate change in the future. By setting targets for emission reductions and requiring the Government to publish information on national adaptation strategies, the Climate Change Bill will help to strengthen the UK's framework for climate change causes and impacts [Defra, 2008].

The ACC Programme is to be implemented in two stages:

- Phase 1 (2008-2011): to develop a robust evidence base about the impacts and consequences of climate change in the UK and raise awareness of the need for adaptation methods to be embedded in policies, standards, programmes and systems.
- Phase 2: to build on Phase 1 and implement a statutory National Adaptation Programme by 2012, as required by the Climate Change Bill.

National Indicator 188 (NI 188) has been introduced by the Government to assess the level at which local authorities are embedding climate change adaptation into their objectives and activities. This Indicator will be assessed by the Audit Commission against a number of levels and the authority will need to regularly report on their progress through the levels. In addition, Local Area Agreements (LAAs) have been set up by Local Strategic Partnerships to bring together local authorities with other public and private partners. Currently around 50 LAAs in England have adopted NI 188 as a performance indicator [Defra, 2008].

9.6 CSS ADAPTATION REVIEW: INTERIM REPORT – SEPTEMBER 2008

The County Surveyors Society published an Adaptation Review Interim Report in September 2008 on [Entec, 2008]. The CSS represents local authority chief officers who manage some of the UK's most pressing issues. This interim report draws together a review of existing adaptation studies and guidance on developing adaptation strategies and actions. The overall objectives of the study were to:

- Provide a comprehensive summary of climate change adaptation issues relating to the range of services and professions encompassed by the CSS;
- Research and disseminate information on the range of tools and guidance available on climate change adaptation issues that are relevant to CSS; and
- Identify deficiencies in knowledge in relation to climate change adaptation measures and identify research needs to inform future CSS research bids.

The report discusses in detail the range of climate impacts of particular relevance to CSS members. These pose particular adaptation challenges and include:

- Rising temperatures
- Extreme rainfall and flooding
- Rising sea levels
- Extending growing season and changing biodiversity
- Wind
- Subsidence and land movement
- Communicating the impacts of climate change

The report discusses how the subject and potential responses to climate change are so diverse that there is no single source of information which delivers all of the support needed to ensure good adaptation choices are made. However, there are many sources which can be used in isolation or combination to develop and assess adaptation responses. These may include checklists, risk assessments, impact identification and costing techniques. The report covers the range of publications, guidance and studies available to assist CSS members in developing adaptation responses to climate change.

The interim report summarises by stating that the main challenge to Local Authorities is keeping pace with the challenging requirements placed on them as a result of climate change. The review carried out has shown that CSS members can take advantage of the tools and guidance available and the CSS needs to maintain the ability to integrate expertise across sectors, enabling members to lead the way in which comprehensive integrated assessments of climate change risk, prioritised action and positive adaptation [Entec, 2008].

9.7 THE HIGHWAYS AGENCY: CASE STUDY

The Highways Agency (HA) has implemented a climate change adaption strategy to deal with the impact of rising temperatures on road surface deformation and failure. By introducing materials developed in France (asphaltic concrete mixtures with a polymer modified binder) and Germany (stone mastic asphalt mixtures with cellulose fibres) as road surface course materials, the HA's network can be much more resilient to permanent deformation in hot weather conditions than historically used hot-rolled asphalt materials.

The application of these alternative materials is also quicker and cheaper to lay than a positive textured surface. This produces additional benefits such as reduced noise pollution and less spray during wet periods. As they are very stiff, have a high binder content and are resilient to deformation from high temperatures, they allow for thinner construction layers than conventionally used materials. The HA has now included these new materials in their pavement design guides and specifications. [Defra, 2008]

The HA has also introduced improved drainage standards for new developments and maintenance works to allow for a predicted 20% increase in rainfall intensity as a result of climate change.

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APPENDIX 1: NATIONAL INDICATOR 188 – ADAPTING TO CLIMATE CHANGE

Rationale

To ensure local authority preparedness to manage risks to service delivery, the public, local communities, local infrastructure, businesses and the natural environment from a changing climate, and to make the most of new opportunities. The indicator measures progress on assessing and managing climate risks and opportunities, and incorporating appropriate action into local authority and partners' strategic planning.

The impacts might include increases in flooding, temperature, drought and extreme weather events. These could create risks and opportunities such as: impacts to transport infrastructure from melting roads or buckling rails, increases in tourism, increased damage to buildings from storms, impacts on local ecosystems and biodiversity, scope to grow new crops, changing patterns of disease, impacts on planning and the local economy and public health.

Examples of the processes, tools and evidence that could be used to reach the various levels have been included. However, this list is not exhaustive and any appropriate methodology can be used.

Definition

Authorities should report the level they have reached as follows:

- Level 0: The authority has not assessed and managed climate risks and opportunities, or incorporated appropriate action into local authority strategic planning.
- Level 1: The authority has undertaken a comprehensive, local risk-based assessment of current vulnerabilities to weather and climate, both now and in the future. It has developed possible adaptation responses explicitly related to other relevant council strategies, plans, partnerships and operations (such as planning, flood management, economic development, social care, services for children, transport etc).
- Level 2: The authority has identified the most effective adaptation responses to address the risks and opportunities, explicitly related to other council strategies, plans and operations. This will yield a set of locally specific, preferred options.
- Level 3: The authority has developed an adaptation action plan to deliver necessary steps to achieve the existing objectives set out in council strategies, plans, investment decisions and partnership arrangements in light of projected climate change.
- Level 4: The authority has implemented an adaptation action plan, and a process for monitoring and review to ensure progress with each measure.

APPENDIX 2: CLIMATE CHANGE TIMELINE FOR THE 3CAP REGION

UKCIP02 climate change predictions are typically reported across a map of the UK, split into grids of 50km or 5km. For this analysis of future climate change predictions for the 3CAP region, the data from UKCIP's 50km resolution grid predictions has been used. Grid square 333 (highlighted in blue in Figure A1) has been selected for analysis as it lies within the central part of the 3CAP region (Derbyshire, Leicestershire and Nottinghamshire) and will adequately represent the changes that will affect the region as a whole. By selecting one grid square within the region (rather than all grid squares that apply to the region), a clear and general understanding of the likely changes in temperature, precipitation and wind speed can be achieved.

