AECOM

Midlands Highway Alliance - Climate Change Adaptation Guidance and Good Practice

Final Report

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Executive Summary

The Midlands Highway Alliance (MHA)[1] has commissioned AECOM Infrastructure & Environment UK Ltd to undertake a study to identify, capture and share examples of how individual MHA authorities (and other local authorities across the UK) are taking action to understand and prepare their highway networks for the future impacts of climate change and an increased frequency and severity of extreme weather events. This study follows on from a previous review of climate change impacts by the 3 Counties Alliance Partnership (3CAP – Derbyshire, Leicestershire and Nottinghamshire County Councils) in 2009[2] and subsequently updated in 2010/11 to reflect the progress made by the three authorities and to incorporate updates in climate change legislation and climate science[3]. A further review was undertaken in 2013/14 to capture any additional measures undertaken by the three authorities in adapting their highway networks, and an assessment of how the wider MHA could benefit from a collaborative approach to climate change adaptation and resilience building through collaborative and partnership working.

The ultimate aim of this project is to develop an evidence base to promote a collaborative approach to building resilience to the impacts of climate change and extreme weather, which is nationally applicable and transferable and has the potential to be showcased as an example of good practice in the transport sector. It should be applicable to all MHA authorities and take into account differences in climate, geography, drivers, policies and standards. This has been achieved through the identification, collation and synthesis of examples of how individual authorities are taking action to mitigate climate change impacts and increase their level of future resilience.

The review has found that local authority highway networks are susceptible to risks associated with climate change and an increased frequency and severity of extreme weather events. Such risks have already presented themselves, with the vulnerability of the local authority highway networks to flooding, wind, extreme winter conditions, coastal erosion and extreme heat becoming increasingly evident.

Opportunities have been identified, and are being implemented, to enhance climate change resilience, along with providing multiple, wider benefits such as enhanced amenity, accessibility and landscape value. The measures identified and detailed as case studies in this report include:

- The development of Adaptation Risk Registers and Action Plans;
- The development of Flood Risk Partnerships and Local Resilience Forums;
- The inclusion of climate change considerations and objectives within Local Transport Plans;
- The development of flood management guidance and toolkits to enhance community preparedness;
- The adaptation and adoption of operational responses, such as enhanced and targeted maintenance regimes;
- The trialling of different (more climate resilient) materials and technologies;
- The implementation of SuDS on a wider scale;
- The expansion of the blue and green infrastructure network; and,
- Revisions to winter service operations and strategies.

Assessing, understanding and responding to climate change risks are most effectively achieved through an integrated and collaborative approach involving a range of stakeholders and across administrative boundaries. Assessing and addressing climate change risks in a collaborative and integrated way ensures the interests of different groups are taken into account, information is shared, and the resources and knowledge available to address risks are maximised.

[1] At the time of writing the MHA comprises: Derby City Council; Derbyshire County Council; Doncaster Council; Highways England; Leicester City Council; Leicestershire County Council; Lincolnshire County Council; Milton Keynes Council; Northamptonshire County Council; Nottingham City Council; Nottinghamshire County Council; Oxfordshire County Council; Peterborough City Council; Rotherham Metropolitan Borough; Rutland County Council; Sandwell Metropolitan Borough; Staffordshire County Council; Stoke-on-Trent City Council; South Derbyshire District Council; Telford and Wrekin Council; and, Wolverhampton City Council.
[2] http://www.leics.gov.uk/climate_change_adaptations.pdf
[3] http://www.leics.gov.uk/final_report_march.pdf

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1 INTRODUCTION

The Midlands Highway Alliance (MHA)[4] has commissioned AECOM Infrastructure & Environment UK Ltd to undertake a study to identify, capture and share examples of how individual MHA authorities (and others across the UK) are taking action to understand and prepare their highway networks for the future impacts of climate change and an increased frequency and severity of extreme weather events.

This guidance document builds on previous reviews of climate change impacts. The initial review for the 3 Counties Alliance Partnership (3CAP – Derbyshire, Leicestershire and Nottinghamshire County Councils) had an objective to identify the 'Effects of Climate Change on 3CAP's Highways Network Policies and Standards'[5]. This study was conducted in 2009 (Phase 1) and was subsequently updated in 2010/11 (Phase 2) to reflect the progress made by the three authorities and to incorporate updates in climate change legislation and climate science[6]. A further review was undertaken in 2013/14 to capture any additional measures undertaken by the three authorities in adapting their highway networks, and an assessment of how the wider MHA could benefit from a collaborative approach to climate change adaptation and resilience building through collaborative and partnership working.

1.1 Background to the Study

The initial 3CAP project completed in 2009 was based on the 2002 UK Climate Impacts Programme (UKCIP02) predictions for climate change up to 2050. These UKCIP02 projections indicated increasingly hotter and drier summers, along with milder and wetter winters, and an increased frequency of extreme weather events. It is considered that these climate change projections, if realised, will have a significant impact on the design, construction, operation and maintenance of local authority highway networks.

To better understand the challenges faced by the 3CAP highway network, and to benefit from partnership working and the sharing of information, individual meetings with the three counties and a joint full-day workshop took place. Subsequently, a risk and probability assessment of the effects of climate change on the 3CAP highway network was carried out to develop and prioritise adaptation responses for seven key policy areas:

- Bridges and other structures;
- Drainage;
- Grass cutting;
- Materials;
- Resurfacing;
- Tree and hedge maintenance; and,
- Winter service.

The assessment was used to develop an Adaptation Action Plan for implementation by the three authorities. As a result of the collaborative study, the three authorities were able to start taking steps towards managing the effect(s) of the potential outcomes of climate change on their highways networks in future years.

Phase 2 of the 3CAP study was commissioned in 2011 to review and highlight 3CAP's progress against the Adaptation Action Plan developed during the Phase 1. The study also assessed the suitability of existing

[4] At the time of writing the MHA comprises: Derby City Council; Derbyshire County Council; Doncaster Council; Highways England; Leicester City Council; Leicestershire County Council; Lincolnshire County Council; Milton Keynes Council; Northamptonshire County Council; Nottingham City Council; Nottinghamshire County Council; Oxfordshire County Council; Peterborough City Council; Rotherham Metropolitan Borough; Rutland County Council; Sandwell Metropolitan Borough; Staffordshire County Council; Stoke-on-Trent City Council; South Derbyshire District Council; Telford and Wrekin Council; and, Wolverhampton City Council.
[5] http://www.leics.gov.uk/climate_change_adaptations.pdf
[6] http://www.leics.gov.uk/final_report_march.pdf

policies and standards for highway construction and maintenance materials in the light of projected climate change and included the development of six decision-making matrices to material choice in light of future climate projections. The report also included a more detailed review of climate change projections for the 3CAP region, and utilised updated 2009 UK Climate Projections (UKCP09) data.

This study provided the three authorities with further evidence to be able to take steps towards managing the potential effects of climate change on their highway network in future years and allowed each authority to work towards aligning their policies and standards to increase resilience to these effects.

In 2013/14, a further review of the progress made by Derbyshire, Leicestershire and Nottinghamshire County Council's against the Adaptation Action Plan was undertaken. As a result of the review, the Adaptation Action Plan was updated to reflect new identified risks, priorities, knowledge and drivers. Although developed specifically for Derbyshire, Leicestershire and Nottinghamshire County Councils, the updated Adaptation Action Plan is open to other MHA members to adopt.

The 2013/14 review also concluded that there was an appetite within the MHA to build on this work to develop a better understanding of, and higher level of resilience to, climate change and extreme weather risks across the wider MHA. To fully define the scope, tasks and outputs associated with this current project, a meeting was held with representatives from MHA authorities in August 2014. The meeting consisted of a series of discussions aimed at capturing the requirements and priorities of each attending authority and to understand what they want to see from the proposed project. The aim of this meeting was also to ensure understanding between MHA authorities and achieve agreement of the project scope, responsibilities and timescales.

The meeting concluded that the aim of the project should be to develop an evidence base to promote a collaborative approach to building resilience to the impacts of climate change and extreme weather. In addition, it was agreed that the project must be applicable to all MHA authorities and take into account differences in climate, geography, drivers, policies and standards. It was anticipated that such an approach provides a holistic, sustainable approach to climate change resilience which can be applied across the entire network, irrespective of regional variances.

Meetings were also held with relevant representatives from interested and proactive MHA authorities to discuss their experiences of climate change and the effects of extreme weather upon their highway network and assets. Additionally, local authorities discussed what (current and future) measures are in place/anticipated to build resilience to these impacts through adapting policies, strategies, specifications and operations. These face-to-face consultation sessions helped to facilitate both an enhanced understanding of, and physical access to, technical and operational documents, case studies and evidence that are not necessarily publically available. Consequently, the MHA authorities that were consulted with directly may appear to be over-represented within the report, as a result of the relative quantities of information made available.

However, to ensure all MHA authorities are fairly represented within this report as far as possible, a desk-based review of each authority's policies, standards and relevant activities was also undertaken to capture any publicly available evidence of climate change and extreme weather risks being experienced and taken into account during decision-making activities. Ways in which local authorities outside of the MHA has also been investigated to capture any other examples of replicable good practice and innovation.

1.2 Aim and Scope of the Project

The ultimate aim of this project is to ***develop an evidence base to promote a collaborative approach to building resilience of local highway networks to the impacts of climate change and extreme weather, which is nationally applicable and transferable and has the potential to be showcased as an example of good practice in the transport sector. It should be applicable to all MHA authorities and take into account differences in climate, geography, drivers and policies and standards***[7]***.***

This has been achieved through the identification, collation and synthesis of examples of how individual authorities are taking action to mitigate climate change impacts and increase their level of future resilience.

This report will build on the MHA's recognition of the strategic and operational importance of effective adaptation and collaboration, whilst ensuring adaptation can, wherever possible, be achieved in a 'business as usual' culture.

The report is structured as follows:

- **Section 2:** To create a baseline for the analysis of adaptation responses, a summary of climate change projections and past experiences of the extreme weather on the MHA highway network is provided.
- **Section 3:** An overview of the key statutory requirements facing local authorities in relation to the management and minimisation of climate change and extreme weather risks on local highway networks is provided. This includes examples of some of the responses and actions taken by MHA authorities and elsewhere in response to these requirements. Evidence of incorporating and embedding climate change into strategic-level and community-level policy and procedures is also provided.
- **Section 4:** A collation of innovative and best practice methods in which individual authorities have responded to climate change and extreme weather risks across a range of key service areas is provided.
- **Section 5:** Finally, conclusions are provided as to how taking action to adapt local authority highway networks to the impacts of future climate change and extreme weather events contributes to overall sustainability, and how community and stakeholder awareness regarding climate change and wider sustainability issues can be achieved.

[7] The original project scope included the development of a series of measurable actions, strategies and aspirations that MHA authorities can sign up to. However, individual meetings with MHA authorities led to the conclusion and agreement that this would not be possible due to the vast differences within the MHA and the complexity associated with developing something that would be meaningful, measurable and relevant to all MHA authorities.

2 CLIMATE CHANGE PROJECTIONS

2.1 UKCP09 projections for MHA region

2.1.1 Projections for changes to average climate conditions

UK Climate Projections 2009 (UKCP09)[8] have been reviewed as part of this study to identify projected change to the climate across the MHA geographical region. Although UKCP09 projections are based on a number of uncertainties and assumptions, they facilitate a sound judgment and understanding of the risks and opportunities associated with a changing climate and allow users to be well placed to make decisions about mitigating and adapting to the effects of climate change.

Table 1 presents key UKCP09 climate change projections for the MHA region, for two time periods; the 2020s (2010-2039) and the 2050s (2040-2069). The ranges shown are from the 10% probability level of the Low Emissions Scenario to the 90% probability level of the High Emissions Scenario (the widest possible range). The central estimate presents the 50% probability level (it is as likely to be experienced as not). The average baseline condition for 1961-1990 is included for comparison where data is available.

Table 1: Summary of UKCP09 climate change projections for the MHA region

Variable	Baseline conditions (average for the period 1961-90)	Summary of projections – showing the full range (Low Emissions Scenario, 10% probability level, to High Emissions Scenario (90% probability level)
Mean daily temperature (annual)	9.1℃	By the 2020s (2010-2039) the mean daily temperature (annual) will be between **9℃** and **12℃**. The central estimate is **11.2℃** By the 2050s (2040-2069) the mean daily temperature (annual) will be between **9℃** and **15℃**. The central estimate is **11.5℃**
Mean daily temperature (summer)	15.1℃	By the 2020s (2010-2039) the mean daily temperature (summer) will be between **15℃** and **18℃**. The central estimate is **16.5℃** By the 2050s (2040-2069) the mean daily temperature (summer) will be between **15℃** and **21℃**. The central estimate is **17.6℃**
Mean daily temperature (winter)	3.6℃	By the 2020s (2010-2039) the mean daily temperature (winter) will be between **3℃** and **6℃**. The central estimate is **4.9℃** By the 2050s (2030-2069) the mean daily temperature (winter) will be between **3℃** and **9℃**. The central estimate is **5.8℃**
Mean daily maximum temperature (summer)	19.9℃	By the 2020s (2010-2039) the mean daily maximum temperature in the summer will be between **18℃** and **24℃**. The central estimate is **21.7℃** By the 2050s (2040-2069) the mean daily maximum temperature in the summer will be between **18℃** and **27℃**. The central estimate is **23.3℃**
Mean daily minimum temperature (summer)	10.3℃	By the 2020s (2010-2039) the mean daily minimum temperature in the summer will be between **9℃** and **15℃**. The central estimate is **11.8℃** By the 2050s (2040-2069) the mean daily minimum temperature in the summer will be between **9℃** and **18℃**. The central estimate is **13.0℃**
Mean daily maximum temperature (winter)	6.7℃	By the 2020s (2010-2039) the mean daily maximum temperature in the winter will be between **6℃** and **9℃**. The central estimate is **8.1℃** By the 2050s (2040-2069) the mean daily maximum temperature in the winter will be between **6℃** and **12℃**. The central estimate is **8.9℃**

[8] http://ukclimateprojections.metoffice.gov.uk/

Variable	Baseline conditions (average for the period 1961-90)	Summary of projections – showing the full range (Low Emissions Scenario, 10% probability level, to High Emissions Scenario (90% probability level)
Mean daily minimum temperature (winter)	1.0℃	By the 2020s (2010-2039) the mean daily minimum temperature in the winter will be between **0℃** and **6℃**. The central estimate is **3.6℃** By the 2050s (2040-2069) the mean daily minimum temperature in the winter will be between **0℃** and **6℃**. The central estimate is **3.4℃**
Change in temperature on the warmest day (summer)	No baseline data available.	By the 2020s (2010-2039) the temperature on the warmest day in summer is unlikely to be more than **2.2℃** colder or more than **5.2℃** warmer than during the period 1961-90. The central estimate is an increase of **1.0℃** By the 2050s (2040-2069) the temperature on the warmest day in summer is unlikely to be more than **2.0℃** colder or more than **8.2℃** warmer than during the period 1961-90. The central estimate is an increase of **2.2℃**
Change in temperature on the warmest night (summer)	No baseline data available.	By the 2020s (2010-2039) the temperature on the warmest night in summer is unlikely to be more than **0.6℃** colder or more than **2.8℃** warmer than during the period 1961-90. The central estimate is an increase of **1.0℃** By the 2050s (2040-2069) the temperature on the warmest night in summer is unlikely to less than **0℃** warmer or more than **5.1℃** warmer than during the period 1961-90. The central estimate is an increase of **2.3℃**
Change in temperature on the coolest day in winter	No baseline data available.	By the 2020s (2010-2039) the temperature on the coolest day in winter is unlikely to be more than **0.2℃** colder or more than **3.0℃** warmer than during the period 1961-90. The central estimate is an increase of **1.4℃** By the 2050s (2040-2069) the temperature on the coolest day in winter is unlikely to be more than **0.2℃** colder or more than **4.4℃** warmer than during the period 1961-90. The central estimate is an increase of 1.7℃
Change in temperature on the coldest night in winter	No baseline data available.	By the 2020s (2010-2039) the temperature on the coldest night in winter is unlikely to be less than **0.4℃** warmer or more than **3.7℃** warmer than the period 1961-90. The central estimate is an increase of **1.8℃** By the 2050s (2040-2069) the temperature on the coldest night in winter is unlikely to be less than **0.8℃** warmer or more than **5.7℃** warmer than during the period 1961-90. The central estimate is an increase of **2.9℃**
Mean daily precipitation (annual)	1.65mm	By the 2020s (2010-2039) the mean daily precipitation (annual) will be between **0mm** and **4mm**. The central estimate is **1.65mm** By the 2050s (2040-2069) the mean daily precipitation (annual) will be between **0mm** and **4mm**. The central estimate is **1.65mm**
Mean daily precipitation (summer)	1.78mm	By the 2020s (2010-2039) the mean daily precipitation in the summer will be between **0mm** and **4mm**. The central estimate is **1.67mm** By the 2050s (2040-2069) the mean daily precipitation in the summer will be between **0mm** and **4mm.** The central estimate is **1.55mm**
Mean daily precipitation (winter)	1.62mm	By the 2020s (2010-2039) the mean daily precipitation in the winter will be between **0mm** and **4mm**. The central estimate is **1.70mm** By the 2050s (2040-2069) the mean daily precipitation in the winter will be between **0mm** and **4mm**. The central estimate is **1.85mm**
Change in precipitation on the wettest day (winter)	No baseline data available.	By the 2020s (2010-2039) precipitation on the wettest day in winter is unlikely to be more than **6%** less or more than **16%** more than during the period 1961-90. The central estimate is an increase of **5%** By the 2050s (2040-2069) precipitation on the wettest day in winter is unlikely to be more than **5%** less or more than **27%** more than during the period 1961-90. The central estimate is an increase of **9%**

2.1.2 Projections for changes to the frequency and severity of extreme weather events

In order to understand the likelihood and frequency of future extreme weather events, the UKCP09 Weather Generator (WG) has been used to develop probabilistic daily climate conditions for the 2020s and the 2050s time periods. The WG's Threshold Detector was also used to assess the likelihood of extreme weather events in the future, such as heatwaves and prolonged heavy rainfall. Table 2 shows outputs from the WG and TD for the 2020s and 2050s. Unless specified, counts are days per year.