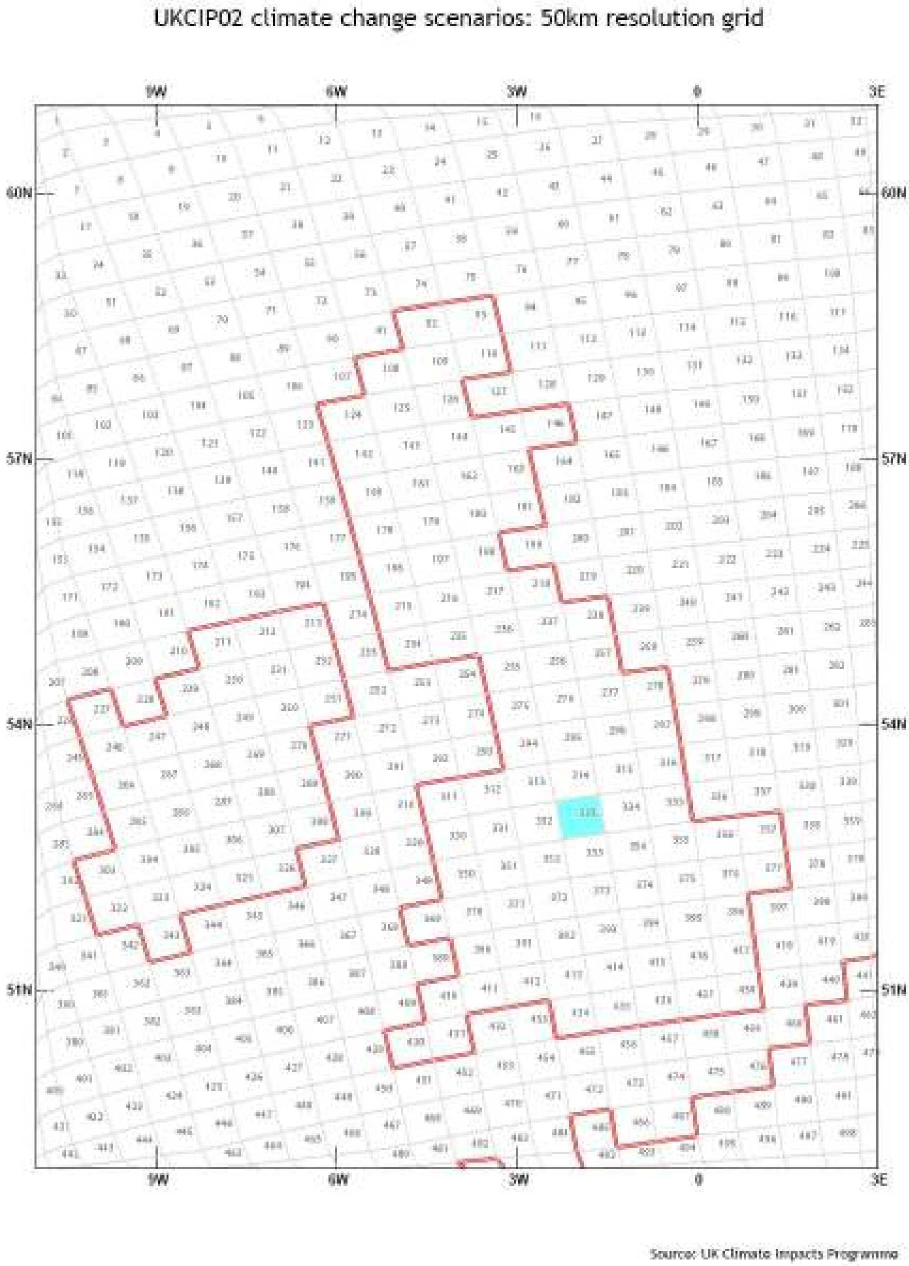


Figure A1: UKCIP Climate Scenarios 50km grid – showing selected grid square 333

The Medium-High Emissions Scenario was selected and UKCIP02 predictions for the three UKCIP 'time-slices' of around the 2020s (2011-2040), 2050s (2041-2070) and the 2080s (2071-2100). All changes are given in relation to the baseline period of 1961 to 1990.

It is important to understand that UKCIP02's four scenarios for predicted future climate change account for the uncertainties that exist about future trends and behaviours, such as; population growth, technological progress and socio-economic development. The changes described for the next 40 years are based on past and current emissions and so all four scenarios display similar patterns. After this period, the impact on weather patterns is dependent upon differing predicted changes to emissions.

N.B

- Where data is given for 'Summer', this represents the months June to August inclusive
- Where data is given for 'Winter', this represents the months December to February inclusive

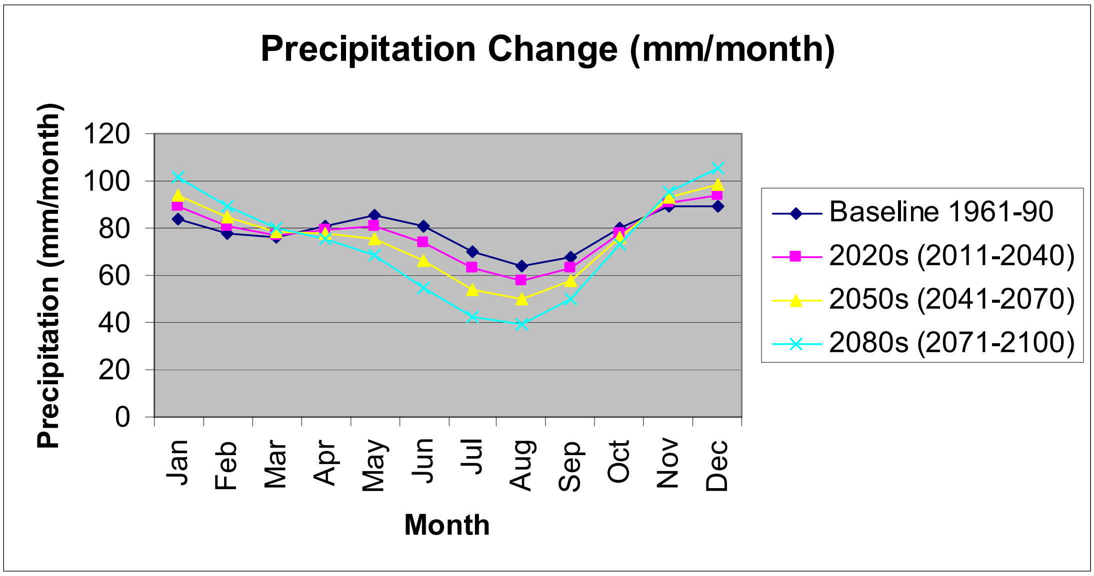
Precipitation

Average (monthly)

Table A1: Average rainfall per month (mm/month)

		Rainfall (mm/month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Timeslice	Baseline 1961-90	84.2	77.85	76	80.78	85.07	80.47	70.31	64.23	67.71	79.7	88.94	89.04
	2020s (2011-2040)	88.86	80.95	77.03	79.25	80.94	73.64	62.72	57.51	62.98	77.88	90.76	93.5
	2050s (2041-2070)	94.11	84.43	78.17	77.52	75.48	65.95	54.18	49.95	57.66	75.84	92.81	98.51
	2080s (2071-2100)	101.64	89.43	79.82	75.04	68.21	54.91	41.94	39.1	50.02	72.92	95.75	105.72

Figure A2: Precipitation change (mm/month)

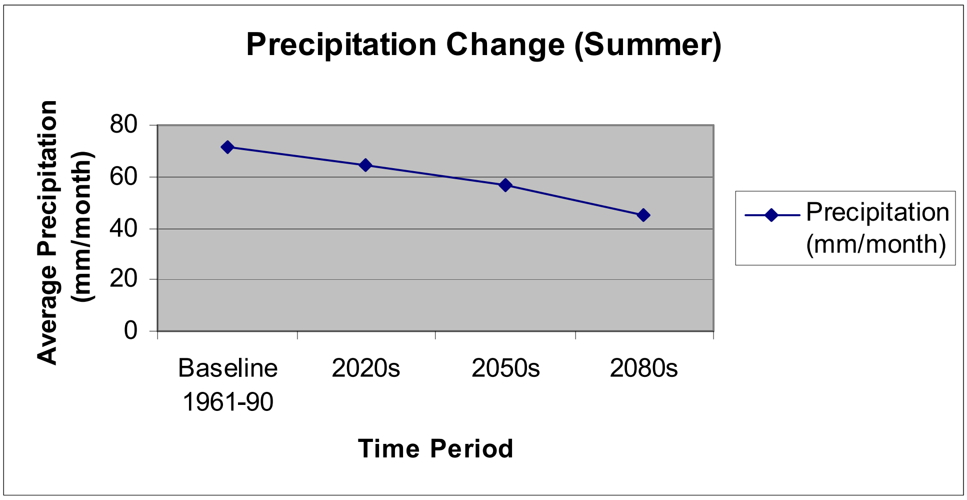


Average (Summer)

Table A2: Average summer precipitation (mm/month)

	Time slice			
	Baseline 1961-90	2020s	2050s	2080s
Precipitation (mm/month)	71.67	64.62	56.69	45.32

Figure A3: Average summer precipitation change

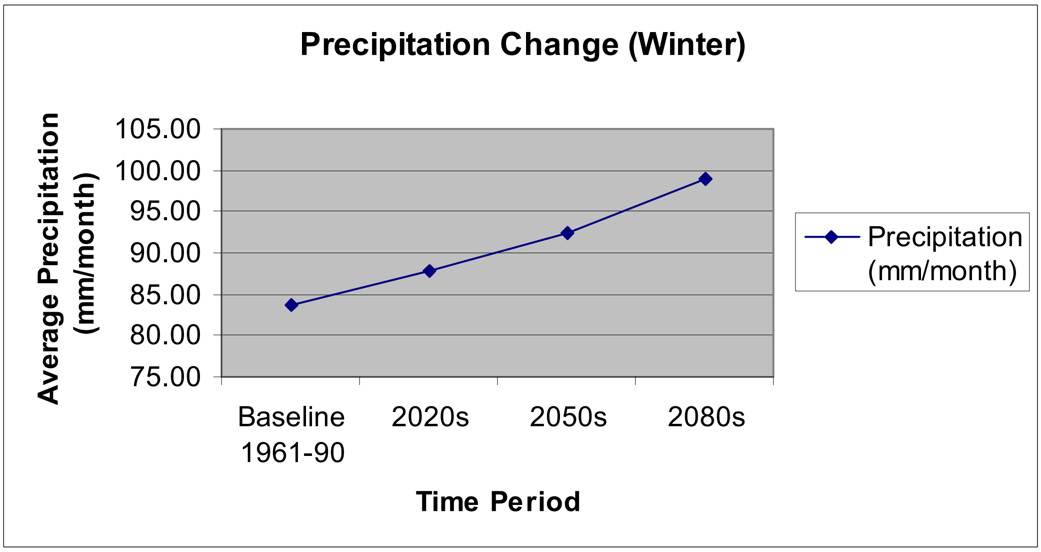


Average (Winter)

Table A3: Average winter precipitation (mm/month)

	Time slice			
	Baseline 1961-90	2020s	2050s	2080s
Precipitation (mm/month)	83.70	87.77	92.35	98.93

Figure A4: Average winter precipitation change



Summary for precipitation

Summer:

- By the **2020s** there will be an average of **9.8% less** precipitation in summer than in the baseline period of 1961-90 (based on average figures of mm/month)
- By the **2050s** there will be an average of **20.9% less** precipitation in summer than in the baseline period of 1961-90 (based on average figures of mm/month)
- By the **2080s** there will be an average of **36.8% less** precipitation in summer than in the baseline period of 1961-90 (based on average figures of mm/month)

Winter:

- By the **2020s** there will be an average of **4.9% more** precipitation in winter than the baseline period of 1961-90 (based on average figures of mm/month)
- By the **2050s** there will be an average of **10.3% more** precipitation in winter than the baseline period of 1961-90 (based on average figures of mm/month)
- By the **2080s** there will be an average of **18.2% more** precipitation in winter than the baseline period of 1961-90 (based on average figures of mm/month)

Annually;

- By the **2020s** there will be an average of **1.9% less** precipitation annually than the baseline period of 1961-90 (based on average figures of mm/month)
- By the **2050s** there will be an average of **4.2% less** precipitation annually than the baseline period of 1961-90 (based on average figures of mm/month)
- By the **2080s** there will be an average of **7.4% less** precipitation annually than the baseline period of 1961-90 (based on average figures of mm/month)

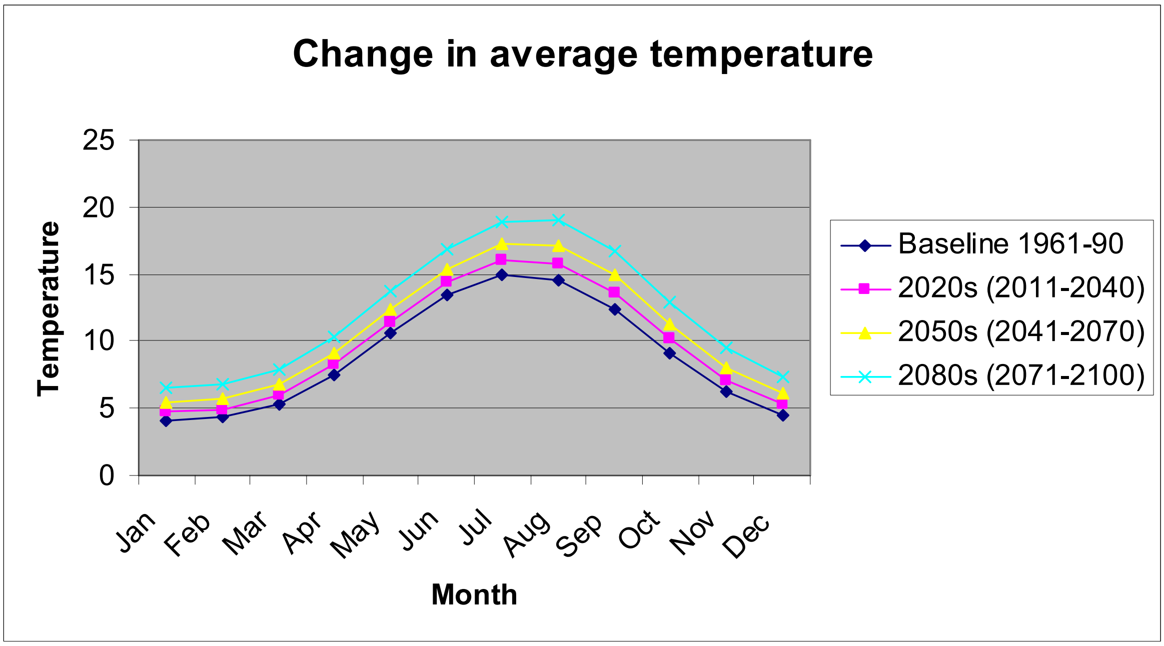
Temperature

Average (monthly)

Table A4: Average monthly temperature (°C)

		Average monthly temperature (°C)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Time Slice	Baseline 1961-90	4.06	4.3	5.28	7.53	10.64	13.43	14.91	14.6	12.39	9.14	6.23	4.53
	2020s (2011-2040)	4.73	4.95	5.97	8.28	11.45	14.35	15.98	15.79	13.56	10.17	7.09	5.28
	2050s (2041-2070)	5.49	5.68	6.74	9.11	12.37	15.39	17.19	17.13	14.88	11.32	8.07	6.12
	2080s (2071-2100)	6.57	6.73	7.84	10.32	13.68	16.87	18.93	19.05	16.77	12.97	9.46	7.32

Figure A5: Temperature change (°C)

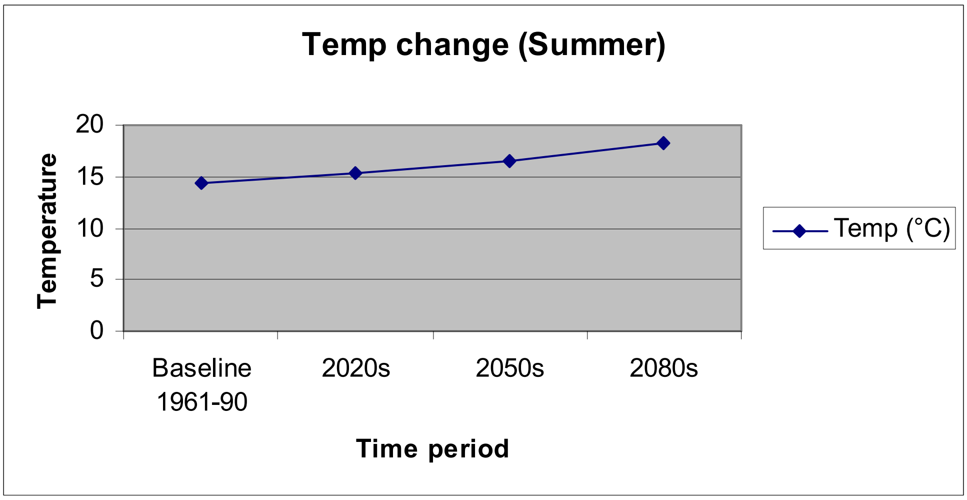


Average (Summer)