Table 2: Probabilistic occurrence of climatic thresholds being exceeded[9]

	Baseline observed average for 1961-90	2020s (2010 – 2039)			2050s (2040 – 2069)		
		Low 10%	Medium 50%	High 90%	Low 10%	Medium 50%	High 90%
Heatwaves (2 days with max daily temp of >29°C and min daily temp of >15°C	0	0	1	5	0	1	8
Hot days (above 28°C)	0	1	4	15	1	7	22
Hot days (above 25°C)	4	4	12	38	7	22	59
Annual highest max temp (°C)	27.6	26.5	29.2	33.9	28.3	31.5	37.6
Dry spells (10+ days)	7	1	3	6	2	5	9
Dry spells (20+ days)	1	0	1	1	0	1	3
Number of days per year when precipitation is > 25mm per day	1.4	1.5	2.3	8.5	2.1	5.5	15.2
Number of days per year when precipitation is > 40mm per day	0.2	0.3	0.8	1.2	0.4	1	1.8

2.1.3 Sea level rise and storm surge

Sea level rise is projected to increase significantly at both the global and national scale unless significant reductions in carbon emissions are achieved. This is as a result of the thermal expansion of water and associated ice sheet and glacial melt.

Table 3 presents the Intergovernmental Panel on Climate Change (IPCC) projections for changes to mean UK sea levels, compared to mean levels for the 1980-1999 baseline period for the low, medium and high UKCP09 emissions scenarios[10].

For marine areas, the IPCC and UKCP09 provide projections for the 50 per cent probability level (central estimate) and for the 5 and 95 per cent probability levels (the widest range of potential changes) only. Therefore, the 95 per cent probability for the high emissions scenario demonstrates the likely 'worst case' scenario and the 5 per cent probability for the low emissions scenario represents the likely 'low regrets' minimum scenario.

[9] When using the UKCP09 WG and TD, the 5km grid square located over the city of Derby was selected as being a suitable proxy to represent the wider MHA region

[10]. http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

Table 3: Projections UK mean sea level rise for 2090-2099 compared to 1980-1999 baseline

Scenario	5% probability level (m)	50% probability level (m)	95% probability level (m)
Low	**0.12**	**0.30**	**0.48**
Medium	**0.13**	**0.37**	**0.61**
High	**0.15**	**0.46**	**0.76**

Table 3 demonstrates that sea level is expected to rise around the UK and therefore, coastal areas will be at a higher risk of flooding and inundation. Mean sea level rise projections are a useful indicator of the future situation. However, relative sea level rise projections provide a more realistic and accurate depiction of future risk. Relative sea level rise measures the change in the elevation of the ocean's water surface with respect to the level of the adjacent land. In addition, relative sea level rise takes into account changes in absolute sea level as well as changes to land-level, ocean circulations, the thermal expansion of ocean waters and geographical variations in water temperature and salinity. It also takes into account the impact of isostatic rebound[11].

Relative sea level rise is a greater concern in southern England than in the north of the UK. This is due to the fact that sea levels have been rising whilst the land mass has been sinking in the south. Relative sea level rise is shown in Figure 1.

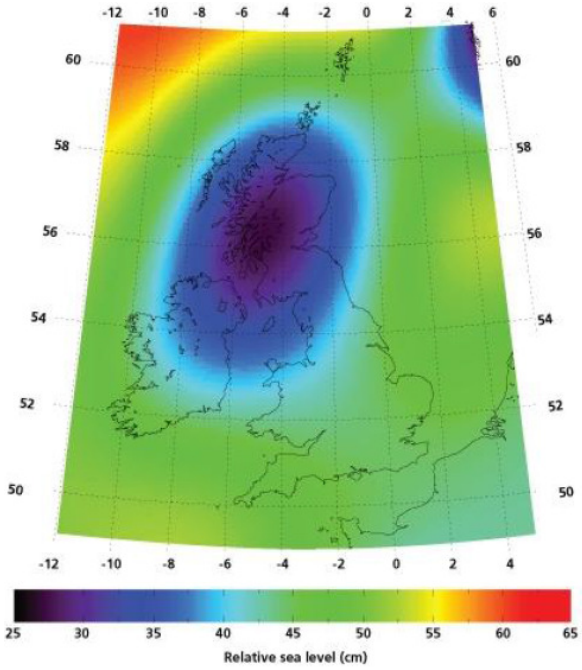


Figure 1: Projected relative sea level rise (cm) by 2095 under the UKCP09 medium emissions scenario

Climate change projections indicate that there will be no significant change to storm surge height around the UK (generally less than a couple of centimetres by the end of the century). However, storm surge should be considered along with projections for relative sea level rise as they have the largest impact at high tide. Such impacts will be exacerbated by a rising sea level.

[11] Isostatic rebound is the rise of land masses that were depressed by the weight of ice sheets during the last glacial period.

2.2 Climate Change Implications for the MHA's Highway Networks

The projected changes to the MHA region's climate are set to have impacts on local authority highway networks. Drier and hotter summers will lead to more incidents of pavement deterioration and subsidence. Wetter winters and more frequent heavy rainfall events are expected to result in more frequent incidences of flooding, particularly in low-lying areas and floodplains, and a higher risk of landslides. Consequently, this will have a significant impact on pavement performance and resilience, drainage capacity and condition, utilities and highways structures (such as bridges, culverts, road signs, street lighting etc.).

Sea level rise and greater storm surge heights will increase the probability of coastal erosion and flooding along coastal highways, which may result in substantial damage and, in certain cases, a partial loss of the road infrastructure.

Projections for more frequent and severe high winds may have safety implications and will have the potential to cause damage to highway structures and trees. Less frequent snowfall will reduce the need for gritting and snow and ice removal but will not necessarily reduce the need for the winter maintenance capacities. Instead, a more flexible, reactive approach to winter service provision is likely to be needed, backed by sufficient resources. Changes to the growing season as a result of warmer overall temperatures may lead to longer grass cutting seasons and 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.

Many MHA authorities have, in the recent past, participated in UKCIP's Local Climate Impact Profile initiative (LCLIP) to investigate their level of exposure to extreme weather **(Box 1).** Developing an LCLIP ultimately aids the identification of which extreme weather types have historically caused the most significant impacts on the local area.

Box 1: Local Climate Impact Profile Tool[12]

The LCLIP tool was developed for public bodies to help them analyse the impacts of past weather events using a range of evidence including media reports and interviews with stakeholders, staff and local communities. The LCLIP tool also provides detailed guidance on how to plan the investigation process, how to structure and conduct the research, who to contact and what information to acquire, and, finally, how to bring together all findings into an appropriate format, so it can generate and support adaptation strategies.

The tool is available online and is free to use.

LCLIPs developed by MHA authorities have typically found that, in recent years, flooding has led to the most significant and frequent weather-related disruption in the region. Snow and cold weather have also had significant impacts on the region's highway infrastructure. Coastal authorities have also experienced impacts associated with coastal erosion and sea level rise. High temperatures have been recorded across the MHA region, but to a much lesser frequency and severity than events relating to precipitation and cold weather events. The amount of documented evidence on the impacts of extreme weather events on highway networks has also become more frequent. For example, Doncaster's LCLIP demonstrates that the number of extreme weather impacts documented per year (on average) has more than doubled since 2006[13].

UKCIP's LCLIP tool and guidance can be used alongside or to compliment other tools which offer similar support for decision-making activities, such as the Severe Weather Impacts Monitoring System (SWIMS **(Box 2).**

[12] http://www.ukcip.org.uk/wizard/current-climate-vulnerability/lclip/
[13] https://www.doncaster.gov.uk/Images/Doncaster's_LCIP_CORPORATE37-88405.pdf

Box 2: The Severe Weather Impacts Monitoring System (SWIMS)[14]

The Severe Weather Impacts Monitoring System (SWIMS) is an online data collection tool enabling organisations to record how their services are affected by severe weather events. The primary goals of this data collection are:

- To analyse what/who is most vulnerable to severe weather;
- To identify the most vulnerable locations, and
- To evaluate the capacity of effected institutions to respond.

The SWIMS is an example of how effective data gathering can provide multiple benefits for local authorities, including:

- Building a clear and robust evidence base of the past weather events capturing impacts and associated costs; and identifying trends;
- Generating severe weather summary reports highlighting areas of best practices and common constraints for effective response;
- Providing a platform for different teams to share experience and to work in partnership to address vulnerability;
- Capturing costs helps to develop an effective business case for action and helps to access and efficiently distribute local and national funding; and
- Identifying pinch points where adverse weather conditions causes actual disruption (e.g. how much rain before a road floods).
-

The SWIMS was developed in 2012 by Kent County Council and now is being rolled out across the country with the support from Climate UK. It has already provided operational, resilience and financial benefits for Kent County Council. For example, having estimated £671,693 being spent for tree clearance, road closures, flood remediation equipment and emergency pothole repairs in 2014, Kent County Council Highway and Transportation (KCC H&T) reviewed its Operational Status Alert and embarked on the development of a Severe Weather Policy and an Emergency Response Dashboard (aimed to identify major strategic and locally important roads to prioritise the enquiries). Furthermore, by utilising recorded data KCC H&T has made a strategic decision to invest £10 million to prepare for and respond to severe weather impacts over the long-term (where £7 million have been acquired from the Department for Transportation and £3 million from KCC funds).

The SWIMS is available free-of-charge online and gives users a unique opportunity to make informed decisions in planning for the future climate. Any local authority or partnership can set up its own admin centre[15]. The SWIMS website also provides a user guide and video tutorial.

[14] http://www.kent.gov.uk/business/Business-and-the-environment/severe-weather-impacts-monitoring-system-swims
[15] Registration is available at https://webapps.kent.gov.uk/KCC.SWIMS.Web.Sites.Public/Unsecure/Register.aspx

3 STATUTORY REQUIREMENTS, GUIDANCE AND INFORMATION SOURCES

3.1 Flood and Water Management Act (2010)

The Flood and Water Management Act (FWMA)[16] places duties on upper tier/ unitary councils (known as Lead Local Flood Authorities (LLFAs)) for the coordination of local flood risk management in their administrative areas. The Act aims to strengthen and consolidate the UK's approach to flood risk management and coastal erosion and provides a framework within which a range of risks, including those from climate change, can be managed. The majority of MHA members are LLFAs. Subsequently, these authorities are required to fulfil the following requirements under the FWMA:

- Manage flood risks from surface water runoff, groundwater and ordinary watercourses through local work programmes;
- Forge partnerships and coordinate local flood risk management;
- Investigate flooding incidents; and
- Establish an asset register.

In addition, LLFAs are also required to undertake a series of tasks to fulfill the requirements of the Flood Risk Regulations 2009:

- Develop a Preliminary Flood Risk Assessment (PFRA) by December 2011;
- Production and publication of Flood and Hazard maps by December 2013; and,
- Production and publication of a Flood Risk Management Plan (FRMP) by December 2015.

A PFRA is considered to be a high-level screening exercise which determines areas of significant flood risk originating from local sources i.e. ordinary watercourses, surface water runoff and groundwater. It does not however consider flooding from Main Rivers. A FRMP considers flood risk from rivers, tidal sources surface water runoff, groundwater and reservoirs and details how Risk Management Authorities (RMAs) can work collaboratively to manage flood risks.

MHA Response to FWMA requirements

As LLFAs, MHA authorities have prepared Preliminary Flood Risk Assessments (PFRAs) for their regions, which include an assessment of previous flooding events and the identification of areas at-risk to future floods. The assessments and plans are presented in various formats. For instance, the Derbyshire Local Resilience Forum has released a local Contingency Flood Plan[17] that indicates major causes of flooding and areas prone to flooding in the county. The plan outlines a set of procedures that provide step-by-step guidance of how to respond to emergency flooding events. This includes procedures for traffic management during flood events. In addition the Contingency Flood Plan references the development of the Derbyshire's Local Flood Risk Management Strategy (LFRMS) (July 2015) which has the overarching aim of reducing flood risk to local communities and businesses whilst *'putting residents of Derbyshire at the heart of all decision making'.*

Along with publishing a PFRA, Doncaster Council has developed a flood event data recording system[18] that contains information on the locations of previous floods, their severity and consequences for the local economy and environment. Having this system in place helps Doncaster Council to more accurately predict the locations and potential impacts of future flooding events. In addition, priority areas for flood resilience and prevention works can be identified.

[16] http://www.legislation.gov.uk/ukpga/2010/29/contents
[17] http://www.derbyshireprepared.org.uk/files/uploads/Flood_Contingency_Plan_Jan_15_Public_Unrestricted_Version.pdf
[18] http://www.doncaster.gov.uk/services/transport-streets-parking/flood-risk-management

Leicester City Council has used hydrological and hydraulic modelling to develop a Surface Water Management Plan (SWMP)[19]. The models show areas at risk of fluvial flooding from ordinary watercourses and areas at risk of pluvial flooding across Leicester. The SWMP recognises flooding 'hotspots' and critical drainage catchments which may require more detailed assessment and modelling. Leicester City Council is dedicated to further developing the study by preparing a strategic risk assessment and flood alleviation programmes for areas identified as being at highest risk. Leicester City Council now also includes flood risk in their Community and Adaptation Risk Registers[20] (Figure 2).

Figure 2: An excerpt from Leicester City Council Adaptation Risk Register[21]

Adaptation Risk Register - List of potential risks to LCC services from future climate change

The Impact and Probability are scored between 1 and 3 (1 low risk 3 high risk). These are multiplied together to give a score between 1 - 9. This is then multiplied by the influence the council has over this risk (scored between 1 - 3, 3 highest influence, 1 little or no influence) to give the final overall risk rating.

Type	Risk? (Effect)	Who/ What's affected?	Result	Impact	Probability	Score	Influence 3, 2 or 1	Overall Risk
Flash Flooding Pluvial (Rain)	Lack of capacity in the storm/sewer and highway drainage system due to lack of maintenance and cleaning or inadequate size	R&C - Regeneration, Highways & Transportation - Highway Management, Transport Strategy, Transport Development (Drainage) Planning and Policy, Environmental Services - Parks and Green Space, Ecology & Riverside Team, Urban Design	System unable to cope with increased rainfall and speed of runoff leading to localised flooding	The impacts of this type of flooding will be severe but localised	There is an increasing probability of such events occurring as the frequency and intensity of extreme rainfall events increases and the sewer system reaches capacity and maintenance is reduced to a reactive basis by the water service companies	4	2 LCC has some responsibility working with the water service company (Severn Trent ST to maintain the sewerage system	8
	Road network flooding due to flash storm events	R&C - Regeneration, Highways & Transportation - Highway Management, Transport Strategy, Transport Development (Drainage) Planning and Policy, Environmental services - Parks and Green Space, Urban Design	1. Residents of Leicester unable to use road network 2. LCC employees unable to get to work 3. LCC employees unable to deliver key services due to disruption to transport network 4. Disruption to public transport 5. Emergency vehicles unable to reach victims of flooding	The impacts of the road network flooding will have more significant implications than that of flooding of the sewer network	The probability of the road network flooding will increase as the duration and intensity of localised rainfall events increases	6	3 LCC has total responsibility for maintenance and operation of the road network with exception of major trunk routes	18
	Damaged to road surface on major routes from flash flooding	R&C - Regeneration, Highways & Transportation - Highway Management, Transport Strategy, Transport Development (Drainage) Planning and Policy, Environmental services - Parks and Green Space, Urban Design	Roads need to be repaired after flash flooding causing major disruption to the road network and having significant financial implications	The impact of damage to road surfaces will be localised but with significant financial implications with much traffic disruption and road closures	The probability of such damage occurring will rise as the frequency and severity of rainfall events increase	4	3 LCC has total responsibility for maintenance and operation of the road network with exception of major trunk routes	12
	Damaged to road surface on minor routes from flash flooding	R&C - Regeneration, Highways & Transportation - Highway Management, Transport Strategy, Transport Development (Drainage) Planning and Policy, Environmental services - Parks and Green Space, Urban Design	Roads need to be repaired after flash flooding but with much less disruption	The impact of damage to road surfaces will be localised but with significant financial implications and road closures	The probability of such damage occurring will rise as the frequency and severity of rainfall events increase	2	3 LCC has total responsibility for maintenance and operation of the road network with exception of major trunk routes	6
	Risk of infection Residents/employees who's homes/workplaces have been flooded	R&C - Environmental Services, Licensing and pollution control (EHO's), Planning and Policy, Planning, Policy and Design, **Adults and Housing** - Community Care Services, Older People Service, **Resources** - Corporate Water Hygiene (James Seaton), Property **Children and Young People's Services,**	Workplace/homes unsuitable for occupancy until thorough clean up has taken place	The impacts will be very localised but with significant health implications for those affected	As flood risk increases so does the risk of infection from polluted floodwater	2	2 LCC has a responsibility to ensure that it's buildings are fit for purpose	4
	Floodwaters polluting clean drinking water		No access to clean drinking water	The impacts will be localised but significant for those affected	As flood risk increases so does the risk of contamination in drinking water from polluted floodwater	2	2 LCC has some responsibility to work with the water service company (ST) to ensure that residents have access to clean water	4

In order for MHA authorities to fulfill their duties as LLFAs, collaborative working is often required to achieve effective sharing of knowledge, resources, expertise and examples of best practice. Such collaborative working facilitates the holistic, sustainable and effective management of local flood risk across the region.
To create a coordinated and informed approach to the management of the flood risk, some MHA authorities have already formed such collaborative partnerships as illustrated by Derby City Council's and Nottinghamshire County Council's Flood Risk Assessment Partnerships shown in Table 4.

[19] http://www.leicester.gov.uk/media/178251/swmp-main-report.pdf
[20] http://www.northamptonshire.gov.uk/en/councilservices/fire/emergencies/pages/local-risks.aspx
[21] Example of Leicester City Council register available at https://www.leicester.gov.uk/your-environment/flooding-and-severe-weather/flood-risk-asset-register

Table 4: Derby City Council's and Nottinghamshire County Council's Flood Risk Assessment Partnerships

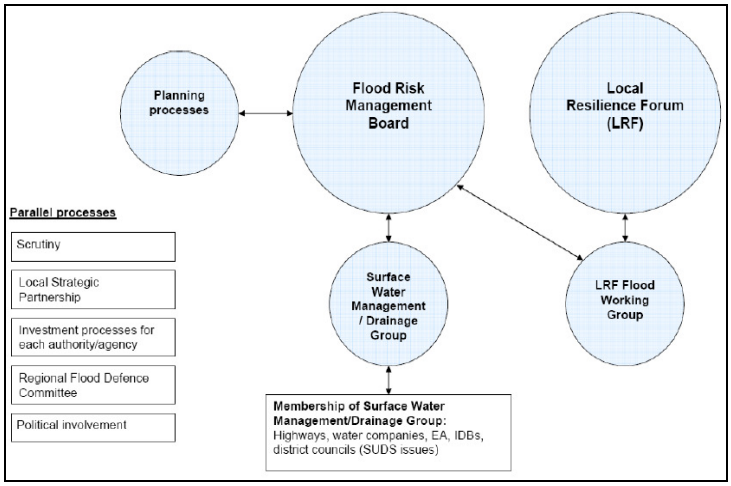
Derby City Council's Partnership Organisations	Nottinghamshire County Council's Partnership Organisations
• The Environment Agency • Severn Trent Water • Derbyshire County Council • Derbyshire Strategic Flood Board[22]	• District and Borough Councils • Drainage Boards • Water Companies • The Environment Agency • Highways England

To coordinate local flood risk management across Nottinghamshire (inclusive of surrounding areas to promote a catchment-based approach), and to ensure wider acceptance of proposed flood risk management actions, Nottingham City and Nottinghamshire County Councils have proposed the formation of a structured Flood Management Board (Figure 3a). A similar structure has been established by Leicestershire County Council under the Local Resilience Forum (Figure 3b) and has proved effective in coordinating three areas of flood risk management:

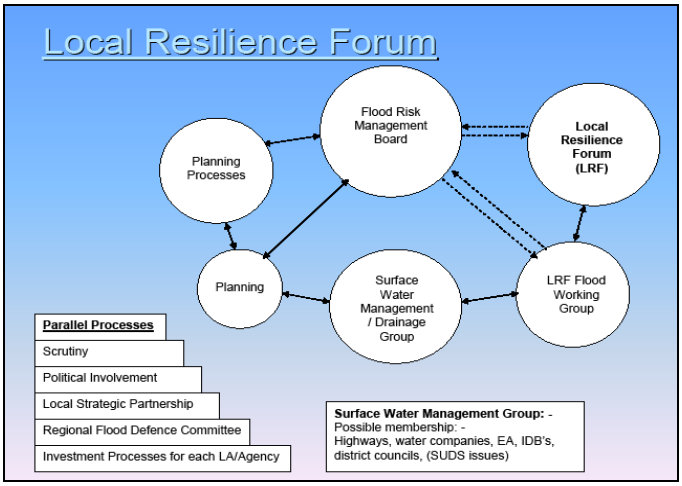
- Emergency response/warning and informing of flood risk;
- Management of surface water drainage assets; and,
- Planning.

Figure 3: Strategic Flood Management Board structure (proposed by Nottingham City and Nottinghamshire County Councils)[23] and Leicestershire County Council's Local Resilience Forum

a



b



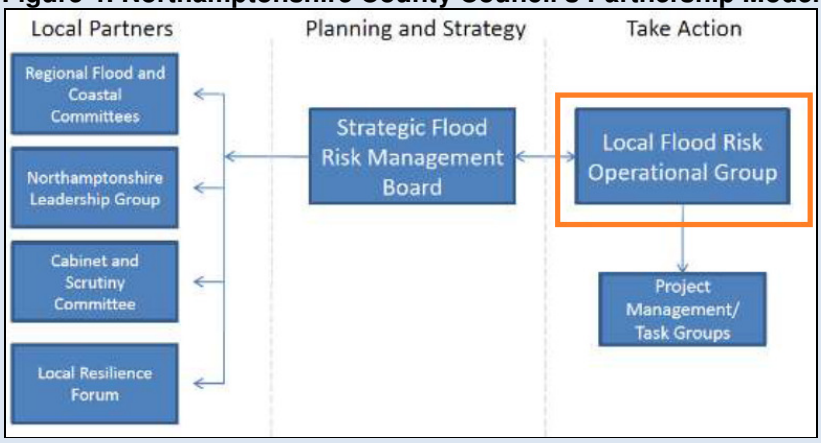
[22] The Board includes representatives of all district authorities within the county, the county flood managers and representative of Derbyshire County Council.
[23] http://www.nottinghamshire.gov.uk/enjoying/countryside/flooding/lead-local-flood-authority/pfra/

Northamptonshire County Council (NCC) has established a Local Flood Risk Operational Group (LFROG) to deliver their work programme as set out in their Local Flood Risk Management Strategy (LFRMS) (**Box 3).**

Box 3: Northamptonshire County Council's Local Flood Risk Operational Group (LFROG)[24]

To help deliver and fulfill its statutory responsibilities under the Flood and Water Management Act (FWMA), NCC has established the LFROG. This group sits within its wider Partnership Model to support local flood risk management delivery and to ensure partnerships are managed in ways which enhance the coordination of policy and actions; and provides strong accountability and transparency (Figure 4).

Figure 4: Northamptonshire County Council's Partnership Model



The LFROG's primary purpose is to ensure effective flood risk management and resilience is built into service delivery in a manner which delivers better protection from flood risk for communities and key infrastructure. Table 5 outlines the aims and members comprising the LFROG:

Table 5: LFROG membership and a list of the Partnership's aims

LFROG members	LFROG aims
• County Council officers; • All 7 District and Borough Councils; • The Environment Agency; • Highways England; • Anglian Water Services; • Northamptonshire Fire and Rescue; • North Northamptonshire Joint Planning Unit; • West Northamptonshire Joint Planning Unit; • The Bedford Group of Drainage Boards; • County Emergency Planning; and, • County Environmental Unit.	✓ To identify new funding opportunities and cost-effective methods of joint working; ✓ To share data, skills and best practices; ✓ To provide a unified voice on flood risk and drainage matters for national policy and funding matters; ✓ To ensure the general public and partner organisations are aware of their respective roles, responsibilities and that work programmes are aligned accordingly; ✓ To receive reports on and provide a strategic input and direction to develop plans, policies and programmes of work developed to manage flood risk in the county; and, ✓ To assist in reporting of flood management activity and programmes etc.

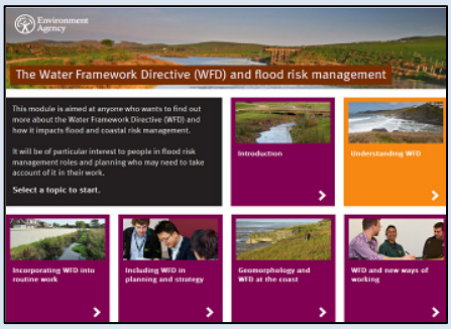
The LFROG provides a good example of a collaborative approach that enables all relevant stakeholders to be involved in flood management and prevention at an early operational stage and ensures proactive, informed investments and decisions are made.

[24] Northamptonshire Local Flood Risk Management Strategy (October 2013). Available at http://www.floodtoolkit.com/wp-content/uploads/2014/12/Northamptonshire-LFRMS-Report-October-2014.pdf?bcsi_scan_E956BCBE8ADBC89F=l7q2TcjulphreKmyGhd9ep6lpHbJAAAA6bOWGg==&bcsi_scan_filename=Northamptonshire-LFRMS-Report-October-2014.pdf

To support authorities in meeting their requirements under the FWMA, Defra, the Environment Agency and the Local Government Association have prepared Flood Risk Management e-learning modules **(Box 4).**

Box 4: Flood Risk Management e-learning support[25]

The Flood Risk Management e-learning portal is a joint effort from Defra, the Environment Agency and the Local Government Association. It has been designed and launched to help LLFAs develop an understanding of the key roles, responsibilities and relationships associated with the FWMA and Flood Risk Regulations 2009. The website outlines the context in which flood risk management decisions need to be made and, where appropriate, links to key guidance are provided. The portal also offers a diverse range of online learning opportunities and short courses, including:



- ✓ Basic Draining Engineering;
- ✓ Flood Risk Management;
- ✓ Climate Change;
- ✓ Guide to FCRM Community Engagement;
- ✓ Local Flood Strategies;
- ✓ Coastal Issues;
- ✓ Partnership Funding; and
- ✓ Property Level Protection.

The website is publicly and freely available at: http://learning.environment-agency.gov.uk/capacitybuilding/.

There are many sustainable flood risk management projects which have been completed or are currently underway by MHA authorities. An example of such a project, delivered by Derby City Council, is provided in **Box 5**. The 'Our City Our River' project represents a successful example of a sustainable flood risk management which aims to protect local communities whilst providing multiple wider benefits such as enhanced amenity and accessibility along the River Derwent.

Box 5: Derby City Council – 'Our City Our River' Project[26]

The 'Our City Our River' masterplan was developed by Derby City Council in collaboration with the Environment Agency to address future development in Derby's 'Blue Corridor' along the River Derwent. The masterplan outlines the areas which are vulnerable to flooding (Figure 5) and recommends appropriate mitigation measures. Along with safeguarding infrastructure, people and property, the masterplan aims to enhance accessibility and the amenity value of the River Derwent to local communities and to ensure the city remains an attractive place to live, visit and work.

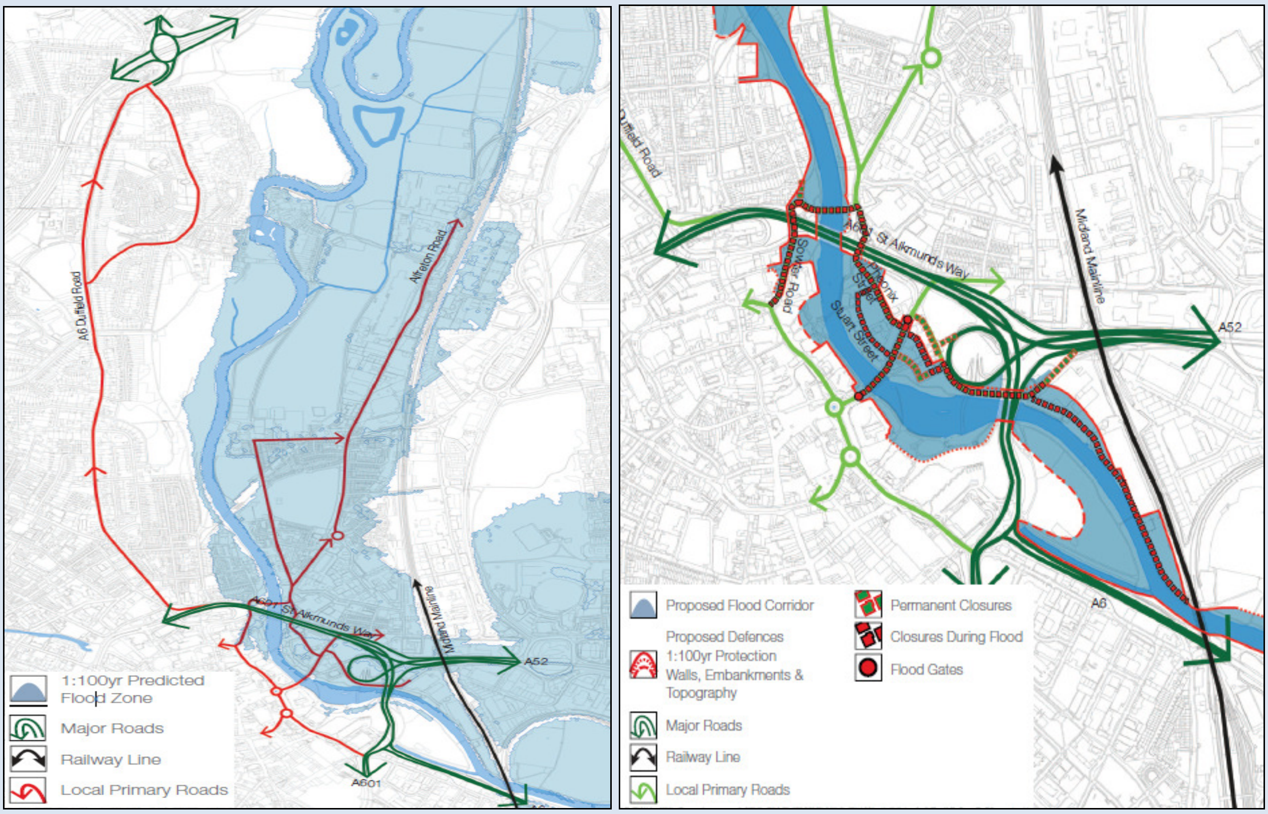
One of the objectives of the masterplan is to protect Derby's strategic highways and enable and ensure access for the emergency services during flooding events. Major opportunities for improvement, as identified by the project include:

- Alteration of the vehicular entry and exit slips at Darwin Place;
- Alteration to the entry and exit slip at Meadow Lane onto the A52;
- Alteration to access along Duke Street;
- Severance/realignment of the link from Darwin Place and Meadow Road;
- A realigned Exeter Street;
- Meadow Lane realignment; and,
- Buses to be re-routed at Meadow Road.

[25] Available at http://learning.environment-agency.gov.uk/capacitybuilding/
[26] Our City Our River Masterplan (Draft) 2012. Environmental Agency & Derby City Council

The proposed measures are expected to have a negligible negative impact on the availability, capacity and operation of the local highway network during construction. However, the longer term economic and environmental benefits associated with reducing flood risk and unlocking development in the city are predicted to outweigh any short term disruption. The proposals have been submitted and are awaiting approval (to be approved in Autumn 2015).[27]

Figure 5: Left-hand map: Existing Highways and Connections Affected by the Predicted Flood Zone; Right-hand map: Highway Closures in a Flood



As part of the Lincolnshire Resilience Forum[28], Lincolnshire County Council has developed a suite of resources to facilitate enhanced resilience to tidal flooding. The resources available include:

- A framework for the development of a personal flood plan;
- Information on how to sign up to receive flood warnings; and,
- Information on flooding mechanisms, local flooding hotspots etc. to enhance both education and awareness of local communities.

To facilitate the sustained, holistic management of flood and coastal erosion risk across the MHA network (as shown in the examples presented above), resources and partnership funding opportunities are essential. Examples of such funding opportunities are shown below in **Box 6**.

[27] Further details at http://www.ourcityourriver.co.uk/
[28] http://www.lincolnshire.gov.uk/lincolnshire-prepared/risks/were-prepared-for-coastal-flooding-are-you/117779.article

Box 6: Potential Flood and Coastal Erosion Risk Management (FCERM) income sources and partnership opportunities[29]

The majority of funding for flood and coastal erosion management in England is sourced and managed through grants from Defra to the Environment Agency. The Environment Agency maintains existing infrastructure relating to 'main rivers' and tidal defenses, invests in new and improved risk management infrastructure and administers a linked capital grant allocations procedure to local authorities and internal drainage boards (IDBs).

Local authorities can apply for a grant for capital investment from the Environment Agency to create new or improved river and coastal erosion management infrastructure, and to tackle groundwater and surface water flooding issues. The allocation from Defra is largely determined by the benefits that would be delivered as a result of a particular scheme, known as cost-benefit ratios.

Additional income can also be secured through the planning system, from contributions secured from major beneficiaries and through fees, charges and local taxation. Such local funding mechanisms could range from the use of existing local authority prudential borrowing and wellbeing powers, the business improvement district model and even increases in council tax precepts, where these are affordable and in the best interest of local communities. Other, new and alternative, funding sources for flood risk schemes are available from a range of organisations and beneficiaries, including:

- Section 106 agreements (s106), local tariffs, supplementary planning documents and the community infrastructure levy (CIL);
- Property level protection schemes such as those facilitated by Defra's Repair and Renew Grant[30];
- Local business rates including 'business rate supplements' and council taxes including specific precepts and 'special expenses', plus fees and charges, where appropriate and affordable; and
- Local activities that can achieve flooding and coastal erosion benefits as a secondary outcome to their primary purpose of securing community benefits and facilitating economic growth and sustainability.

3.2 The UK Climate Change Risk Assessment

The UK Climate Change Risk Assessment (CCRA)[31], introduced in 2012, is the first assessment of its kind for the UK. Over 700 potential impacts of climate change were identified as part of the assessment, 100 of which were take forward for more detailed analysis across eleven key sectors, one of which being Transport. The two risks identified for road infrastructure were:

- Roads at significant risk of flooding; and,
- Scouring of road and rail bridges.

The CCRA also recommended options for responding to, and mitigating, each identified risk. For the Transport sector, the key areas of opportunity were highlighted as:

- Embedding adaptation in policies and plans, including:
  - Local Flood Risk Management Strategies;
  - Local Plans; and

[29] Local Government Association: Special FCERM income sources. Available at http://www.local.gov.uk/paying-for-flood-and-coastal-erosion-risk/-/journal_content/56/10180/3600920/ARTICLE
[30] UK Government (2014) Repair and Renew Grant Scheme Opens Today. Available at: https://www.gov.uk/government/news/repair-and-renew-grant-scheme-opens-today
[31] Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69487/pb13698-climate-risk-assessment.pdf

  - Sustainable Drainage Systems (SuDS) Approval Bodies (SAB) (this element has now been withdrawn and will be addressed by the Planning System with LLFAs now taking on the Statutory Consultee role for major applications to ensure that SuDS measures are incorporated).
- Developing the evidence base to successfully embed climate change adaptation and resilience into plans and policies. Local authorities will need to build their understanding of what climate change means for their area in terms of exposure, vulnerability and adaptive capacity.
- Work with others to drive action at a local level. Local authorities need to raise awareness of their partners' roles in adaptation, and work collaboratively to support them in embedding climate change resilience as part of their work. This may be through formal mechanisms, such as Local Nature Partnerships or Local Resilience Forums.

Defra, the Environment Agency and ClimateUK provide support to local authorities on raising awareness, building capacity and making the case for action. However, local authorities must demonstrate their own leadership and commitment to adapting their services and networks.

The CCRA will be updated in 2017 to reflect legislative and policy updates, progress made by key sectors in regards to climate change adaptation and resilience, and the latest climate change projections.