Table A5: Average summer temperature (°C)

	Time slice			
	Baseline 1961-90	2020s	2050s	2080s
Temp (°C)	14.31	15.37	16.57	18.28

Figure A6: Average summer temperature change (°C)

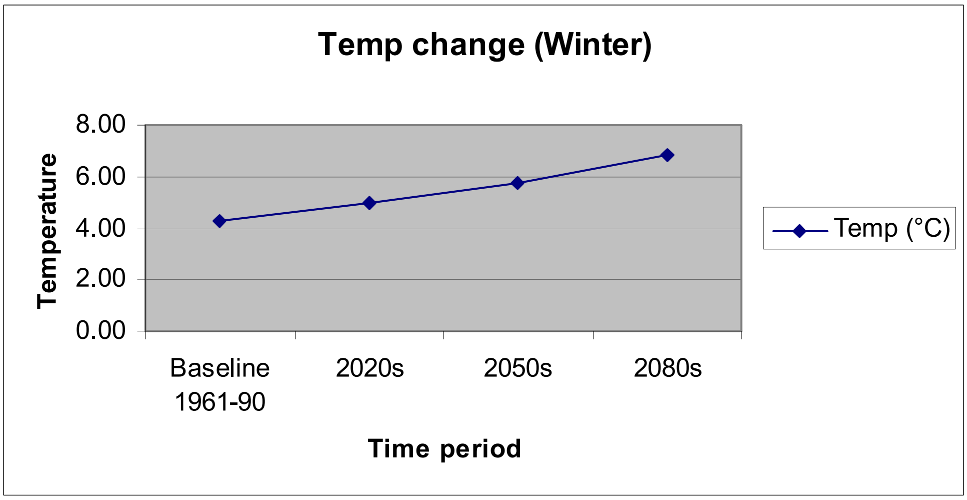


Average (Winter)

Table A6: Average winter temperature (°C)

	Time slice			
	Baseline 1961-90	2020s	2050s	2080s
Temp (°C)	4.30	4.99	5.76	6.87

Figure A7: Average winter temperature change (°C)



Summary for temperature

Summer:

- By the **2020s** it will be an average of **1.1°C warmer** in summer than the baseline period of 1961-90
- By the **2050s** it will be an average of **2.3°C warmer** in summer than the baseline period of 1961-90
- By the **2080s** it will be an average of **4.0°C warmer** in summer than the baseline period of 1961-90

Winter:

- By the **2020s** it will be an average of **0.7°C warmer** in winter than the baseline period of 1961-90

- By the **2050s** it will be an average of **1.5°C warmer** in winter than the baseline period of 1961-90
- By the **2080s** it will be an average of **2.6°C warmer** in winter than the baseline period of 1961-90

Annually:

- By the **2020s** it will be an average of **0.9°C warmer** annually than the baseline period of 1961-90
- By the **2050s** it will be an average of **1.9°C warmer** annually than the baseline period of 1961-90
- By the **2080s** it will be an average of **3.3°C warmer** annually than the baseline period of 1961-90

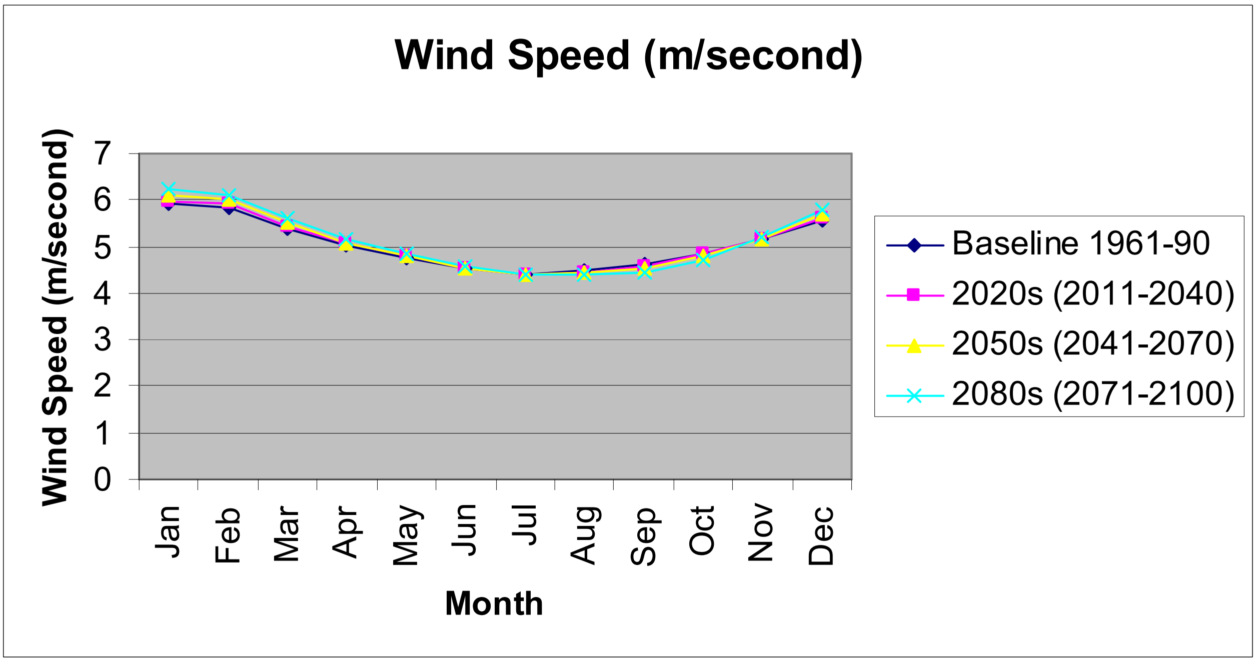
Wind Speed

Average (monthly)

Table A7: Average wind speed (m/second)

		Average wind speed (m/second)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Time slice	Baseline 1961-90	5.91	5.83	5.39	5.03	4.77	4.51	4.38	4.47	4.64	4.86	5.16	5.57
	2020s (2011-2040)	5.99	5.91	5.45	5.06	4.79	4.53	4.39	4.44	4.59	4.83	5.17	5.63
	2050s (2041-2070)	6.09	6.00	5.51	5.09	4.80	4.55	4.39	4.42	4.54	4.79	5.18	5.69
	2080s (2071-2100)	6.22	6.12	5.6	5.14	4.83	4.58	4.41	4.38	4.46	4.73	5.20	5.79