MHA Response to CCRA Findings and Wider Adaptation Requirements

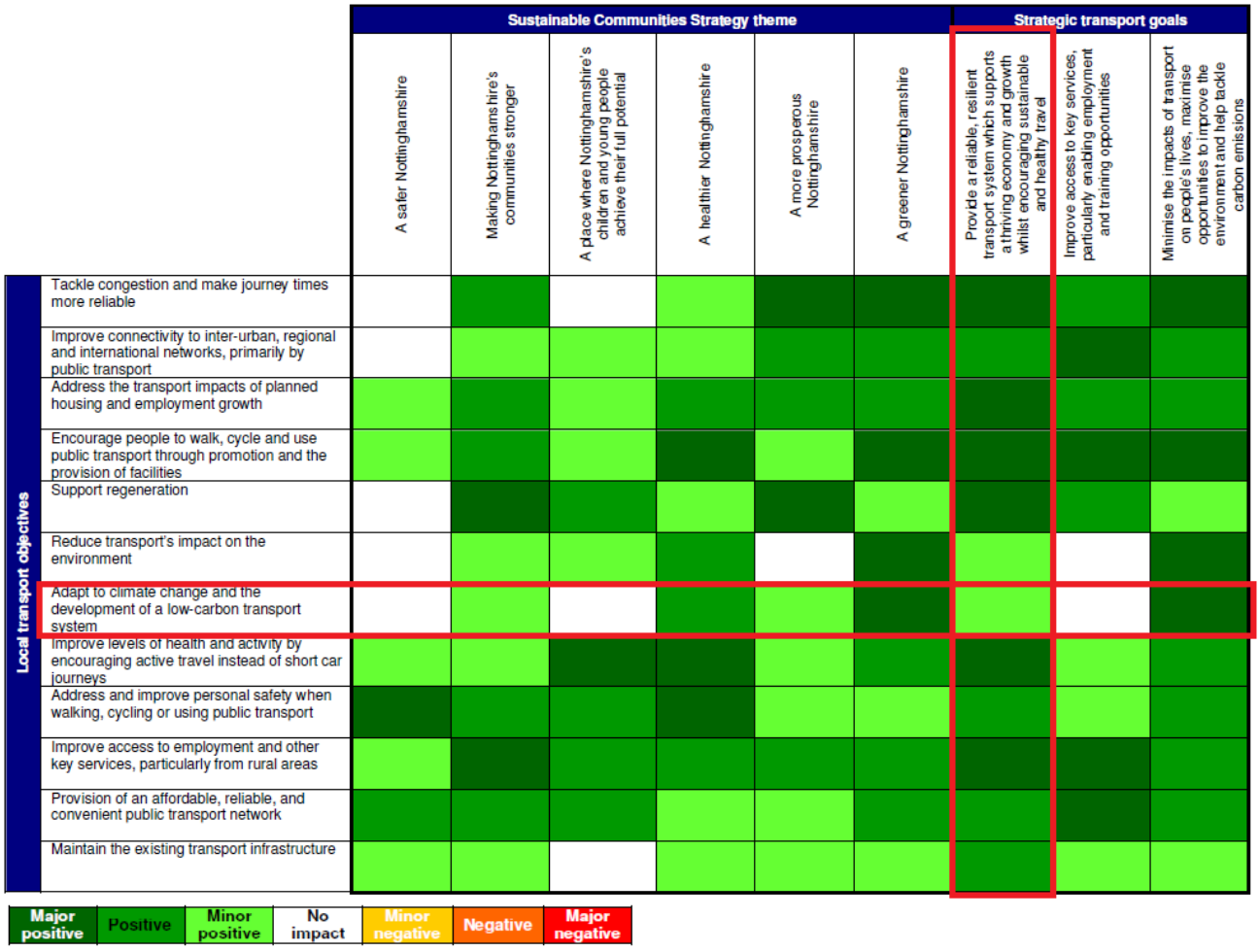
MHA authorities generally understand the risks and opportunities posed by climate change on their highway networks and acknowledge the advantages of embedding climate change adaptation and resilience into wider policies and strategies. Many Local Transport Plans (LTPs), and supporting strategies and policies, developed by MHA authorities include tackling climate change as one of their objectives. For example, three out of five Derby City Council's goals within their 2011-2026 LTP either directly or indirectly refer to the potential impacts and disruption caused by climate change and extreme weather:

- Goal 1: Support growth and competitiveness**, *by delivering a reliable and efficient transport network;***
- Goal 2: To ***contribute to tackling climate change*** by developing and promoting low-carbon travel choices*;* and,
- Goal 3: To contribute to better safety, security and health for all people in Derby ***by improving road safety, improving security on transport networks and promoting active travel.***[32]

Other MHA authorities have strategic transport goals linked to local sustainable community strategies; an example from Nottinghamshire County Council is shown in Figure 6. This illustrates the interconnections and interdependencies between the local transport network and local businesses and communities.

[32] http://www.derby.gov.uk/transport-and-streets/transport-policy/planning-transport-policy/

Figure 6: Nottinghamshire County Council's Local and Strategic Transport Goals in relation to its Sustainable Community Strategy themes



Generally, local authorities tend to combine climate change mitigation and adaptation measures within their LTPs. A review of MHA LTPs and implementation plans has highlighted a number of commonly proposed priority adaptation and mitigation measures to be delivered over the next 15 years, for example:

- Reducing greenhouse gas emissions through new technologies and cleaner fuels, energy efficiency measures, and encouraging 'smarter choices' of car sharing, using public transport, cycling and walking;
- Predicting and coping with the potential disruption of extreme weather events to the transport network;
- Continuing to raise awareness of the issue of climate change and promote what people, organisations and businesses can do to help;
- Assessing flood risk, and ensuring future transport infrastructure developments and maintenance interventions do not increase flood risk;
- Change-resilient design and maintenance strategies;
- Adaptation responses to bridges, structures and drainage;
- Carriageway surfacing adaptation responses;
- Maintenance of vegetation which has a longer growing season;
- Winter maintenance activities adaptation responses;

- Grass verges adaptation responses;
- Tree and hedge maintenance adaptation responses;
- Event management to reduce private car use;
- Improving the reliability and resilience of the national road network using a range of management measures;
- Focusing new development along key public transport corridors and in place adjacent to existing shops and services (to work closely with planning department);
- Developing public transport that connects people to jobs and training in both urban and rural areas;
- Ensuring the network is well-maintained;
- Encouraging active travel and develop high-quality cycling and walking network;
- Providing information and travel advice for the users of all modes of transport, so that they can make informed travel choices; and,
- Improving safety and the perception of safety on public transport.

These measures are typically delivered through Climate Change Adaptation Plans, Local Transport Implementation Plans, Strategic Flood Risk Assessments and Strategies, Winter Maintenance Plans and other relevant policies and procedures. Regularly reviewing and updating these policies and procedures to take account of new information and evidence regarding climate change and extreme weather risk is an important step when looking to effectively embed climate change adaptation into highway network planning, construction, operation and maintenance.

In this respect Derbyshire, Leicestershire and Nottinghamshire, through the 3 Counties Alliance Partnership (3CAP), commissioned a joint study in 2008 to identify the degree to which their highway network policies, plans and standards needed to be adapted to take account of projected climate change and an increase in the severity and frequency of extreme weather events. The study identified the key climate change risks facing their highway networks, examples of best practice, opportunities for innovation and collaboration and areas where there are opportunities for resilience and adaptation works to be strengthened. The main project deliverable was an Adaptation Action Plan, which was adopted by the three authorities and used to inform changes to maintenance and operational policies and standards (see **Box 7**).

Box 7: 3 Counties Alliance Partnership (3CAP) – Climate Change Adaptation Action Plan[33].

An Adaptation Action Plan was developed and adopted in 2009 as part of this project for 3CAP and includes proposed adaptation responses across seven key highway policy areas. The Adaptation Action Plan underwent an evaluation process to determine the progress made in relation to each action in 2011 and was updated in 2014 to reflect progress made by the three authorities, the availability of new evidence and changing priorities. The seven policy areas and associated adaptation response details are provided below in Table 6.

Table 6: 3CAP Climate Change Adaptation Action Plan

Policy/standard area	Adaptation response details
Bridges and other structures	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.
	Increase the number and frequency of maintenance works carried out to increase the Bridge Condition Index (BCI) values for bridges assessed as liable to risks from climate change. Ensure all strengthening and repair work that is outstanding for failed or below standard bridges is carried out.
	Carry out flood studies with the help of other agencies and organisations.
	Ensure all data (new and historical) is transferred into a single system to make assessments of maintenance and repair priorities and needs, more effective.
Drainage	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.
	Undertake a risk assessment to determine vulnerable areas and establish a prioritised scheme for maintenance.
Grass cutting	Increase the frequency of grass cutting and the length of the grass cutting season
	Treat grass with growth retardant and/or fertiliser to produce slower growing and/or better quality grass
	Carry out an inspection and inventory to assess which parts of the network are most at risk from excessive heat.
Materials	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.
	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.
	Ensure asset management plans take account of adaptations required for climate change in resurfacing programmes.
Resurfacing	Review new material and treatment choices and specify appropriate replacements.
	Use polymer modified binders that are less prone to stripping and other materials with a greater 'stiffness'.
	Increase verge maintenance and grass cutting frequencies to reduce the risk of 'root invasion' and vegetation ingress on the highway.
Tree and hedge Maintenance	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.
	Review the species choice for new trees to ensure the most appropriate species are selected.
Winter service	Carry out risk assessment surveys to establish which routes have the highest risk of ice formation.
	Re-assess and re-classify priority routes based on future climate change predictions.
	Review established resources for winter service provision and consider if changes need to be made.
	Provide a more flexible and responsive winter service.

33 http://www.leics.gov.uk/climate_change_adaptations.pdf?bcsi_scan_ab11caa0e2721250=0&bcsi_scan_filename=climate_change_adaptations.pdf

The 3CAP Adaptation Action Plan helped to inform and justify a number of changes to highway network policies and standards. For example, since publication of the Adaptation Action Plan in 2009, Leicestershire County Council has started using Coarse Visual Inspection (CVI) data to map areas of heat-induced surface deterioration on their highway network. In addition, Leicestershire County Council has begun to map damage caused by frost and ice against damage from excessive heat in order to identify any possible correlation. Furthermore, Leicestershire County Council has undertaken a risk assessment of their drainage assets to determine areas of their network most vulnerable to flooding. This has facilitated the identification of priority maintenance and investment requirements in Blackfordby, Syston and in Market Harborough.

Similarly, Derbyshire County Council has developed an online system to help monitor and manage their highway network assets. Data is accessible to staff in a mapped format and provides a comprehensive overview of current network and asset conditions along with information relating to both current and planned works. The system also enables priority areas for future works and maintenance programmes to be identified and targeted. There are opportunities for the future inclusion of climate change data and extreme weather event records and trends to be incorporated into this online system. This would enable risks to be fully accounted for in future network maintenance decisions.

3.3 Local Collaboration and Information Sources

MHA authorities recognise the need to work in partnership with other local departments, businesses, organisations and communities in order to identify, prepare for and respond to the impacts of climate change and extreme weather. A collaborative approach and continuous engagement with these stakeholders will help to ensure effective and targeted action is achieved and that all relevant parties are involved at an early stage in the decision-making process.

An example of effective collaboration is the 'Derbyshire Climate Change Charter (2014-2019)'[34], which was developed by Derbyshire County Council and the Derbyshire Partnership Forum[35] as a publicly accessible resource for climate change information. Its aim is to facilitate the development of collective adaptation/mitigation measures across different sectors, including transportation. Development of the Charter is an ongoing process with the ultimate aim of facilitating a long-term approach to tackling future climatic changes through commitment of the members and the prioritisation of actions.

In addition to the Climate Change Charter, the Derbyshire Local Resilience Forum has developed 'Derbyshire Prepared'[36], a website that provides information and advice on how residents, local businesses and communities can be better prepared for extreme events and emergencies, and how to effectively recover from them. Along with more general safety advice, the online platform contains a wide range of specialist guidance and recommendations for how to prepare and react to extreme weather events. 'Derbyshire Prepared' also directs users to relevant sources of external information (e.g. the Met Office website, emergency services contact details and guidance, and Climate East Midlands[37]).

The 'Derbyshire Prepared' website has a particular focus on flood risk management. Users are encouraged to sign up to a flood alert system and to prepare a flood plan for their home or business. Guidance and templates for this are provided. A leaflet to increase flood risk awareness has also been prepared and distributed to local residents by the Local Resilience Forum. A Community Risk Register is also available on the website. Derbyshire Emergency Volunteers are recruited through the initiative and these volunteers are trained to help residents who have to be evacuated from their homes following an incident or emergency.

[34] http://www.derbyshire.gov.uk/images/Climate%20Change%20Charter%20final_tcm44-252695.pdf?bcsi_scan_AB11CAA0E2721250=0&bcsi_scan_filename=Climate%20Change%20Charter%20final_tcm44-252695.pdf
[35] The Derbyshire Partnership Forum (DPF) is the countywide local strategic partnership, and was established in 2000. The DPF brings together over 60 public, private, voluntary and community sector organisations who work together to improve the quality of life for the people of Derbyshire.
[36] http://www.derbyshireprepared.org.uk/
[37] http://www.climate-em.org.uk/

Similar initiatives have been undertaken by other MHA authorities, for instance:

- Leicester, Leicestershire & Rutland Prepared (LLR prepared) – the official website for the Leicester, Leicestershire and Rutland Local Resilience Forum (http://www.localresilienceforum.org.uk/); and,
- Nottinghamshire Prepared – the official website for the Nottingham and Nottinghamshire Local Resilience Forum (http://www.nottinghamcity.gov.uk/prepared/index.aspx?articleid=6529).

Northamptonshire County Council has been successful in securing funding to more effectively and formally engage and work with local communities to increase resilience to the impacts of flooding through the Defra Community Resilience Pathfinder Project (see **Box 8**).

Box 8: Pathfinder Project

In 2013 Northamptonshire County Council, along with thirteen other local authorities, was selected by Defra to receive funding for a national community flood resilience initiative – the 'Pathfinder' project[38]. This project evolved from the devolution from national flood risk management to a more localised and community level, subsequently empowering communities to take steps to protect their homes, work places, businesses and other community assets.

Northamptonshire County Council's ultimate aim of this two year project was to support 15 communities in improving their resilience to flooding. To date, funding from Defra has been used to:

- Undertake flood awareness raising and community engagement activities;
- Develop and distribute flooding educational packs to schools within the county;
- Conduct local ground surveys to identify locations particularly at risk from flooding;
- Recruit, educate and train Community Emergency Wardens;
- Establish and maintain Flood Stores;
- Create Community and Emergency Flood Plans;
- Establish and run the 'Don't be a numpty' campaign (see below);
- Set up surface water Rain Gauge alerts across the 15 communities county; and,
- Develop and launch the 'Flood Toolkit' website (see below).

Flood Toolkit

Under the Pathfinder project, Northamptonshire County Council has developed an online Flood Toolkit[39]. This website had been designed to act as a central resource for all county-level flood risk information and to be used by communities, individuals, businesses and other authorities and agencies. Its ultimate aim is to ensure the county is better prepared for and able to mitigate flood risk. The Flood Toolkit website contains live flood risk maps, practical advice on how to prepare homes, businesses and communities from flooding and the measures to take should a flood event occur.

The 'Homeowners Guide to Flood Resilience'[40] is available on the Flood Toolkit Website. This provides valuable information on the following:

- How to assess the risks to a home from flooding;
- How to obtain affordable insurance;
- How to find out if a home is at risk of flooding (based on local flooding maps);
- How to choose an appropriate level of flood protection;
- How and where to obtain help when flooding occurs;

[38] https://www.gov.uk/government/publications/flood-resilience-community-pathfinder-scheme-prospectus
[39] http://www.floodtoolkit.com/
[40] https://www.floodtoolkit.com/wp-content/uploads/2015/02/FloodGuide_ForHomeowners.pdf or http://www.knowyourfloodrisk.co.uk/

- How to establish temporary and permanent resilience to flooding events; and,
- What flood protection products and suppliers (property-level protection and community solutions) are available to purchase.

A number of case studies are also included on the website to illustrate the range of potential approaches to effective flood protection.

A 'Flood Advice for Businesses' booklet has also been developed and provides step-by-step guidance for local businesses on undertaking flood vulnerability assessments. It includes links to the relevant external sources of information. A funding toolkit supported by a 'Funding for Flood Alleviation'[41] document is available, which outlines funding opportunities available to a community for managing flood risk.

Planners and developers are encouraged to use the Flood Toolkit to obtain updates on flood risk across the county and to understand local and national flood and water management legislation.

'Don't be a numpty' initiative[42]

Under the wider Pathfinder Project, Northamptonshire County Council has also designed and launched the *'Don't be a numpty'* campaign, which provides emergency prevention advice for different types of emergencies in an interactive way. The online videos prepared as an integral part of the project provide a good illustration of potential threats of flooding, fire, road incidents etc. and have been developed in a way that is easy to access and understand.

Various MHA authorities engage with and involve farmers when preparing for and responding to extreme weather events. In Nottinghamshire, for example, local farmers assist with snow clearance on pre-arranged and agreed routes, and get paid a fee to do so. Nottinghamshire Parish Councils have also locally appointed Snow Wardens, who are trained and provided with equipment to organise and manage snow clearance activities within their communities. These Snow Wardens act as local point of contact for providing up-to-date information on local conditions to the Nottinghamshire County Council. A similar initiative has been introduced by Derbyshire County Council, where Town and Parish Councils have engaged with their wider communities to sign up to a local 'Snow Warden Scheme' and help clear snow and ice from pavements and footpaths. These Town and Parish Councils also update local communities about driving conditions on the county's roads[43].

Leicestershire County Council has created a network of over 100 specially-trained Community Flood Wardens. These wardens help ensure communities receive flood warnings, help them to prepare for floods, identify vulnerable people, and report blocked drains and ditches to the council[44].

Elsewhere in the UK, following a series of extreme rainfall events in 2008, Devon County Council has taken steps to develop a community approach to increasing flood resilience across the county **(Box 9).**

[41] Available at http://www.floodtoolkit.com/pdfs/7%20Funding%20Flood%20Alleviation/7.Funding-flood-alleviation.pdf
[42] Available at http://www.northamptonshire.gov.uk/en/councilservices/fire/emergencies/emergency-prevention/pages/default.aspx
[43] More details at https://www.derbyshire.gov.uk/transport_roads/roads_traffic/road_maintenance/snow_info/tackling_snow/winter_service/default.asp?VD=snowwardens
[44] Tackling Flood Risk in Leicestershire, Case Study. Climate East Midlands

Box 9: Devon County Council Community Resilience[45]

Intense rainfall (177mm over 3 hours) occurred in Devon in 2008 and resulted in severe flooding which impacted local communities and affected 350 properties in rural areas. This demonstrated a need to reduce and manage the risks of flooding and led to a partnership project to increase flood resilience in East Devon – 'The East Devon Flood Recovery Group'. This group was created by Devon County Council and East Devon District Council with the aims of:

- Assisting local people with recovery after a flood;
- Reviewing lessons learnt; and,
- Developing cost-effective solutions to minimise the risk of future flood events.

In response to the 2008 flooding, the Environment Agency assisted with clearing blockages from storm pipes, replaced damaged drains, and conducted surveys of key drainage systems and local fields. The results showed that 60% of the fields surveyed comprised of compacted, impermeable soil, which led to increased levels of surface run-off and flash flooding risk.

To mitigate these risks, Devon County Council and the Environment Agency have been working with the local community to implement solutions to prevent future flooding. The solutions include 270 acres of farmland being treated with a 'Sub-Soiler' machine to break up compacted soil to facilitate better drainage. Additionally, funding has been established (£35,000) to help and encourage local people to purchase items, such as portable flood barriers, to protect their homes from future flooding.

Through combining technical expertise and local knowledge, cost-effective solutions have been identified to improve local resilience and to reduce the frequency and implications of future flooding events.

Online tools and maps are available to help local authorities prepare for and deliver effective responses to a changing climate. The publicly and freely available 'Climate Just' portal **(Box 10)** and the Eco Cities Spatial Portal **(Box 11)** are two good examples of online tools that can be used to map vulnerability to climate change at a local/ neighborhood scale.

Box 10: Climate Just

Climate Just[46] is an online portal that has been developed to provide evidence to support local action on adapting to climate change. The portal:

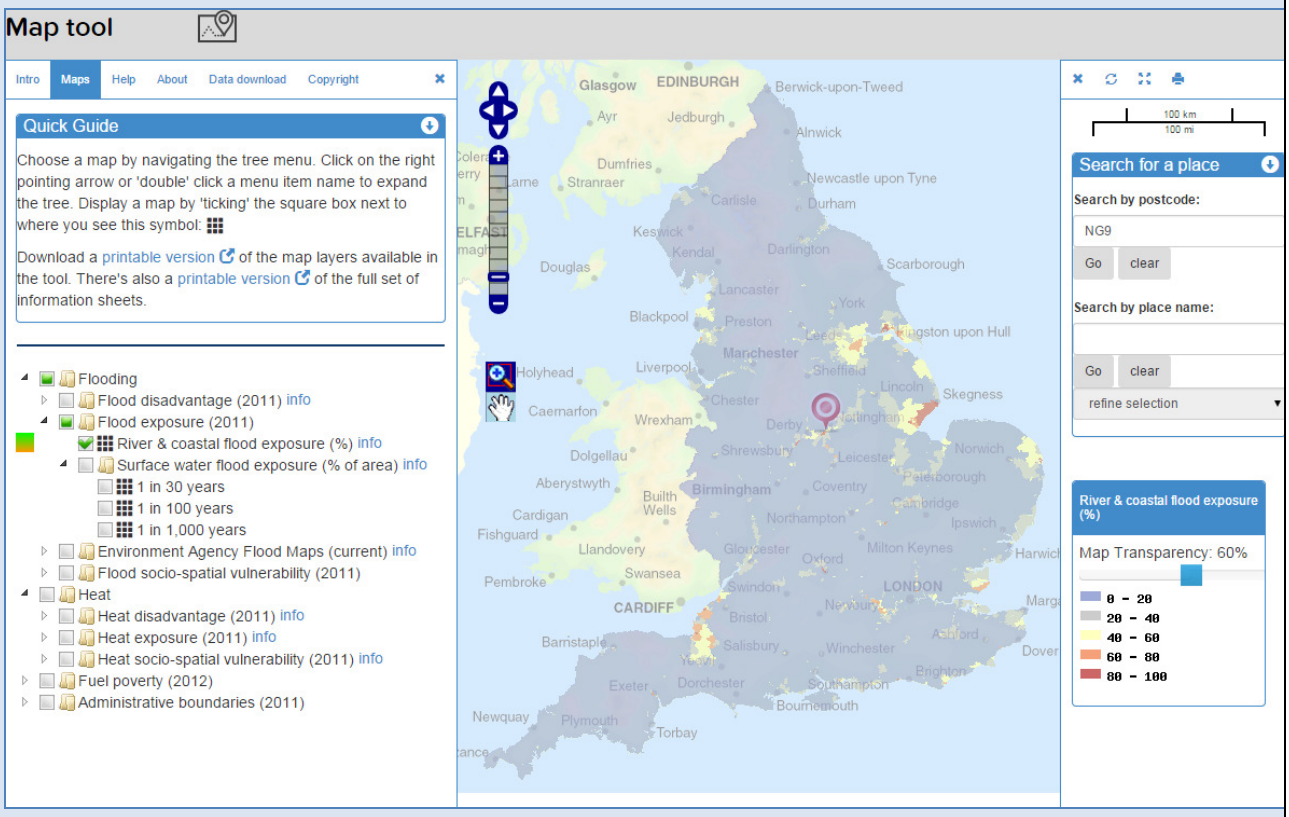
- Highlights which people and places are likely to be most vulnerable to the impacts of extreme weather, including flooding and extreme heat, and the areas which might be most affected;
- Examines fuel poverty and inequalities in energy policy and how these can be tackled locally;
- Provides maps to identify the issues in local areas; and,
- Provides guidance, case studies and resources on actions that can be taken to help build local resilience.

Interactive maps (an example of which is shown below) are also available on the website and presents vulnerability levels at a neighborhood scale, taking into account issues such as:

- Flood exposure (different types of floods are considered);
- Heat exposure;
- Social-spatial vulnerability;
- Administrative boundaries; and,
- Levels of fuel poverty.

[45] http://www.ukcip.org.uk/low-cost-measures-increase-resilience-to-flooding-in-a-rural-area/
[46] http://www.climatejust.org.uk/

Figure 7: Climate Just Map Tool (example output)[47]



Local authorities can use this mapping tool to identify the current and future level of exposure of their highway networks and assets to flooding and heat risks. The extent to which the communities and stakeholders that use their networks are vulnerable to these impacts can also be determined.

The Climate Just website also provides case studies to showcase effective ways of reducing climate risk and vulnerability.

Box 11. The Eco Cities Spatial Portal – applicable for Greater Manchester

The Eco Cities online tool[48] provides information on how to improve education and enhance understanding on the issues relating to climate change vulnerability. The tool covers various service areas, including roads which might be impacted by various weather hazards (such as flooding and heatwaves).

The Eco Cities portal makes it possible to visualise UKCP09 weather projections by super-imposing them on highway network maps to identify potentially critical road infrastructure. Although only currently applicable to Greater Manchester, the tool offers a good replicable example of how climate change risks can effectively be mapped and understood at a spatial level.

Guidance is also available for managing climate risk through the planning process and through effectively engaging with planning partners and communities (see **Box 12**).

[47] http://www.climatejust.org.uk/map
[48] http://www.ppgis.manchester.ac.uk/ecocities/

Box 12: Climate change adaptation frameworks, tools and guidance - Adaptation Scotland '5 Steps to Managing Climate Risk[49]

Adaptation Scotland, in collaboration with public bodies from across Scotland, has developed "Five Steps" of guidance for managing climate risks. The guidance takes into account legislative changes and builds on recent adaptation planning successes in Scotland. This was developed, in part, to help public bodies respond to and meet the requirements of the Climate Change (Scotland) Act 2009.

The guidance can be used as a basis to identify cost-saving actions, for example, by working with communities and community planning partners to build resilience.

Adaptation Scotland provide a range of free-to-download tools on their website (http://www.adaptationscotland.org.uk/5/170/0/Five-steps-to-managing-your-climate-risks.aspx) including:

- A screening questionnaire;
- A weather impacts table;
- A climate impact assessment; and,
- A climate risk matrix.

[49] http://www.adaptationscotland.org.uk/Upload/Documents/v6SNIFPublicSectorGuidelines.pdf.

4 OPERATIONAL RESPONSES TO CLIMATE CHANGE

4.1 Maintenance and Design of Drainage Assets and Networks

Climate change and an increase in the frequency and severity of extreme precipitation events in particular, can put pressure on the drainage capacity of the local highway network's drainage assets and systems (such as gullies and culverts). Consequently, many local authorities have already initiated drainage capacity and condition surveys with the intention of using the information gathered through this exercise to inform the development of prioritised inspection and maintenance regimes.

For example, Leicestershire County Council has carried out Yotta surveys to gather information on the location and condition of most of their gullies and utilise this information to inform and establish prioritised gully maintenance programmes. In addition, Leicestershire County Council is now undertaking site investigations with respect to developing an asset database of structures at risk from the effects of flooding. Similar work has been undertaken by Leicester City Council **(Box 13).**

Box 13: Leicester City Council – Using asset data to address flood risk[50]

In developing Leicester's Surface Water Management Plan, pluvial modeling identified areas of significant flood risk across the city. By using accurate gully location and sewer network data, Leicester City Council has modelled system performance under various flooding scenarios. This has demonstrated that a well-designed and well-maintained highway drainage system can help to reduce surface water flood risk.

The modelling has shown that flood risk increases significantly if the drainage system is either poorly maintained or has insufficient capacity. An additional benefit from this modelling has been the identification of key components of the local water company's sewer network that *must* operate at a satisfactory level for the highway drainage system to remove the required volume of surface water.

Leicester City Council works with the local water company to ensure identified at-risk assets are highlighted in their records and maintained appropriately.

A similar approach of using asset data to address flood risk is being applied by Nottinghamshire County Council where continuous asset management and location reviews and drainage surveys are being carried out to improve the knowledge of the location and condition of their drainage assets. Derbyshire County Council have also awarded a three-year contract to cleanse and carry out CCTV condition surveys of their highway culverts and to record the collected data in a GIS database. As a consequence of these works, Derbyshire County Council hopes to better understand the condition of their drainage assets and to be able to establish an effective and targeted inspection and maintenance programme.

An innovative, flexible and accessible approach to help road authorities identify areas of flooding risk across the highway network is being developed by the European Road Administrations (ERA) as part of an ERA-NET ROAD transnational research programme called *'Road Owners Getting to Grips with Climate Change*[51]*.* This approach will enable road authorities to focus on vulnerable locations and identify where action should be taken to reduce flood vulnerability. The project indicates that inadequate maintenance is the primary cause of highway drainage problems (rather than failure associated with the original design) and subsequently provides guidance on how to promote and ensure effective maintenance **(Box 14).**

[50] http://www.highwaysefficiency.org.uk/efficiency-resources/asset-management/guidance-on-the-management-of-highways-drainage-assets.html
[51] http://trid.trb.org/view.aspx?id=1149180

Box 14. SWAMP – Storm Water Prevention, Methods to Predict Damage from the Water Stream in and near Road Pavements in Lowland Areas[52]

The SWAMP project targets the critical issue of finding the most vulnerable parts of the road network, using GIS as a basis, and provides guidance on how to prepare highway networks for flooding by applying modelling methodologies and targeted field inspections. The 'Blue Spot Concept' (or the concept of finding locations vulnerable to flooding) is proposed as a method for use by highway network owners and operators to systematically analyse, adapt and protect the network with respect to flood risks.

The outputs of the SWAMP project also include:

- Adaptation guidance for engineers in charge of inspection, maintenance and repair;
- Flood reduction information for decision makers responsible for renewal of the drainage system; and,
- Practical suggestions on how to prepare a road network before, during and after a heavy rain event.

As aforementioned in Section 3, most local authorities are working towards meeting the requirements placed on them by the FWMA. MHA authorities generally recognise the benefits provided by Sustainable Drainage Systems (SuDS) and work to promote them locally. SuDS are seen as an effective way of managing rainfall in a built environment by replicating natural drainage systems and principals. The delivery of SuDS schemes can provide multiple benefits inclusive of socio-economic and environmental advantages to local areas.

In December 2014, the Government issued a written statement outlining the strengthening of existing planning policy in relation to SuDS with the clear stipulation that the UK Government expects SuDS to be provided in new developments. In addition, where planning applications constitute major development, a Local Planning Authority (LPA) must ensure SuDS are included within development plans unless it can be demonstrated that they would be inappropriate[53].

Consequently an LPA will have to determine whether all major planning applications are in accordance with national standards i.e. Defra's Non-Statutory technical standards for SuDS and local policy. From 6 April 2015, the LPA (upon assessing applications) must be sure that:

- Any proposal meets national and local policies;
- The proposed minimum standards of operation are appropriate;
- The minimum standard is set out to which the SuDS must be maintained; and,
- Through the use of planning conditions or planning obligations there are clear arrangements in place for ongoing maintenance over the lifetime of the development, including clearly identifying who will be responsible for maintaining SuDS and that funding for maintenance is fair for householders and premises occupiers.

Local authorities should consult the Construction Industry Research and Information Association (CIRIA) SuDS manual (C697)[54] for good practice guidance.

An example of a local authority acknowledging the importance of SuDS measures and actively promoting them within their administrative area is Peterborough City Council, through their online initiative 'Peterborough SuDS'[55]. This provides a comprehensive overview of how to choose appropriate SuDs measures according to locality and requirements, the benefits sought and the regulatory requirements.

[52] http://www.eranetroad.org/index.php?option=com_docman&task=cat_view&gid=91&Itemid=53
[53] http://www.susdrain.org/delivering-suds/using-suds/legislation-and-regulation/national-standards-for-sustainable-drainage.html
[54] http://www.ciria.org/Resources/Free_publications/the_suds_manual.aspx
[55] http://www.peterborough-suds.org/

Peterborough City Council uses the online portal to provide detailed information for different categories of users, including homeowners and developers **(Box 15).**

Box 15: Peterborough City Council SuDS[56]

Peterborough City Council acknowledges the multiple benefits offered by SuDS and has developed an online platform to inform, educate and promote the use of SuDS amongst homeowners, developers and other stakeholders which may be involved and/or interested in surface water management.

The 'Peterborough SuDS' website includes;

- Up-to-date information on planning legislation, restrictions and requirements associated with SuDS for homeowners and developers;
- Examples of SuDS applications with details on the of benefits they provide;
- SuDS planning pre-application advice and guidance during the planning stage; and,
- Links to a number of SuDS case studies and relevant informational sources.

A number of additional functionalities and information sources are expected to be added to the website in the near future.

SusDrain is another online platform that provides useful advice, guidance and case studies on SuDS being used across the UK[57]. It is developed and maintained by CIRIA. In particular the SusDrain website provides a number of useful, interesting and replicable case studies on where SuDS measures have been implemented effectively. A selection of case studies from the SusDrain website, and elsewhere, are summarised in **Boxes 16 to 20**.

Box 16: Permeable Paving in Park Lane, Peterborough

Park Lane was identified by Peterborough City Council as having an appropriate ground profile to construct permeable paving to an adoptable standard (S38). Site investigation revealed made ground from approximately 0.2-0.8m comprising brown clay and sand. The underlying natural soils comprise variable soft to stiff grey, brown and orange mottled clay.

The housing estate road was constructed in permeable block paving with a perforated pipe running the length of the road. Flow from the system discharges via a 43mm orifice plate to a surface water system, which limits the discharge rate for the site to 3.5 l/s for the 1 in 100 year storm plus 30% allowance for climate change.

All driveways have also been constructed in permeable block paving with the sub-base linked to the estate road sub-base. All roof water runoff from dwellings discharge into the driveway sub-base via a perforated diffuser pipe. Figure 8 shows a schematic of the permeable paving system used, Figure 9 shows the permeable paving system being constructed.

[56] Available at http://www.peterborough-suds.org/
[57] Available at http://www.susdrain.org/

Figure 8: Schematics of permeable paving approach in Park Lane, Peterborough

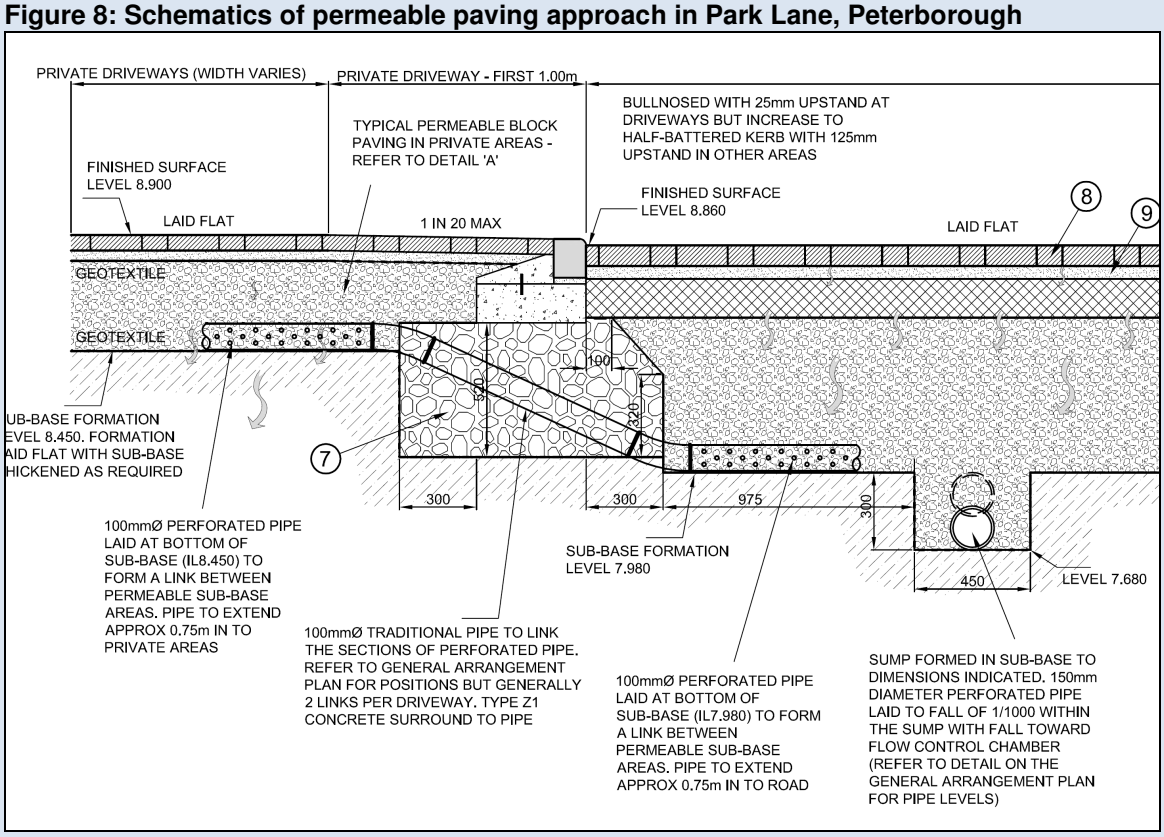


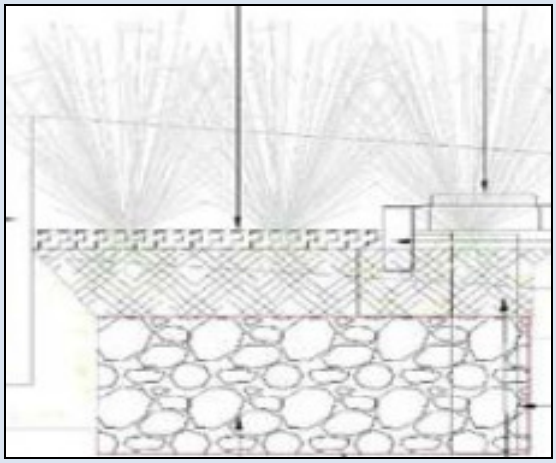
Figure 9: Permeable paving construction stages

Box 17: Retrofit Rain Garden Project in Ribblesdale Road, Nottingham[58]

A pilot 'rain garden' retrofit project was implemented in a quiet residential road (67 properties) in Nottingham through a collaborative effort between the Environment Agency, Nottingham City Council, Groundwork Greater Nottingham and Severn Trent Water. A total of 21 linear rain gardens (148m^2) were constructed within the grass verge. The rain gardens utilise a combination of clean stone aggregate and propriety units to create a void space beneath a planted topsoil layer (Figure 10). They are designed to capture runoff from 5500m^2 of highway, manage surface water runoff from a 1:30 year Annual Exceedance Probability (AEP) event and to always intercept and treat the first flush of highway runoff. Existing highway gullies have been retained to allow for overflow when the rain gardens reach capacity.