Figure A8: Wind speed change

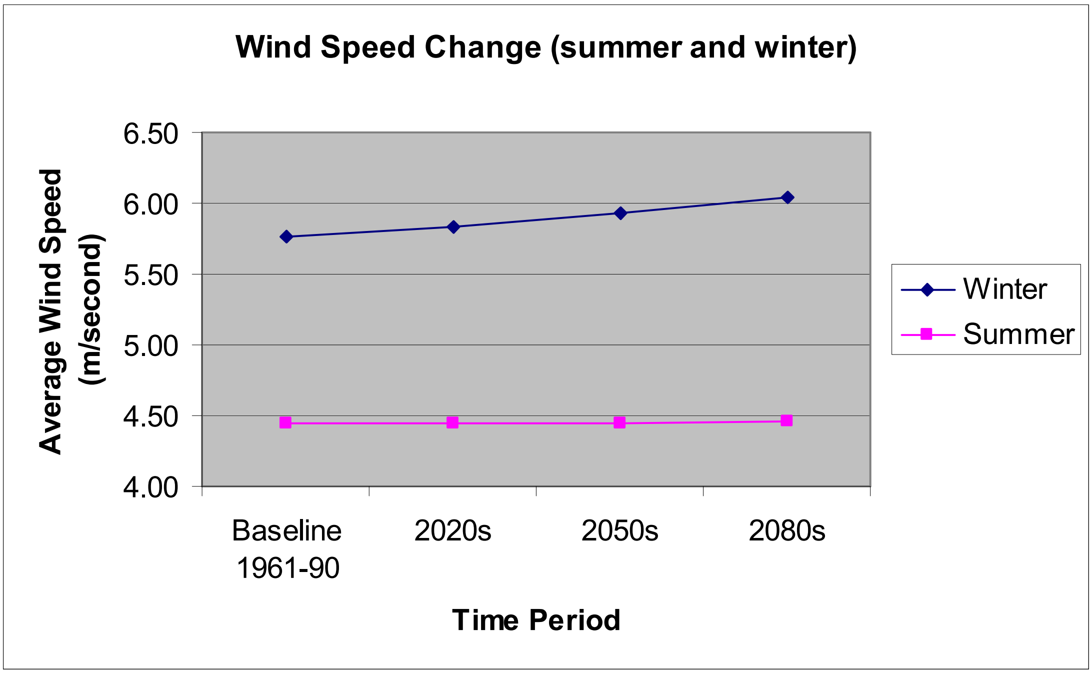


Average (Summer and Winter)

Table A8: Average wind speed change (m/second)

	Time slice			
	Baseline 1961-90	2020s	2050s	2080s
Winter	5.77	5.84	5.93	6.04
Summer	4.45	4.45	4.45	4.46

Figure A9: Average winter and summer wind speed change (m/second)



Summary for wind speed

Summer:

- By the **2020s** there will **no significant change** in average summer wind speed (m/second) compared to the baseline average for 1961-90
- By the **2050s** there will be **no significant change** in average summer wind speed (m/second) compared to the baseline average for 1961-90
- By the **2080s** there will be a **2.2% increase** in average summer wind speed (m/second) compared to the baseline average for 1961-90

Winter:

- By the **2020s** there will be a **1.2% increase** in average winter wind speed (m/second) compared to the baseline average for 1961-90
- By the **2050s** there will be a **2.8% increase** in average winter wind speed (m/second) compared to the baseline average for 1961-90
- By the **2080s** there will be a **4.7% increase** in average winter wind speed (m/second) compared to the baseline average for 1961-90

Annually:

- By the **2020s** there will be a **0.4% increase** in average annual wind speed (m/second) compared to the baseline average for 1961-90
- By the **2050s** there will be a **0.9% increase** in average annual wind speed (m/second) compared to the baseline average for 1961-90
- By the **2080s** there will be a **1.6% increase** in average annual wind speed (m/second) compared to the baseline average for 1961-90

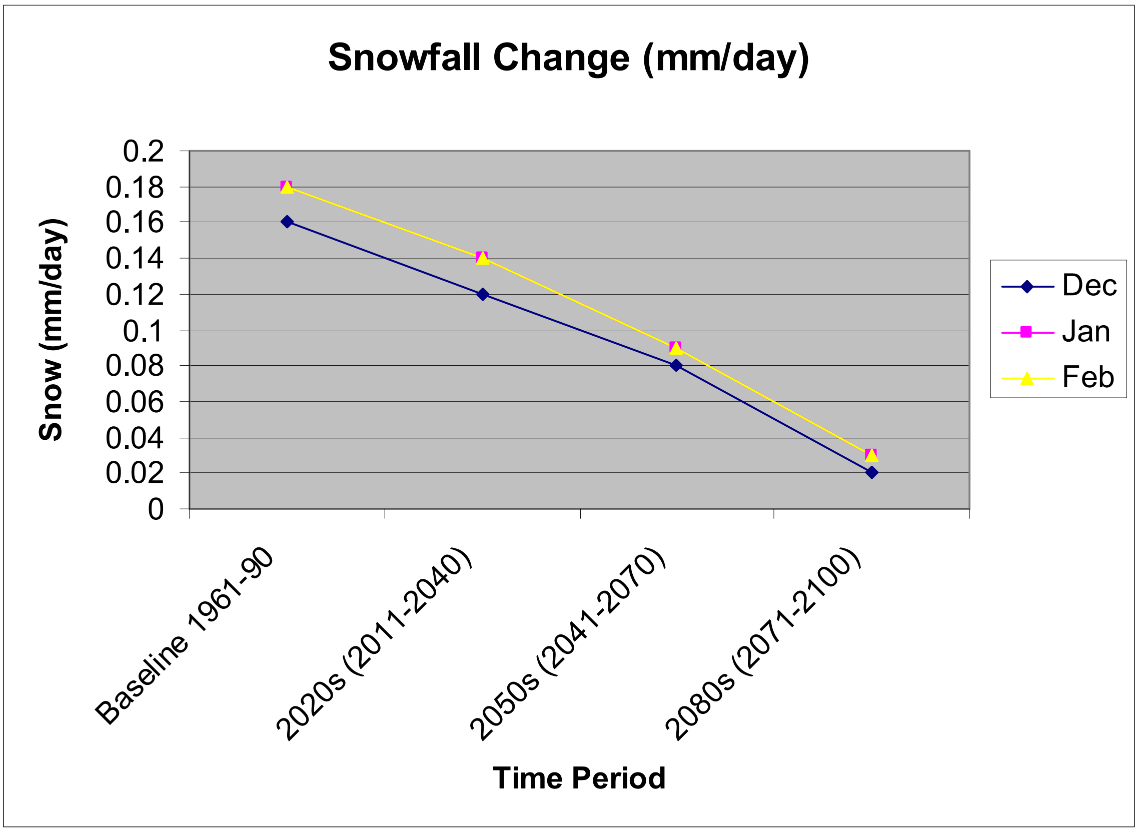
Snowfall

Average (monthly)

Table A9: Average monthly snowfall (mm/day)

		Average snowfall (mm/day)		
		Dec	**Jan**	**Feb**
Time slice	**Baseline 1961-90**	0.16	0.18	0.18
	2020s (2011-2040)	0.12	0.14	0.14
	2050s (2041-2070)	0.08	0.09	0.09
	2080s (2071-2100)	0.02	0.03	0.03

Figure A10: Predicted monthly snowfall change (mm/day)

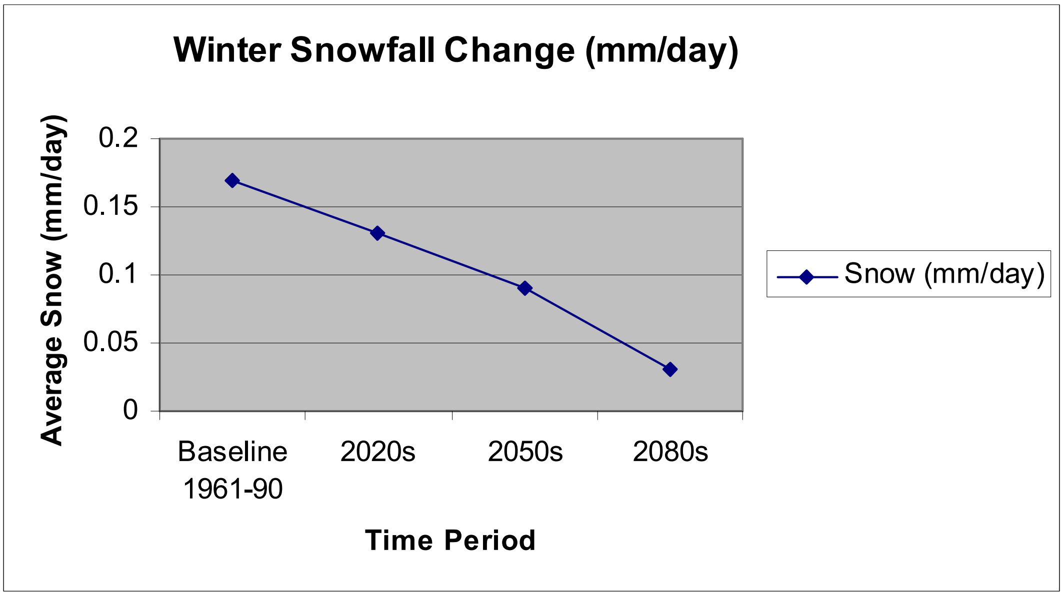


Average (Winter)

Table A10: Average winter snowfall (average over Jan, Feb and March), (mm/day)

	Time slice			
	Baseline 1961-90	2020s	2050s	2080s
Snowfall (mm/day)	0.17	0.13	0.09	0.03

Figure A11: Predicted average winter snowfall change (average over Jan, Feb and March), (mm/day)



Summary for snowfall

Annually:

- By the **2020s** there will be an average of **23.5% less** snowfall in winter than the baseline period of 1961-90 (based on average figures of mm/day)
- By the **2050s** there will be an average of **47.1% less** snowfall in winter than the baseline period of 1961-90 (based on average figures of mm/day)
- By the **2080s** there will be an average of **82.4% less** snowfall in winter than the baseline period of 1961-90 (based on average figures of mm/day)

APPENDIX 3: ADAPTATION RESPONSE EVALUATION CALCULATIONS

Bridges and other Structures

Evaluation Criteria	B1. Increase the number and frequency of maintenance works carried out to increase the BCI average and critical values	B2. Carry out a risk assessment to identify which structures are most at risk from the effects of climate change	B3. Ensure that all strengthening and repair work that is outstanding for failed or below standard bridges is carried out	B4. Ensure that all data (new and historical) is transferred into a single system to make assessments of maintenance and repair priorities and needs more effective	B5. Carry out a culvert assessment programme using the CSS National Bridge Condition Indicator System (as carried out for bridges)	B6. Evaluate the Depreciated Replacement Cost (DRC) for all highway structures to allow for an assessment of the impact of spending to be made	B7. Carry out a programme of culvert replacement for those that are beyond repair	B8. Introduce an inspection programme for retaining walls	B9. Apply plant and wildlife resistant substances to structures to discourage intrusion	B10. Develop a bridge waterproofing programme for concrete bridges with no or failing waterproofing, and for masonry arch bridges susceptible to freeze thaw damage through water penetration	B11. Carry out a programme of improvement to safety barriers and parapets as identified from a Risk Assessment	B12. Carry out flood studies with the help of other agencies and organisations (the EA etc)	B13. Slow down and manage the velocity of water flows	B14. Review the county council's existing policies and standards on weight restrictions	B15. Carry out wind modelling on major structures	B16. Increase the use of warning signs on high bridges and roads to warn against the dangers during high winds	B17. Fell trees that pose a risk to structures during periods of high winds and storms	Weighting (out of 1)
Cost - capital (3 = low capital cost)	2	2	2	2	2	2	1	2	2	2	2	2	1	2	2	1	3	0.1
Cost - whole-life (3 = low whole-life cost)	3	3	3	3	3	3	2	2	2	2	2	3	1	3	2	2	1	0.1
Technical feasibility (3 = high techical feasibility)	3	3	2	3	2	2	2	2	2	2	2	3	1	2	2	2	2	0.1
Risk of no action (3 = high risk associated with doing nothing)	3	3	3	2	2	2	3	2	2	2	2	3	2	2	2	2	2	0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	3	3	2	3	2	3	2	2	2	2	2	3	2	3	2	2	1	0.1
Sustainability of the response (3 = highly sustainable)	3	3	3	3	2	2	2	2	2	2	2	3	1	2	2	2	2	0.075
Practicality (3 = highly practical)	3	3	3	2	2	2	2	2	2	2	2	2	1	2	1	2	1	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	3	3	3	3	2	2	2	3	2	2	3	2	2	2	2	2	2	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	3	2	3	2	2	2	3	2	2	2	2	2	2	2	2	2	2	0.075
Politically acceptable (3 = politically favourable)	3	3	3	3	3	3	2	2	1	3	2	3	2	2	3	2	1	0.05
Publically acceptable (3 = publically favourable)	3	3	3	3	3	3	3	3	1	3	2	3	2	2	3	2	1	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	0.05
Future-proof (3 = high likelihood of being future-proof)	3	3	2	2	2	2	2	2	2	2	2	3	1	2	2	2	2	0.05
Total Score (out of a maximum of 3)	**2.85** 95%	**2.775** 93%	**2.6** 87%	**2.55** 85%	**2.2** 73%	**2.3** 77%	**2.125** 71%	**2.125** 71%	**1.9** 63%	**2.1** 70%	**2.075** 69%	**2.625** 88%	**1.45** 48%	**2.2** 73%	**2.025** 68%	**1.9** 63%	**1.725** 58%	

Score

>2.5	Very high
2.25 - 2.5	High
2 - 2.25	Medium
1.75 - 2	Low
< 1.75	Very low

Drainage

Evaluation Criteria	D1. Improve the knowledge of drainage assets	D2. Undertake a risk assessment to determine vulnerable areas and establish a prioritised scheme for maintenance	D3. Change to an ad-hoc gully emptying strategy based on demand and need	D4. Increase the frequency of highway network drainage inspections	D5. Increase gully emptying frequency	D6. Increase highway budgets for drainage maintenance	D7. Provide sealed edges to pavements to prevent silted drains	D8. Invest in asset management and location reviews	D9. Carry out drainage condition surveys	D10. Make enforcement on landowners easier	D11. Improve flood protection	D12. Define alternative routes and ensure that they are adequate for if flooding occurs	D13. Increase the use of SUDS and clarify responsibilities and ownership	D14. Capture and store water (tanks, containers etc)	D15. Build more temporary buildings and structures	Weighting (out of 1)
Cost - capital (3 = low capital cost)	3	2	2	2	2	2	2	2	2	3	1	2	1	1	1	0.1
Cost - whole-life (3 = low whole-life cost)	3	3	2	2	2	1	2	2	2	2	1	2	1	1	1	0.1
Technical feasibility (3 = high techical feasibility)	3	3	3	2	2	2	2	3	2	2	2	2	2	1	2	0.1
Risk of no action (3 = high risk associated with doing nothing)	3	3	3	3	3	3	2	3	3	2	3	2	2	2	2	0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	2	3	3	2	2	3	2	3	3	3	2	3	2	2	1	0.1
Sustainability of the response (3 = highly sustainable)	3	2	2	2	2	1	1	2	2	2	2	2	2	2	2	0.075
Practicality (3 = highly practical)	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	2	2	2	3	2	1	2	2	2	2	2	2	2	2	2	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	2	3	2	2	2	2	2	2	3	2	3	1	2	2	2	0.075
Politically acceptable (3 = politically favourable)	3	3	3	2	2	2	2	3	3	2	2	2	2	2	1	0.05
Publically acceptable (3 = publically favourable)	3	3	3	3	3	3	2	3	3	1	3	2	2	2	2	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	0.05
Future-proof (3 = high likelihood of being future-proof)	3	2	2	3	2	2	2	2	2	2	2	2	2	1		0.05
TOTAL SCORE (out of a maximum of 3)	**2.625** 88%	**2.575** 86%	**2.4** 80%	**2.275** 76%	**2.15** 72%	**2** 67%	**1.925** 64%	**2.4** 80%	**2.375** 79%	**2.15** 72%	**2.025** 68%	**2.025** 68%	**1.675** 56%	**1.525** 51%	**1.55** 52%	

Score

Score	
>2.5	Very high
2.25 - 2.5	High
2 - 2.25	Medium
1.75 - 2	Low
< 1.75	Very low