Figure 10: a) Schematics of rain garden; b) Rain garden in Ribblesdale Road, Nottingham

a



b

There are two different rain garden designs presented in the setting (usage of proprietary water attenuation cells vs. stones), the difference in performance of which will be evaluated over the coming years. Stipia, Carex 'evergold', Miscanthus Yakushima Dwarf and Festuca blue fox species were used throughout the rain gardens as they met the following project criteria:

- Tolerance of wide fluctuations in soil moisture levels;
- Provision of sufficient structure to assist pedestrian and driver differentiation;
- Use of evergreen species; and,
- Aesthetics.

The project cost an average of £460 per m^2 (based on a total area of 148 m^2). The cost for rain gardens filled with aggregate was around £300 per m^2 and significantly more where attenuation cells were used. It is expected that maintenance regime will be limited to the annual upkeep of vegetation, with occasional mulching and clearing of the inlet. As the rain gardens were constructed within the existing grass verge, the reduction of grass cutting is projected to off-set the cost of the new maintenance regime.

To facilitate the on-going evaluation of the successfulness of the rain gardens, a data logger was installed to provide continuous water depth recording within the void space beneath a test rain garden. The initial results suggest a 33% reduction in surface water flows reaching the nearby sewer during a 1 in 1 year AEP return period storm. A survey was also undertaken amongst local residents to gather their views and opinions on the rain gardens. The survey concluded that there was mixed public opinion in regards to the rain gardens with some local residents being highly supportive of the scheme. Other residents felt that the rain gardens took away valuable parking spaces and created a hazard for pedestrians and cyclists.

[58] http://www.susdrain.org/case-studies/case_studies/nottingham_greening_streets_retrofit_rain_garden_project.html

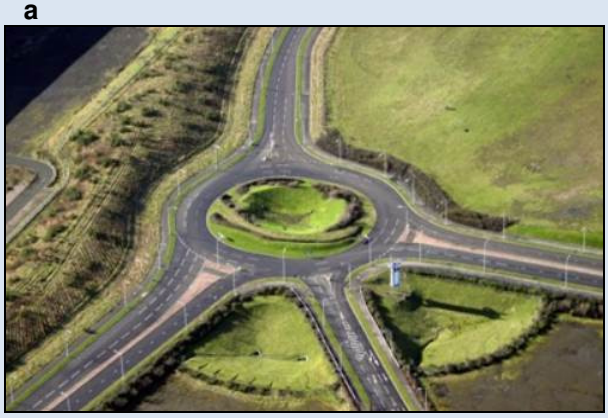
Box 18: SuDS in Dunfermile Eastern Expansion (DEX), Scotland[59]

The Dunfermline Eastern Expansion (DEX) is a 5.5 km^2 area located to the east of Dunfermline (Scotland) which was previously predominantly a greenfield site. In the 1990s, the site was redeveloped to a mixed use development of industrial, commercial, residential and recreational areas. Post-development, increased surface water runoff was shown to have adverse impacts on water quality downstream. Additionally, fluvial flooding became increasingly problematic on the site. In response to both water quality and flooding issues, SuDS were introduced.

There are a number of different SuDS techniques used at the DEX. Much of the spine road system is drained using offlet kerbs, filter drains and swales, which discharge into extended detention basins and wetlands which also serve adjoining housing areas (Figure 11). Treatment of the surface water runoff from the development is achieved through a system of regional ponds and wetlands prior to discharge to the local watercourse. Ponds and basins are widely used to achieve maximum attenuation of storm flows. Some residential roads are planned to be served by soakaways, where soil permeability permits.

Figure 11: a) *Detention basin DEX Roundabout (University of Abertay/SUDSNET) b) Pond at Dex (Scottish Government)*

a



b

DEX is the first site of its size and complexity to use SuDS across the entire development. The use of SuDS was supported by the Scottish Environment Protection Agency (SEPA).

Adoption issues have presented some barriers to the use of SuDS on the DEX site. Local highway authorities were initially unwilling to accept responsibility for any drainage methods other than traditional piped systems or soakaways. However, they have since agreed to adapt most of the local strategic road system to incorporate SuDS. Local authorities were also initially anxious about safety near open water; however, barrier planting and shallow reed planted margins have resolved this issue and offer adequate health and safety provision.

[59] Available at http://www.susdrain.org/case-studies/case_studies/dunfermline_eastern_expansion_scotland.html

Box 19: North Gosforth/ River Ouseburn Integrated Urban Drainage[60]

In June 2005 North Gosforth (Newcastle Upon Tyne) was affected by floods which caused significant damage to a number of properties in the area. The local community raised concerns regarding the development of the Newcastle Great Park and the influence it may have in increasing future flooding within the catchment.

In response, Northumbrian Water Ltd (NWL) instigated an investigation to determine potential flooding mechanisms and identified that the sewer system had insufficient capacity resulting in a reduced level of protection to the area. To address this, NWL implemented a £3.4 million capital scheme which included the separation of surface water from the sewer network and the installation of new overflows to reduce pressure on the sewer capacity. The interaction between the sewer system and the River Ouseburn was identified to be one of the main contributing factors to the flood.

In addition, investigations to establish new ways of managing the catchment to minimise the risk of future flooding have been conducted, as a result of this Sustainable Drainage Ponds have been constructed in the Great Park to reduce the level of surface runoff. Another outcome of the study has been to raise community awareness that there are a number of ways that local communities can get involved in mitigating flood impacts, through property level protection, for example.

Box 20: Skinner Street and Spa Fields Park SuDS Design Statement[61,62]

The 'Promoting Sustainable Drainage Systems Design Guidance for Islington' identifies the techniques, stages of implementation and the benefits of designing, introducing and retrofitting SuDS into an urban environment.

The Skinner Street and Spa Fields Park SuDS design demonstrates how SuDS can be incorporated into an existing street landscape, and it consists of three main components:

- Shallow collectors to bring road runoff into the park;
- Under-drained swales to provide 'source control' and initial cleaning of the runoff using a free draining 'rootzone'; and,
- Establishment of a wetland to store and clean runoff leading to social and biodiversity benefits.

The benefits achieved from the implementation of this design include:

- The drainage function is integrated into the landscape;
- Quality of runoff is improved through silt interception and filtration;
- Storage is provided on the surface as well as in the soil and under-drain drainage layer;
- Clean water can soak directly into the subsoil enhancing base flows and re-hydrating clays;
- The landscape is watered naturally, particularly in summer when rainfall is lower;
- Moist soils and vegetation improve air quality during hot weather; and,
- Clean water is provided and passed onward, enhancing visual amenity for the community and creating biodiversity opportunities.

The design statement demonstrates the effectiveness of incorporating retrofit SuDS into urban environments by utilising existing parks and open spaces.

[60] http://climatenortheast.com/manageContent.aspx?object.id=11060
[61] http://www.islington.gov.uk/publicrecords/library/Environmental-protection/Information/Guidance/2011-2012/(2012-03-03)-Skinner-Street-and-Spa-Fields-SUDS-Design.pdf
[62] http://www.islington.gov.uk/publicrecords/library/Environmental-protection/Information/Guidance/2011-2012/(2012-03-03)-Islington-SUDS-Guidance-low-res.pdf?bcsi_scan_AB11CAA0E2721250=5UZVTjws0mwGqpHquFShNCEYFS0VAAAAVWZIIQ==&bcsi_scan_filename=(2012-03-03)-Islington-SUDS-Guidance-low-res.pdf

Derby City Council is currently working towards publishing a Highways Drainage Policy / HD Service standard policy, which will enable the authority to implement drainage improvement schemes which aim to manage the impacts of projected climate change. As part of this, the authority is already identifying opportunities to store storm water runoff from the carriageway and whenever practicable, implementing schemes which increase the capacity of the highways drainage system. Six examples of schemes recently constructed are detailed in **Box 21**.

Box 21: Developing a Resilient Network - Derby City Council

Case Study 1: Derby Rail Station Forecourt.

A masterplan commissioned by Derby City Council for the rail station forecourt recommended the refurbishment of the existing area as a key project for the regeneration of the city. The perception was, that the then existing rail station forecourt presented a poor first impression for visitors coming in to the city. The solution included the creation of a quality transport interchange to improve accessibility to sustainable transport and to improve the public realm around the main station entrance.

The original scheme proposal was to utilise the existing surface water drainage system as part of the overall station forecourt improvement scheme. However, a pre scheme drainage CCTV showed the surface water carrier pipes to be close to collapse. The survey also showed that there was no viable outfall on the system and provided evidence that the existing system had been percolating in to the ground under the carriageway.

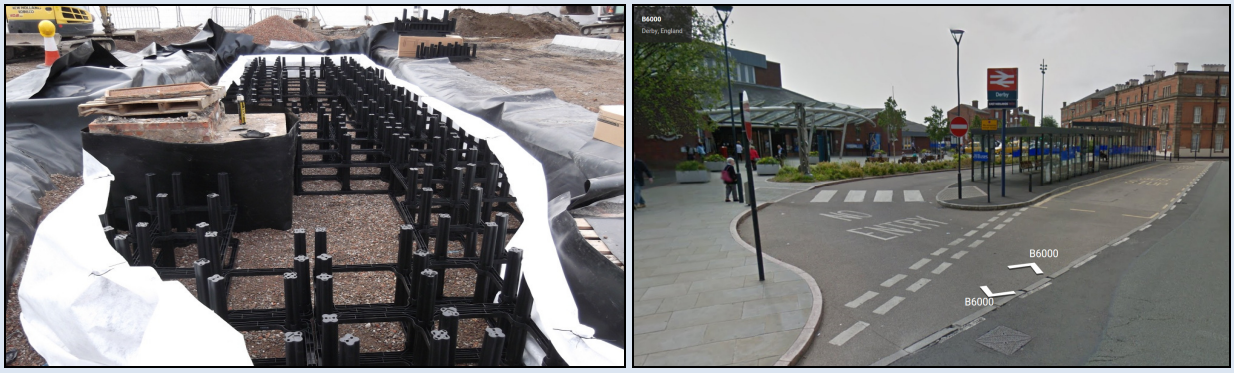
The original proposal was to replace the existing piped system on a like for like basis. However following a proposal put forward by the authority's in-house drainage consultants, it was decided that improvements to the highways drainage network would be made at the same time as rail station forecourt improvement works as a combined regeneration scheme, working in partnership with Network Rail and East Midland Trains. A decision was also made, that where practicable sustainable drainage methods would be used to provide treatment of runoff discharges from the site and amenity benefits.

The sustainable drainage design made use of a series of underground cellular storage tanks constructed below a planted area adjacent to the rail station entrance. The runoff from the carriageway is passed through catchpits which provide one level of treatment, before discharging in to the storage facility. The surface water is then passed through a planted area, which provides a second level of runoff treatment before being passed forward to outfall in to the combined sewer which runs past the station forecourt.

The cellular storage tanks have sufficient capacity to store water from a 1 in 75 year event below ground. The discharge from the tanks is controlled by a simple orifice plate type arrangement. Figure 12 shows the tank scheme during and after construction.

Figure 12: a) *Storage tank under construction (Derby City Council)* ***b)*** *Scheme after completion (Derby City Council)*

a **b**



Case Study 2: Derby City Council Partnership Working to Deliver Flood Risk Benefits

Derby City Council has been working with developers to enable sustainable development to be delivered which also provides flood risk reduction benefit.

An example of this working in partnership is a proposed development to the north of Mickleover known as Hackwood Farm. Although the site is in Flood Zone 1 it is drained by a small watercourse known locally as Egginton Brook. Egginton Brook drains towards an old railway line that ran in a cutting to the north of Mickleover. The brook crosses the old railway via an aqueduct which then flows at a high level along the south side of the railway cutting.

The wet summer of 2012 resulted in the catchment of Egginton Brook becoming saturated. An intense storm event on 6th July 2012 caused rapid runoff from the catchment, which in turn caused Egginton Brook to overtop. This event caused external flooding to a number of properties.

An existing proposal to construct new properties within this catchment was therefore somewhat of a concern and, as a result, Derby City Council approached the developer, Miller Homes, with a view to investigating a method by which a development proposal could be delivered in such a way that it would offer north Mickleover a degree of flood risk reduction and protection. Derby City Council also consulted with the Environment Agency. As a result of the consultation the following proposals were adopted:

1. Derby City Council and Derbyshire County Council to apply for Local Levy Funding to construct a flood bund along the old railway to divert flood waters away from the development.
2. Miller Homes to construct a wetland flood attenuation area on Egginton Brook to offer a minimum of 30% reduction in flows.
3. Miller Homes to provide SuDS using a series of ponds and swales that direct site runoff away from the old railway and discharge the flow further downstream into Egginton Brook and away from the urban fringe.
4. A further catchment transfer to be provided by draining an area of the development away from Egginton Brook into the onsite drainage network that discharges back into Egginton Brook 1.8km downstream.

Item 1 has now been delivered. Items 2, 3 and 4 will be implemented subject to the development being granted full planning permission.

Case Study 3: Alvaston District Centre Improvements

Derby City Council's regeneration team promoted a scheme to refurbish the Alvaston District Shopping area, as part of a strategy to promote business growth and provide improved public amenities. The team held a pre-scheme public information day, in order to gauge local public opinion about the proposed scheme. During the public information day, many members of the public reported long-standing surface water ponding issues on the carriageway on the major A Road. Derby City Council had no previous records of reported surface water drainage problems in the area, and commissioned. an investigation of the highway drainage network for the whole of the catchment area. Figure 13 shows photos of carriageway flooding provided by residents.

Figure 13: *Flooded carriageway* (Derby City Council)


A CCTV camera survey confirmed the condition of the carrier pipe network to be in a very poor state on both sides of the duel carriageway. As a result, a design team was assembled from Derby City Council's Regeneration, Highways Design and Land Drainage departments to devise an improvement masterplan. Subsequently, a more effective way to control surface water discharges from the site was identified. This involved the diversion of the highway's surface water drainage network to discharge through a series of catchpits to remove contaminants and then through a below ground storage tank, before connecting in to the nearby Severn Trent surface water sewer. The storage tank was sized to accommodate a 1 in 75 year storm event below ground, with up to a 1 in 100 year event being stored within the kerbed area of a service road.

The new underground storage tank takes surface water runoff from approximately 8000m^2. The tank lies wholly within a privately owned service road to the front of the shops. Derby City Council wrote to each affected property owner to outline the proposals to construct the tanks, with reference to the powers the authority has under the Highways Act, Section 100 – 1(a) to 'construct or lay, in the highway or in land adjoining or lying near to the highway, such drains as they consider necessary'. Derby City Council received no objections or requests for compensation by local residents for perceived loss of land value.

Figure 14 shows the tank under construction and the completed scheme.

Figure 14: a) *Storage tank construction (Derby City Council)* ***b)*** *Completed scheme (Derby City Council)*

a

b

Case Study 4: Osmaston Park Road Footway Drainage Scheme

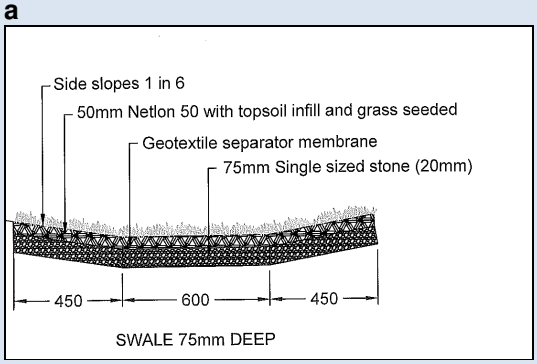
Footways on Osmaston Park Road in Derby had suffered from a long standing water issue, which saw property frontages periodically flooded by surface water runoff from the footways, following short duration storms. There was little in the way of a freely available positive surface water drainage system in the area, which could be used to discharge surface flows. The potential cost of providing a positive drainage system was evaluated and deemed to be very prohibitive.

Private driveways which run from the main Osmaston Park Road to property frontages were bounded on both sides by large grass verges. Using a 'keep it simple' approach Derby City Council decided to drain the footways using sustainable drainage swales (wherever possible), which would lie alongside the footways.

The swales were formed using plastic grasscrete sections, which were infilled using gravel material, topped with topsoil and subsequently grass seeded. The grasscrete sections allow residents to park their vehicles alongside the swales without damage. A total length of 175m of swale constructed, draining approximately 1000m^2 of footway, which would have normally discharged to the nearby combined sewer. Figure 15 shows the design of the swale, and the footway before and after the scheme.

Figure 15: a) *Swale design (Derby City Council)* ***b)*** *Flooded footway before the scheme (Derby City Council)* ***c)*** *footway after the scheme*

a



b

c

Case Study 5: T12 Link Road Drainage and Surface Water Management

The T12 project has been built as a Link Road in Derby to allow for better transport links from the A50 to the Rolls Royce plant and to service a new build industrial park; Infinity Park Derby.

Drainage for the scheme has been designed to accommodate a 1 in 100 year storm, with a +30% allowance for climate change projections. The drainage system has been designed using current standards and adopts natural features and piped sections to allow for a more sustainable solution to flood risk and alleviation. The drainage system consists of the following:

- Kerb drain units to take the water off the roads
- Catch pits/silt traps to help trap oils and sediment
- Catch pits discharge into small swales that run adjacent to the footways on both sides of the road
- Small swales outfall into larger transfer swales or into the piped system
- The piped systems and one of the larger swales outfall into three detention basins, which store water
- Each detention basin and the larger swale then outfall into one of the two brooks that run through the site
- There is a hydro brake at each outfall to control the release of water into the watercourses to match Greenfield run-off rates for the area

Provisions have also been made within the scheme to mitigate any damage to the road caused by flooding. This has included the construction of a Flood Alleviation Area (FAA) with a widened mouth into and out of the watercourse to help prevent high water levels and subsequent flooding of the road. The FAA incorporates a gabion stone finish at the mouth of the area to slow water progress and prevent scour Figure 16 shows the aerial view of the site and the flood alleviation area under construction.

Figure 16: ***a)*** *aerial view of the site (Derby City Council)* ***b)*** *flood alleviation scheme under construction (Derby City Council)*

a

b

Case Study 6: Trash Screen Maintenance / Watercourse CCTV

Derby City Council is responsible for the maintenance of approximately 60 highways drainage / watercourse culverts trash screens positioned in various locations throughout the city.

Blocked trash screens which lie adjacent to residential properties or critical highways structures are one of the major contributors to flooding. With this in mind, Derby City Council commenced a programme of recording the position and condition of all of its highways culverts and trash screens, together with undertaking a risk assessment of flooding criticality.

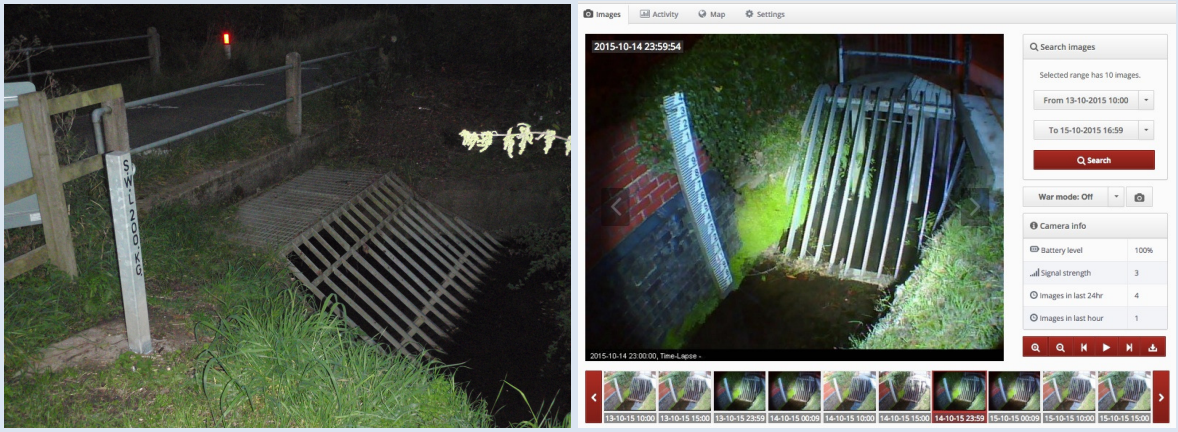
The culverts that were identified as presenting the greatest level of flood risk to nearby properties and adjacent critical infrastructure have been fitted with hydro flood warning systems/ level gauges (Hydro-Logic Services), which monitor rainfall and water level to therefore help manage flood risk. These level gauges provide an indication of when the screens required cleaning and provide an alarm when water levels are high so action could be taken if necessary.

Two gauges have been installed at each trash screen to be monitored, one upstream and one downstream of the screen. The difference between to the two levels gives an indication of the amount of debris on the screen. Data is downloaded to the 'Timeview' telemetry website and can be accessed from any device with an internet connection. The Hydro-logic system is also capable of sending texts message warning of an impending flooding problem. Additionally the most critical screens are also monitored using solar powered cameras from iDefigo.

Figure 17 shows a trash screen over Littleover Brook Culvert and a CCTV image of a trash screen.

Figure 17: ***a)*** *trash screen installed over a culvert (Derby City Council)* ***b)*** CCTV image (Derby City Council)

a **b**



Derby City Council is now proposing to use the data to help calibrate an InfoWorks model that has been produced for the catchment. This will allow rainfall data to be used to calculate the return period of storm event.

There are a number of SuDS application tools and guidance that help local authorities evaluate and prioritise SuDS options for their local conditions. CIRIA, for instance, has developed a new, free tool – the Benefits of SuDS Tool (BeST) – that makes the assessment of SuDS easier, without the need for full scale economic interrogation and analysis[63]. BeST provides a structured approach to evaluating a wide range of benefits,

[63] http://www.susdrain.org/resources/best.html

based upon overall drainage system performance, and is a valuable assessment tool that can assist local authorities with the following tasks:

1. Undertaking a more robust economic appraisal for different drainage options (supporting decision making for different stakeholders);
2. Adopting a robust, standard approach to assessing the benefits of SuDS that is open to scrutiny (increasing support from partner organisations);
3. Sharing information and improving engagement with other stakeholders;
4. Enhancing transparency of benefits associated with SuDS (increasing the potential for partnership working and shared funding opportunities); and,
5. Improving understanding of who benefits and hence who may implement, manage, maintain and pay for drainage improvements.

In relation to SuDS, large scale natural flood management techniques (including alteration, restoration and use of landscape features) have received closer attention in recent years. Derbyshire County Council, for instance, is implementing upstream water management schemes by working with upstream villages to prevent downstream flooding and landslips. The River Derwent Land Management Project[64] was initiated to reduce flood risk along the major river, using (amongst other methods) upland management techniques.

Elsewhere in the UK, the River Devon (Clackmannanshire, Scotland) *'Slowing the flow'* and the *'Slowing the Flow at Pickering'* projects are exploring a new approach to flood management (**Box 22 & 23**). Furthermore, the World Wildlife Fund (WWF) has published a 'Flood Planner'[65] that provides useful information of how to choose and monitor suitable natural flood protective options.

Box 22: Slowing the Flow – River Devon[66]

The River Devon project uses natural flood management techniques to reduce flood risks and manage water flows from upland to downstream settlements. A range of natural solutions and interventions have been applied:

- Restoration of natural dams;
- Restoration of natural sponges (wetlands);
- Replanting woodland protection;
- Managing forestry drains;
- Soft engineering downstream;
- Connecting rivers with their floodplains;
- Replanting natural barriers; and,
- Speeding the flow through town.

The WWF supervised the project and acknowledged multiple environmental and economic benefits of the solutions/interventions utilised. However, it is important to note that techniques such as upland reforestation, restoration of wetlands, and rehabilitation of drains typically take a significant amount of time to become effective and protect the area from flooding.

Moreover, before recommending any natural water management techniques, flooding events should be observed and detailed records collected to identify which areas are suitable for restoration interventions.

64 http://www.littlechester.org.uk/floodreport/report.pdf?bcsi_scan_AB11CAA0E2721250=0&bcsi_scan_filename=report.pdf
65 http://www.wwf.org.uk/wwf_articles.cfm?unewsid=2103
66 http://www.wwf.org.uk/wwf_articles.cfm?unewsid=2097

Box 23: 'Slowing the flow at Pickering', North Yorkshire[67]

The 'Slowing the flow at Pickering' project was commissioned by Forest Research to look at how changes in land use and land management could help to reduce flood risk at the catchment scale, as well as provide wider multiple benefits for North Yorkshire communities. The following natural management practices have been implemented as part of this project:

- Construction of two bunds;
- Construction of 100 large woody debris dams;
- Planting 13 ha of farm woodland on sensitive soils;
- Blocking moorland drains causing rapid runoff and erosion in the Pickering Beck catchment and installation of farm-based measures;
- Establishment of no-burn buffer zones;
- Revision of Forest Design Plan with restoration of 370 m of streamside buffer zone; and,
- Creation of 4.1 ha of riparian and floodplain woodland.

The local community was engaged from the beginning of the project planning process and has largely embraced the concept of whole-catchment approach to flood risk management. To-date the project has delivered an estimated £203,687.00 value of ecosystem services. A key recommendation emerging from the project is to develop and trial a payment system for ecosystem services aimed at securing wider benefits of targeted land management measures to reduce flood risk for affected communities across the UK.

4.2 Selection of Materials

Climate change and extreme weather are expected to have adverse implications upon many existing highway construction and maintenance materials and techniques. A number of MHA authorities have acknowledged these threats and have taken various steps to review material specifications in order to assess their properties and subsequent resistance to a changing climate. For example, a 2011 study by the 3 Counties Alliance Partnership (3CAP) included a detailed assessment of current materials, standards and specifications used by the three authorities to understand how changing temperatures and precipitation trends will impact on pavement condition and longevity. Subsequently, recommendations for ways in which material specifications and application techniques can be amended to become more resilient to changing weather patterns were identified.

The project also included the development of resurfacing decision-making matrices that provide the councils with tools for selecting the most appropriate resurfacing materials for their network in respect to short- and longer-term climatic projections **(Box 24).**

[67] http://www.forestry.gov.uk/pdf/stfap_final_report_Apr2011.pdf/$FILE/stfap_final_report_Apr2011.pdf

Box 24: Resurfacing decision-making matrices[68]

The 3CAP study included the development of a series of resurfacing decision-making matrices to demonstrate the likely level of resilience of various road types, resurfacing materials and techniques in light of future climate change projections.

The extract shown below provides an indication of the likely resilience level of various pavement types to extreme rainfall projections for the 2050s (where extreme rainfall events are projected to become more frequent and severe).

The capacity of different pavement designs to be resilient to the effects of extreme rainfall is considered according to two design scenarios - (1) according to current practice and (2) with adaptation measures carried out:

	Current practice			**Adaptation carried out**		
Scenario (for 2050s)	Low emissions scenario (10% probability level)	Medium emissions scenario (50% probability level)	High emissions scenario (90% probability level)	Low emissions scenario (10% probability level)	Medium emissions scenario (50% probability level)	High emissions scenario (90% probability level)
2a: Strategic 'Regional' Route - Designed (Asphalt)						
2b: Strategic 'Country' Route – Designed (Asphalt)						
3a: Main Distributor – Designed (Asphalt)						
3b: Secondary Distributor – Designed (Asphalt)						

	Good resilience - similar to current situation
	Moderate resilience - some maintenance, rehabilitation and material changes likely
	Poor resilience- significant maintenance, rehabilitation and material changes likely

The matrices illustrate a need to revise many existing and commonly used material specifications for almost all pavement types in response to the predicted variations in future climate. The study also provides a detailed list of recommendations for how construction and/or maintenance decision and processes can be adapted to enhance resilience. Recommendation examples include:

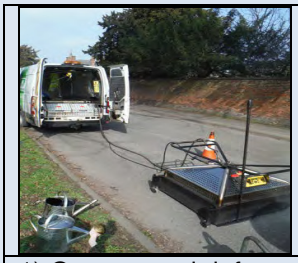
- Enhance asphalt mixtures to wider variations in temperature and humidity through the application of mixture additives such as hydrated lime and polymer modified binders;
- Adopt minimum PSV values for parent grit material for use within SMA mixtures, in order to promote skid resistance;
- Always ensure a good bond between pavement layers to avoid cracks initiation and propagation, particularly in thin pavement systems;
- Encourage the use of bond coats rather than tack coats to improve durability;
- Encourage in situ recycling wherever possible (such as Repave and Remix methods);
- Specify the thickness of micro surfacing if it is to be used (a thicker layer tends to provide a longer surface life, e.g. 20mm); and,
- Consider climate change projections when establishing the laying season for surface dressing.

68 http://www.leics.gov.uk/final_report_march.pdf?bcsi_scan_AB11CAA0E2721250=0&bcsi_scan_filename=final_report_march.pdf

Similarly, and in response to an increasing incidence of weather and climate induced road defects, Nottinghamshire County Council has trialled a modern system of road repair as part of their reactive maintenance systems and arrangements review. This 'Nu-Phalt' system has been tested and its advantages and disadvantages evaluated **(Box 25).**

Box 25: Testing of Nu-Phalt System in Nottinghamshire

Two units of the Nu-Phalt system have been introduced in Nottinghamshire since 2014. The Nu-Phalt process is shown below:

			
1) Once a road defect is identified the system heats a 1 m^2 area of the carriageway or footway	2) After approximately 8 minutes the area is up to temperature and then raked and re-mixed	3) Extra material is added to make up the shortfall left by the defect	4) The repaired area is then compacted with a vibrating plate to leave the finished patch

Testing of the Nu-Phalt system has reported mixed results depending on the location of the repair. Advantages and disadvantages of the system have been identified:

Advantages:

- Reduced traffic management arrangements – the site 'footprint' is quite small with only one vehicle being used;
- Reduction in noise, and vibration (restricted to the use of the vibrating plate);
- Environmental advantages – vastly reduced usage of quarried materials with no materials going to landfill; and,
- Aligned with logistical advantages, reduced fuel consumption and increased productive time on site.

Disadvantages:

- The slow speed of the system - maximum output is approximately 20m^2 per day, therefore somewhat expensive on an m^2 basis.

It has been concluded that the Nu-Phalt system is best suited to the evolved network, particularly in urban areas where it is best viewed as a replacement to overlay repairs.

In relation to changing soil moisture levels, Lincolnshire County Council is addressing the problem of cracking on asphalt carriageways. The use of geomesh to increase the ability of a highway to withstand soil moisture deficit was tested over a six year period on the A1073 **(Box 26).**

Box 26: The use of geomesh to increase the ability of a highway to withstand soil moisture deficit[69]

Lincolnshire County Council has undertaken a trial to assess the use of a steel reinforcement grid to protect asphalt carriageway from cracking caused by soil moisture fluctuations. A section of A1073 has been used for the trial and has been subjected to longitudinal cracking, previously resulting in disruption for several years. Cyclic shrinkage and heave of the underlying clay soils were defined as a primary cause of the damage. Cracks have historically been filled with hot bitumen or a bituminous inlay, but cracks typically returned within a short timeframe.

In 1997/98 seven test sections were laid on a 700m stretch of the A1073. Each of the seven test sections comprised a different variation of materials. For example, sections included the following combinations:

- No mesh;
- One or two sheets of mesh;
- Varying depths of dense binder course (DBC); and,
- Use of a concrete base.

The open drains adjacent to the road were filled in on some sections to move the wetting/drying zone away from the road. Monitoring of the section over six years revealed that the sections with mesh and at least 155 mm of DBC were in a good structural condition, as was the section built with a concrete base and 75 mm DBC. Filling in the drains also helped to prevent cracking.

This case study illustrated the benefits of geomesh for stabilising carriageways prone to cracking due to soil moisture variations.

4.3 Maintenance of Bridges and Other Structures

MHA authorities acknowledge that highway structures, such as bridges, are at risk from future climate change and an increased frequency and severity of extreme weather events; particularly heavy and/ or prolonged precipitation events. In response to these risks, certain MHA authorities have undertaken assessments to quantify the risks and to identify and prioritise adaptation measures.

For example, Derbyshire County Council has conducted surface water mapping for the county and has completed two pilot drainage scheme studies. Full underwater inspections are also carried out every 2-3 years for high risk structures situated across or adjacent to watercourses. Similarly, Leicestershire County Council has identified its high priority and high risk bridges. Consequently, underwater inspections are carried out for these structures as necessary. Structures affected by scour have also been identified and remedial action is being considered alongside standard and routine bridge maintenance activities.

Nottinghamshire County Council has identified which of their major bridges are most at risk from flooding and scour damage and undertake regular inspections at these locations. They are now working to better understand how a change to the frequency and severity of extreme precipitation events may affect their structures. Structural data collated by Nottinghamshire County Council has now been transferred onto a GIS-based database which is likely to facilitate sustainable asset management.

4.4 Maintenance of Green Infrastructure and the Soft Estate

Urban green spaces and green infrastructure can provide numerous benefits when looking to enhance the resilience of the man-made environment to the impacts of climate change and extreme weather. Forest Research has published guidance on the benefits of green infrastructure for urban and peri-urban areas, including heat amelioration, flood risk reduction and water quality and air quality improvements[70].

[69] 'Maintaining Pavements in a Changing Climate' (2008), Department for Transport, p. 47.
[70] Forest Research (2010). *Benefits of green infrastructure*. Report by Forest Research. Forest Research, Farnham. For climate change adaptation/mitigation benefits go to pp.7-12

Forest Research has also developed an online 'Search Tree Species' tool[71] that informs users as to which trees are most suitable for planting in urban areas in order to mitigate the adverse impacts associated with climate change and extreme weather. The interface provides an opportunity to customise the search according to an area's soil type, required ornamental qualities, and the nature of the environment that the proposed tree will be planted in.

In addition to the 'Search Tree Species' tool, a 'Capital Asset Valuation for Amenity Trees' (CAVAT) tool produced by the London Tree Officers Association provides guidance on maintaining green infrastructure in the public domain **(Box 27).**

Box 27: Capital Asset Valuation for Amenity Trees (CAVAT)[72]

The CAVAT tool promotes and provides guidance on managing trees in the UK as public assets rather than liabilities. It is designed not only to be a strategic tool and to aid decision-making in relation to the tree stock as a whole, but also to be applicable to individual cases, where the value of a single tree can be expressed in monetary terms. CAVAT is designed for use by the local authorities and other parts of the public sector but can also be used by the private sector and individuals. Where possible, CAVAT draws upon objective evidence and published data, yet also relies on expert arboricultural knowledge and in some cases assessments that are specific to the tool.