Grass Cutting

Evaluation Criteria	GC1. Increase the frequency of grass cutting	GC2. Treat grass with growth retardant and/or fertiliser to produce slower growing/better quaity grass	GC3. Change the species of trees/ grasses/ plants on the soft estate to slower growing species	Weighting (out of 1)
Cost - capital (3 = low capital cost)	3	3	1	0.1
Cost - whole-life (3 = low whole-life cost)	3	3	3	0.1
Technical feasibility (3 = high techical feasibility)	3	3	3	0.1
Risk of no action (3 = high risk associated with doing nothing)	2	2	2	0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	2	2	3	0.1
Sustainability of the response (3 = highly sustainable)	3	3	2	0.075
Practicality (3 = highly practical)	2	2	2	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	3	3	2	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	2	2	2	0.075
Politically acceptable (3 = politically favourable)	3	2	2	0.05
Publically acceptable (3 = publically favourable)	3	3	2	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	3	3	1	0.05
Future-proof (3 = high likelihood of being future-proof)	2	2	2	0.05
TOTAL SCORE (out of a maximum of 3)	2.6 87%	2.6 87%	2.15 72%	

Score	
>2.5	Very high
2.25 - 2.5	High
2 - 2.25	Medium
1.75 - 2	Low
< 1.75	Very low

Materials – Highway Pavements

Evaluation Criteria	M1. Monitor ground water levels – in order to assess the adequacy of the current drainage provision	M2. Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat	M3. Sanding of asphalt surfaces in summer – to prevent loss of skid resistance	M4. Increased maintenance to seal all faces/joints/cracks to prevent water ingress	M5. Review existing materials specifications - General	M6. Use performance related specifications which promote properties which resist the adverse effects of climate change	M7. Specification: Consider using high modulus base/binder materials and rut resistant surface course material	M8. Closer control: During construction ensure compaction of pavement layers and adequate curing	M9. Specification: Consider the application of bond coats to reduce voids at layer interfaces	M10. Specification: Consider using hydraulically bound layers with a low coefficient of expansion coarse aggregate and/or smaller slab sizes by induced cracking	M11. Specification: Consider using light coloured/reflective aggregate and/or modified colour asphalt in the surface course to increase solar reflectance	M12. Specification: Consider using aggregates less prone to stripping, anti-stripping agents (e.g. hydrated lime), and/or more viscous binders to reduce stripping.	M13. Consider increasing the permeability of the surface course to reduce the run-off and adjust road crossfall/alignment to prevent water ponding	M14. Restrict or redirect heavy traffic during prolonged periods of hot and dry conditions	M15. Develop a long-term programme to locate and assess the adequacy and condition of the current drainage provision, and ensure it is well maintained.	Weighting (out of 1)
Cost - capital (3 = low capital cost)	2	2	2	1	2	2	2	2	1	1	2	1	2	2	1	0.1
Cost - whole-life (3 = low whole-life cost)	2	3	2	1	3	3	3	2	3	2	3	2	2	3	3	0.1
Technical feasibility (3 = high techical feasibility)	2	2	3	3	2	2	3	2	2	2	2	2	1	2	3	0.1
Risk of no action (3 = high risk associated with doing nothing)	1	3	2	3	3	2	3	1	3	2	3	2	1	1	3	0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	3	3	2	2	2	3	3	3	2	2	2	1	2	1	3	0.1
Sustainability of the response (3 = highly sustainable)	2	3	1	2	2	3	2	1	2	1	2	1	1	1	2	0.075
Practicality (3 = highly practical)	1	3	2	2	2	2	3	1	2	1	2	2	1	1	2	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	2	3	3	3	2	2	2	3	2	2	2	2	2	2	2	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	1	1	1	3	3	2	3	1	3	2	3	3	1	2	3	0.075
Politically acceptable (3 = politically favourable)	2	3	2	3	2	3	3	1	2	2	2	2	2	1	3	0.05
Publically acceptable (3 = publically favourable)	2	3	2	2	2	2	2	1	2	2	2	2	2	1	3	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	2	2	2	2	1	2	1	3	1	1	1	2	1	2	2	0.05
Future-proof (3 = high likelihood of being future-proof)	1	2	1	1	2	3	2	1	2	2	1	2	2	2	2	0.05
Total Score (out of a maximum of 3)	1.8 60%	2.55 85%	1.975 66%	2.15 72%	2.225 74%	2.375 79%	2.55 85%	1.75 58%	2.125 71%	1.7 57%	2.175 73%	1.8 60%	1.525 51%	1.65 55%	2.475 83%	

Score

Score	
>2.5	Very high
2.25 - 2.5	High
2 - 2.25	Medium
1.75 - 2	Low
< 1.75	Very low

Materials – Highway Structures

Evaluation Criteria	**M16. Specification: Amend BA 59/94 bridge design for scour; and/or BD 63/07 regular 2-yearly bridge inspections; and/or BA 74/06 method for quantitative assessment of scour at existing structures; and/or BD 37/01 design wind loads; and/or BD 37/01 bridge design for thermal effects**	**M17. Assess lightweight structures for sensitivity to wind loading**	**Weighting (out of 1)**
Cost - capital (3 = low capital cost)	3	1	0.1
Cost - whole-life (3 = low whole-life cost)	3	2	0.1
Technical feasibility (3 = high techical feasibility)	1	3	0.1
Risk of no action (3 = high risk associated with doing nothing)	1	1	0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	3	3	0.1
Sustainability of the response (3 = highly sustainable)	1	3	0.075
Practicality (3 = highly practical)	1	2	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	1	3	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	1	1	0.075
Politically acceptable (3 = politically favourable)	1	3	0.05
Publically acceptable (3 = publically favourable)	2	2	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	1	2	0.05
Future-proof (3 = high likelihood of being future-proof)	2	2	0.05
Total Score (out of a maximum of 3)	**1.7** 57%	**2.125** 71%	

Score		
(red)	>2.5	Very high
(orange)	2.25 - 2.5	High
(amber)	2 - 2.25	Medium
(light orange)	1.75 - 2	Low
(white)	< 1.75	Very low

Materials – Highway Verges (Flora)

Evaluation Criteria	M18. Identify where soil comprises clay with a high plasticity index and avoid planting/removing forest trees from within at least 15m from the road edge	M19. Specification: Appropriate planting - tree types and locations	M20. Tree maintenance regimes should be established, to control the size of each tree and its water requirement	M21. Avoid creating tree wind-throw risks when undertaking works such as copse or tree line thinning, removing hedgerows or earth works.	Weighting (out of 1)
Cost - capital (3 = low capital cost)	1	3	2	3	0.1
Cost - whole-life (3 = low whole-life cost)	2	3	2	3	0.1
Technical feasibility (3 = high techical feasibility)	1	2	2	2	0.1
Risk of no action (3 = high risk associated with doing nothing)	1	2	2	2	0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	2	3	3	3	0.1
Sustainability of the response (3 = highly sustainable)	2	3	3	3	0.075
Practicality (3 = highly practical)	1	2	2	2	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	2	2	2	2	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	2	2	2	2	0.075
Politically acceptable (3 = politically favourable)	2	2	2	2	0.05
Publically acceptable (3 = publically favourable)	2	2	2	2	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	1	2	2	2	0.05
Future-proof (3 = high likelihood of being future-proof)	2	2	2	2	0.05
Total Score (out of a maximum of 3)	**1.575** 53%	**2.375** 79%	**2.175** 73%	**2.375** 79%	

Score		
	>2.5	Very high
	2.25 - 2.5	High
	2 - 2.25	Medium
	1.75 - 2	Low
	< 1.75	Very low

Resurfacing

Evaluation Criteria	S1. Undertake a risk assessment to identify the most vulnerable areas of the network and develop priority actions to be carried out	S2. Implement a targetted programme of improvement	S3. Increase the frequency of carriageway surface inspections	S4. Implement a cyclic programme of carriageway resurfacing and maintenance (rather than on demand)	S5. Consider tree felling to reduce the soil moisture deficit in summer	S6. Use chamfered edges to reduce the risk of spalling during expansion in hot weather	S7. Review local experience of the durability of surface dressing and consider whether other measures may be more appropriate	S8. Use polymer modified binders that are less prone to binder stripping and other materials with a greater 'stiffness'	S9. Sand/dust bituminous surfaces in summer	S10. Trial reinforcement of the carriageway to reduce subsidence	S11. Induce transverse cracks to pavements during resurfacing and repair activities to reduce the risk of cracking in high temperatures	S12. Restrict the periods where resurfacing activities are carried out (not during high temperatures)	S13. Increase gully emptying and inspection frequency	S14. Increased verge maintenance and grass cutting frequencies to reduce the risk of 'root invasion' and vegetation ingress on the highway	S15. Revise the parameters for the design storm to reduce the risks and effects of flooding	S16. Introduce surface/sub-surface drainage during maintenance works where they do not exist at present	Weighting (out of 1)
Cost - capital (3 = low capital cost)	2	2	2	3	1	2	2	2	2	1	1	2	2	2	1	1	0.1
Cost - whole-life (3 = low whole-life cost)	3	2	2	2	2	2	3	2	2	2	2	3	2	2	2	1	0.1
Technical feasibility (3 = high techical feasibility)	2	2	2	2	2	2	3	2	2	1	2	2	2	3	1	2	0.1
Risk of no action (3 = high risk associated with doing nothing)	3	2	3	2	2	2	2	2	2	2	2	3	3	2	3		0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	3	2	2	2	1	2	3	2	2	2	2	2	2	2	2	3	0.1
Sustainability of the response (3 = highly sustainable)	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	0.075
Practicality (3 = highly practical)	2	2	2	2	2	2	3	2	1	1	2	2	2	2	1	2	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	3	3	3	2	2	2	2	2	3	2		2	2	3	1	2	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0.075
Politically acceptable (3 = politically favourable)	3	3	2	2	1	2	3	2	3	2	2	2	2	3	2	2	0.05
Publically acceptable (3 = publically favourable)	3	3	3	2	1	2	3	3	2	2	2	2	3	3	2	2	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	0.05
Future-proof (3 = high likelihood of being future-proof)	3	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	0.05
TOTAL SCORE (out of a maximum of 3)	**2.525** 84%	**2.175** 73%	**2.225** 74%	**2.1** 70%	**1.65** 55%	**2** 67%	**2.475** 83%	**2.05** 68%	**2.05** 68%	**1.725** 58%	**1.75** 58%	**2.15** 72%	**2.15** 72%	**2.35** 78%	**1.75** 58%	**1.7** 57%	

Score

Score	
>2.5	Very high
2.25 - 2.5	High
2 - 2.25	Medium
1.75 - 2	Low
< 1.75	Very low

Tree and Hedge Maintenance

Evaluation Criteria	T1. Improve the knowledge of existing tree stock	T2. Undertake a risk assessment to determine vulnerable trees and establish a prioritised scheme for maintenance	T3. Increase the frequency of tree and hedge inspections	T4. Increase the budget available for tree and hedge maintenance	T5. Carry out a programme of tree condition surveys	T6. Increase the frequency of tree training and pruning	T7. Make enforcements on landowners easier	T8. Make enforcements on utility companies easier	T9. Fell trees that are deemed to be a threat to highway structures or a threat to road safety	T10. Develop a tree management strategy for implemetation across the county councils (to include all trees, not just those on or near to the highway)	T11. Replace felled trees with slower growing varieties, rather than of the same species	T12. Review the species choice for new trees to enusre the most appropriate species is selected	Weighting (out of 1)
Cost - capital (3 = low capital cost)	2	2	2	2	1	2	2	2	1	2	2	2	0.1
Cost - whole-life (3 = low whole-life cost)	2	2	2	2	2	2	2	2	2	2	2	2	0.1
Technical feasibility (3 = high techical feasibility)	2	2	2	2	2	2	2	1	2	3	2	2	0.1
Risk of no action (3 = high risk associated with doing nothing)	2	3	2	3	3	2	2	2	3	2	1	3	0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	3	3	2	3	2	2	3	3	1	3	2	2	0.1
Sustainability of the response (3 = highly sustainable)	3	2	2	2	2	2	2	2	2	2	3	2	0.075
Practicality (3 = highly practical)	2	2	2	2	2	2	1	2	2	2	2	2	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	2	2	2	2	3	2	2	1	2	2	2	2	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	2	2	2	2	2	2	2	2	2	3	2	3	0.075
Politically acceptable (3 = politically favourable)	3	3	2	2	2	2	2	2	2	3	2	3	0.05
Publically acceptable (3 = publically favourable)	3	3	3	2	2	2	1	2	1	3	2	3	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	2	2	2	2	2	2	2	2	2	2	2	2	0.05
Future-proof (3 = high likelihood of being future-proof)	2	2	2	2	2	2	2	2	2	2	2	3	0.05
TOTAL SCORE (out of a maximum of 3)	2.275 76%	2.3 78%	2.05 68%	2.2 73%	2.075 69%	2 67%	1.975 66%	1.925 64%	1.85 62%	2.375 79%	1.975 66%	2.325 76%	

Score

(red)	>2.5	Very high
(orange)	2.25 - 2.5	High
(yellow)	2 - 2.25	Medium
(light orange)	1.75 - 2	Low
(white)	< 1.75	Very low

Winter Service

Evaluation Criteria	W1. Carry out risk assessment surveys of the region to establish which routes are highest risk for ice formation	W2. Re-assess and re-classify priority routes based on future climate change predictions	W3. Move to using gritting materials that are more resistant to thaw and surface-water run-off (move from crushed rock salt to pre-wetted salting methods etc)	W4. Increase the capacity to carry out reactive salting to react more rapidly and effectively to changing weather predictions and uncertainty	W5. Establish more monitoring stations and/or invest in new monitoring technologies that enable more accurate readings and predictions to be made	W6. Invest in new gritters that are able carry out salting more rapidly and efficiently	**Weighting (out of 1)**
Cost - capital (3 = low capital cost)	2	2	1	2	1	1	0.1
Cost - whole-life (3 = low whole-life cost)	3	3	2	2	2	2	0.1
Technical feasibility (3 = high techical feasibility)	3	3	2	2	2	2	0.1
Risk of no action (3 = high risk associated with doing nothing)	2	2	2	2	2	1	0.1
Environmental impact (3 = no significant adverse environmental impacts or significant beneficial environmental impacts)	3	3	2	2	2	2	0.1
Sustainability of the response (3 = highly sustainable)	3	3	2	2	2	2	0.075
Practicality (3 = highly practical)	2	3	2	2	1	2	0.075
Level of county council control/ responsibility (3 = full county council control/ responsibility)	3	3	3	2	2	2	0.075
Scale/ impact of the response (3 = the adaptation response will have significant impact)	2	2	2	2	2	2	0.075
Politically acceptable (3 = politically favourable)	3	3	2	2	2	1	0.05
Publically acceptable (3 = publically favourable)	3	3	2	3	2	2	0.05
Resources/ skills/ knowledge available to implement the adaptation (3 = readily available resources/ skills and knowledge)	3	2	2	2	1	2	0.05
Future-proof (3 = high likelihood of being future-proof)	3	2	2	2	2	2	0.05
TOTAL SCORE (out of a maximum of 3)	**2.65** 88%	**2.625** 88%	**1.975** 66%	**2.05** 68%	**1.775** 59%	**1.75** 58%	

Score

(red)	>2.5	Very high
(orange)	2.25 - 2.5	High
(yellow)	2 - 2.25	Medium
(light orange)	1.75 - 2	Low
(white)	< 1.75	Very low