CAVAT works by calculating a unit value for each square centimetre of tree stem, (by extrapolation from the average cost of a range of newly planted trees), and then adjusting this to reflect the degree of benefit that the tree provides to the local community. The adjustment is designed to allow the final value to reflect realistically the contribution of the tree to public welfare through tangible and intangible benefits[73]. There are two versions of the CAVAT assessment: 'Full' and 'Quick'. The 'Full' method is recommended when precision is required and sufficient time is available for a full assessment. The 'Quick' method is intended specifically as a strategic tool for management of the stock as a whole.

In line with Forest Research guidance and the CAVAT tool, Northamptonshire County Council has developed a Guidance Note for Highway Cultivation (for trees, hedges, amenity grass and native wildflower verges). This Guidance Note helps planners and developers identify the most appropriate tree(s), shrub(s) and grass species for cultivation on highway verges. The guidance highlights those trees and shrubs that most effectively complement different highways environments – urban/residential and rural. Preference is given to native species and considerations include water demand, habitat, ecology and benefits to the wider community (see Figure 18).

[71] http://www.forestry.gov.uk/website/forestresearch.nsf/searchtreespecies
[72] Available at http://www.ltoa.org.uk/resources/cavat
[73] Capital Asset Value for Amenity Trees. Full and Quick Methods: User's Guides 2010. Available at http://ltoa.org.uk/component/docman/cat_view/98-capital-asset-value-for-amenity-trees-cavat

Figure 18: Excerpt from the list of recommended tree and shrub species (Northamptonshire)

Scientific name	Recommended cultivars/ varieties	Common name	Crown shape	Mature crown spread (m)	Native		Minimum verge width	Soils		Tolerances		Features										Other
								Acidic	Calcareous	Heavy	Wet	Air pollution	Exposure	Drought	Soil compaction	Autumn colour	Bark interest	Evergreen	Flowering	Fruiting	
Urban/Residential																						
Shrubs and small trees																						
Amelanchier lamarckii	'Robin Hill'	Snowy mespilus	Spreading	8			3m		✓							✓			✓		
Betula albosinensis	'Fascination'	Chinese red birch	Conical	8			3m				✓						✓				
Carpinus betulus	'Fastigiata'		Spreading	10			3m		✓	✓						✓					
Prunus cerasifera		Cherry plum	Spreading	8			3m												✓	✓	
Prunus serrula		Paperbark cherry	Spreading	8			3m										✓				
Prunus sp.	'Pandora'		Spreading	8			3m									✓			✓	✓	Fruits produced only occasionally
Sorbus aucuparia	'Sheerwater Seedling'		Spreading	5			3m	✓												✓	Excellent for pollinators
	'Streetwise'		Columnar	3			3m	✓													Excellent for pollinators
Sorbus commixta	'Embley'		Spreading	5			3m									✓				✓	
Medium trees																						
Acer campestre		Field maple	Spreading	10	✓		4m	✓	✓✓	✓		✓	✓	✓		✓					Excellent for pollinators
	'Elsrijk'		Conical	6			3m		✓			✓		✓	✓	✓					
	'Streetwise'		Conical	5			3m		✓					✓		✓					
	'William Caldwell'		Fastigiate	4			3m							✓		✓					
Acer lobelii		Lobels maple	Fastigiate	4			3m														
Betula ermanii		Ermans birch	Columnar	12			3m									✓	✓				
Betula pendula		Silver birch	Conical	14	✓		3m	✓✓	✓	✓		✓✓	✓✓		✓						

This guidance document aims to minimise the ongoing maintenance requirements of highway grass verges and to ensure resilience to a changing climate. Within the guidance, preference is given to a slow/low growing, climate resilient, native grass seed mix that is currently being trialled on a number of verges throughout the county. Northamptonshire County Council also encourages, where appropriate, the replacing of amenity grass with transitional windflower meadows to create visually attractive wildlife friendly spaces, and to increase biodiversity. Furthermore, wildflowers grow more slowly that amenity grass and can therefore require lower levels of maintenance.

Manchester University has developed a tool that facilitates a comparison of different green infrastructure scenarios to minimise the impacts of increasing temperature and surface water runoff **(Box 28).**

Box 28: Surface Temperature and Runoff (STAR) tools

The STAR tools[74] were developed through collaboration between Manchester University and a range of stakeholders to allow users to assess the potential for green infrastructure to contribute to climate change adaptation. It includes a surface temperature tool and a surface water runoff tool. The STAR tools can be used at a neighbourhood scale to test the impact of different land cover scenarios on surface temperatures and runoff under different temperature and precipitation scenarios.

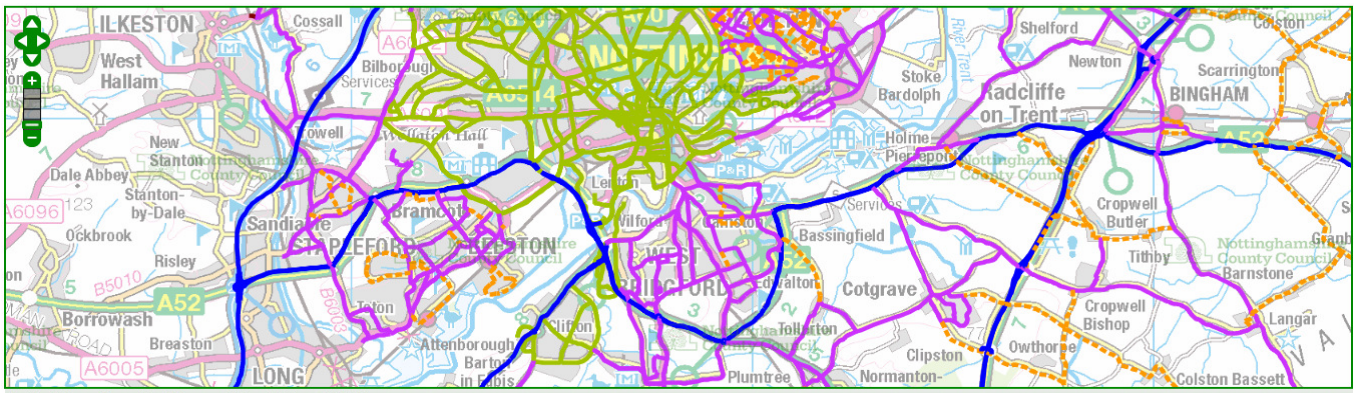
Outputs of the STAR tools can be used to inform policy, strategy, and development. STAR outputs are of use to a range of professionals and organisations with an interest in understanding more about the influence of urban greening on their local climate. This includes planners, developers, masterplanners, local authorities, urban forestry initiatives, non-governmental organisations and academics.

4.5 Winter Service

Several MHA authorities have reported that their winter service and winter response plans have been reviewed and updated as a result of the severe winters of 2009-2010 and 2010-2011. This includes the reclassification of salting and gritting routes based on the roads hierarchy and risk levels. Figure 19 provides an example of the classification of routes by Nottinghamshire County Council.

[74] Available at http://maps.merseyforest.org.uk/grabs/

Figure 19: Excerpt from Nottinghamshire County Council salting and gritting routes classification



At present, it is typically only major/main routes that are precautionary treated/ salted by local authorities. Remaining routes are generally treated in reactive manner. In this respect, Derbyshire County Council, for example, has introduced a 'Tertiary' classification for certain routes. During periods of heavy snow and ice, many of these 'Tertiary' routes are treated and cleared by Derbyshire County Council's 60-70 winter service contractors – consisting mainly of farmers and Parish Wardens.

Leicestershire County Council has also recently reviewed their route classification and has redefined their 'Priority 3' routes. They have strengthened and increased the contracts they have in place with farmers and other contractors to undertake elements of reactive winter service and have recruited additional Snow Wardens in 2013. Leicestershire County Council is also working with Town and Parish Councils to increase the number of salt bins around the county.

Derbyshire County Council is currently looking at route optimisation options and is considering investing in technologies or systems that can help to achieve and implement these options. Derbyshire County Council has also plotted their salt bins on GIS, which is linked to their website. This allows the public to report when the bins need refilling to the council.

Leicestershire County Council has also undertaken a route optimisation review and has implemented the findings. In addition and similarly to Derbyshire County Council, Leicestershire County Council updated their winter service website in 2013 to include salt bin maps and public guidance and information.

In an effort to further enhance community awareness as to winter service issues, some MHA authorities now use Twitter accounts to communicate 'live' winter service updates to the public.

5 CONTRIBUTION TO OVERALL SUSTAINABILITY

There is a shared understanding among MHA authorities that adaptation of the highway network to the risks posed by climate change can contribute to overall sustainability and will '*allow local communities to prosper within locally and globally sustainable environments*'[75]. A review of the approach taken by local authorities (as undertaken by this study) has identified a variety of diverse approaches taken to facilitate more resilient highway networks and assets.

Effective adaptation has the potential to derive benefits across the three pillars of sustainability (social, environmental and economic). For instance, the effective use of SuDS can provide enhanced biodiversity and water quality, improve amenity value (which may benefit health and wellbeing) and lead to reduced costs associated with responding to flooding events.

Summaries of how adaptation links to the achievement of wider sustainability aspects are provided below.

5.1 Social sustainability

Local authorities understand the importance of social integration and involvement in the effective delivery of climate change adaptation and resilience works, ultimately to achieve 'community buy-in'. Consequently, many local authority efforts include social elements. By involving local communities in climate change adaptation and resilience works, a number of benefits are derived, including:

- Improved accessibility and amenity value (as a function of biodiversity, water quality and landscape enhancements) leading to improved health and wellbeing of user groups;
- Further enhancements to health and wellbeing as a function of the encouragement of 'smarter choices' of travel such as walking and public transport (facilitated by improving the accessibility, usability and image of public transport;
- Enhanced health and safety provision included within highway asset design;
- Enhanced community spirit and feeling of involvement, which may dissipate tensions in the local environment between local authorities/agencies and community groups;
- Enhanced ability of communities to increase their level of resilience to climate change and extreme weather as a result of improved awareness and education (see below); and,
- Partnership working between local land owners and farmers aids the development of a culture of understanding, a mutualistic relationship and equal partnerships, which is important for the continued maintenance of the rural network and for the delivery of SuDS measures, etc.

Climate Change Communication and Education Campaigns

There is a growing body of evidence which suggests that one of the most important roles for a local authority during an extreme weather event is to provide local leadership by promptly responding to an incident. This approach ultimately helps to retain a good reputation and the trust of the residents. Effective communication with the residences in this sense is one of the most essential elements to provide an adequate response. A series of principles for climate change communication are put forward in the guide developed by the Local Government Association (LGA) **(Box 29).** Similarly, the US Federal Highway Administration (FHWA) has also provided guidance on strategies for successful implementation and making the case for climate change adaptation **(Box 30).**

[75] http://www.derby.gov.uk/environment-and-planning/climate-change-and-energy-management/climate-change-strategy/ .

Box 29: A guide for communicating during extreme weather – Local Government Association[76]

The LGA has developed a guidance document that indicates in specific details how to plan, prepare and have resources in place to provide reliable and timely communication during an extreme weather event. The steps outlined include the following:

- Develop a communication strategy that will cover:
  - Identification of possible issues a council may have to deal with;
  - Identification of the audiences to communicate with (e.g. residents, partners, local stakeholders, etc.);
  - Development of key messages (these will vary depending on an incident and area);
  - Allocation of roles and responsibilities before, during and after extreme weather event (a lead spokesperson, a person responsible for authorising media statements, etc.); and,
  - Ensuring out-of-hours contact details for key communication personnel and partners are available and updated.
- Establish communication channels:
  - Through developing a proactive extreme weather media plan that may include press releases months in advance of winter weather, updates about council's preparedness level to extreme events, preparing strong reactive line to rebut any potential criticism, etc.;
  - Through Social Media (e.g. highlighting the work of winter service teams by uploading photos and videos in Twitter and Facebook accounts); and,
  - Through a local authority's website (that should include links to relevant services and further information such as insurance claims and compensations).
- Maintain effective internal communication:
  - By keeping staff informed (e.g. regular updating staff by email about conditions before, during and after the event); and,
  - By informing staff when extreme weather affects their place of work.

The document is available online and can be a valuable source of information for any local authority aiming to improve its communication streams during extreme weather events.

Box 30: Strategies for successful communication

A 2010 pilot study into the communication of climate change vulnerability by the US Federal Highway Administration (FHWA) identified several successful and effective strategies:

- In order to avoid confusing the issue of climate change adaptation with the politics of climate change mitigation, some authorities use the terms "extreme events," "event management," "all-hazard management," and "resilience" as effective terms for communicating impacts and adaptation issues.
- Expand conceptions of sustainability and asset preservation to include resilience. Authorities can emphasise that climate change adaptation is simple, good business practice that should be integrated throughout the authority.
- Frame adaptation as better planning and responsible risk management.
- Frame adaptation as saving money. Stress that preventing impacts is almost always cheaper than cleaning up and rebuilding after an extreme weather event.
- Use past events, such as a memorable flood or heat wave, to help communicate the meaning of climate projections.
- Highlight possible solutions to climate impacts. Frame the issue as one of rising to the challenge.
- Use graphics.

[76] Available at http://www.local.gov.uk/web/guest/publications/-/journal_content/56/10180/6724894/PUBLICATION

- Tailor the message to your audience.
- Talk in the here and now. Explain how the climate is already changing in the geographic area the audience is concerned with and the impact on assets and services that the audience values (many individuals are not aware that climate change impacts are already occurring).

5.2 Environmental Sustainability

Adaptation measures can facilitate multiple wider benefits, such as:

- The implementation of SuDS can result in habitat creation and an increasing biodiversity. For instance the development of rain gardens can encourage bee communities;
- Increased vegetative coverage can enhance soil stability and integrity, which can prevent weathering;
- The increasing use of vegetation in landscaping can enhance local air quality and help to sequester emissions from vehicles;
- Landscape value is further improved by assessing the risks to vulnerable tree communities in tandem with tree assessments;
- The use of rain gardens (particularly in urban areas) has the potential to enhance water quality through the filtration and purification of water; and,
- The 'linking up' of grey, green and blue infrastructure has the potential to deliver a wide range of benefits to receptors including biodiversity, landscape, health and wellbeing and education and research.

5.3 Economic Sustainability

There are many climate change adaptation and resilience measures which may indirectly deliver economic benefits as follows:

- By 'helping people to help themselves' (i.e. through the development of community flood plans etc.), emergency response costs are likely to be reduced meaning that constrained resources can be utilised elsewhere within the social system;
- By enhancing climate change resilience (i.e. through lengthened design lives), costs associated with maintenance are likely to be reduced;
- Proactive responses taken by local authorities are likely to save costs in the future, for instance, through avoided damage repair costs;
- Improved health and wellbeing derived from enhanced amenity and access is likely to reduce financial implications on health services across the region; and,
- Energy savings are likely to result as a consequence of the installation of energy efficiency measures and energy savings techniques.

6 CONCLUSION

Climate change and an increased frequency and severity of extreme weather events are set to have significant impacts on the design, construction, maintenance and operation of local highway networks. For example, drier and hotter weather will lead to more incidences of infrastructure subsidence and heat damage to pavements and structures; more frequent heavy precipitation events will result in increased incidences of flooding in low-lying areas and floodplains; and sea level rise may make some networks and assets temporarily or permanently inaccessible. These impacts will lead to disruption to services and increased operational, maintenance and emergency repair costs.

In order for local highway networks, assets and services to be resilient in the face of a changing climate, effective and targeted action must be taken to minimise this disruption, damage and cost. Existing design, construction, maintenance and management policies and standards are typically based on historical climate data but attention now needs to shift to these future predictions. Local authority highway departments must therefore look to adapt their programmes, strategies, activities, policies and standards for these changes.

The aim of this project has been to develop an evidence base to promote a collaborative approach to building resilience of local authority highway networks to the impacts of climate change and extreme weather, which is nationally applicable and transferable and has the potential to be showcased as an example of good practice in the transport sector. It is applicable to all MHA authorities (and other local authorities in the UK) and takes into account differences in climate, geography, drivers and policies and standards.

This has been achieved through the identification, collation and synthesis of examples of how individual authorities are taking action to mitigate against climate change impacts and increase their level of future resilience.

The review has found that local authority highway networks are susceptible to risks associated with climate change and an increased frequency and severity of extreme weather events. Such risks have already presented themselves, with the vulnerability of the local authority highway networks to flooding, wind, extreme winter conditions, coastal erosion and extreme heat becoming increasingly evident.

Opportunities have been identified from within the MHA and wider and are beginning to be implemented to enhance climate change resilience, along with providing multiple, wider benefits such as enhanced amenity, accessibility and landscape value. These measures are highlighted in this report and include:

- The development of Adaptation Risk Registers and Action Plans;
- The development of Flood Risk Partnerships and Local Resilience Forums to facilitate collaborative working and the sharing of information;
- The delivery of community education, awareness and engagement programmes;
- The inclusion of change considerations and objectives within Local Transport Plans;
- The development of flooding guidance and toolkits to enhance community preparedness;
- The undertaking of vulnerability assessments to determine the most at risk assets and receptors;
- The adaptation and adoption of operational responses, such as enhanced and targeted maintenance regimes;
- The trialling of different (more climate resilient) materials and technologies;
- The implementation of SuDS on a wider scale;
- The expansion of the blue and green infrastructure network; and,
- Revisions to winter service operations and strategies.

As a result of these measures, a wide range of benefits have already been realised in regards to environmental, social and economic sustainability. Generally, social benefits are delivered through a greater inclusion of local communities in climate change resilience projects, the protection and improvement of human health and wellbeing and an enhanced preparedness of communities to extreme weather events.

Environmental receptors such as biodiversity, air, water, landscape and soils benefit from climate change adaptation and resilience works undertaken by local authorities. A number of economic benefits have already

been realised, such as reduced costs associated with responding to flooding events through the incorporation of effective and appropriate SuDS methods and technologies.

Assessing, understanding and responding to climate change risks is most effectively achieved through an integrated and collaborative approach involving a range of individuals, groups and stakeholders, and also across administrative boundaries. This can include includes designers, asset management specialists, environmental experts, operational staff, policy makers and the supply chain. Assessing and addressing climate change risks in a collaborative and integrated way ensures the interests of these different groups is taken into account, information is shared, and the resources and knowledge available to address risks are maximised.