Climate Risk and Vulnerability Assessment

Climate Leadership Gloucestershire

November 2025

AtkinsRéalis

sustainability west midlands

Climate Leadership Gloucestershire

The organisations that have influenced and developed the Climate Risk and Vulnerability Assessment, to shape a vision for a well-adapted Gloucestershire, consist of the following organisations:

AtkinsRéalis are a world-class engineering services organisation that connects people, data and technology to transform the world and engineer solutions to humanity's challenges. AtkinsRéalis have led the technical development of Gloucestershire's climate risk and vulnerability assessment, outlining the methodology taken, ensuring a consistent approach with that taken in the UKCCRA3. AtkinsRéalis has led on the technical input, assessing climate risk and developing priority adaptation actions for Gloucestershire.

Sustainability West Midlands is an independent, not-for-profit organisation that works across the private, public, and third sectors to promote and deliver sustainability initiatives. Sustainability West Midlands led the stakeholder engagement on this project, identifying key stakeholders, organising and delivering interviews, ensuring the Climate Risk and Vulnerability Assessment has been co-developed with key stakeholders across Gloucestershire[1].

Gloucestershire County Council is the upper tier local authority in Gloucestershire, its primary functions are highways, social services, education, waste disposal and libraries. The county council works closely with the six district councils of Gloucestershire to deliver these services.

Gloucester City Council is the lead council for Climate Leadership Gloucestershire work on adaptation. Its mission is to ensure that the council is prepared for climate change[3].

Cotswold District Council exists to provide vital services to residents, businesses and visitors. Cotswold District Council is embedding climate resilience into its operations focusing on community energy, digital innovation and flood and sewerage management[4].

Forest of Dean District Council is a stronghold for nature with one of England's largest areas of woodland. The council declared a climate emergency in 2018 and has been working with Town and Parish councils on climate change adaptation.

Stroud District Council sits within Climate Leadership Gloucestershire and is responsible for Stroud in Gloucestershire. Stroud District Council has taken a pioneering approach to climate action and ecological resilience. Stroud District Council aims to take a progressive approach to community collaboration and strategy governance[6].

Tewkesbury Borough Council is the council responsible for the borough of Tewkesbury. The council places communities at the heart of all activities, focusing on people, place and the environment to influence strategic planning and decision making[7].

Cheltenham Borough Council is a key partner in Climate Leadership Gloucestershire, contributing to county-wide adaptation planning. The council integrates climate risk into its planning and development policies and promotes sustainable transport, energy efficiency, and biodiversity[8].

NHS Gloucestershire Integrated Care Board (ICB) forms part of the One Gloucestershire Integrated Care System (ICS), which brings together NHS organisations, local authorities, and voluntary sector partners to improve health outcomes and reduce inequalities[9].

Gloucestershire Hospitals NHS Foundation Trust (GHNHSFT) is the main provider of acute hospital services in Gloucestershire, operating Cheltenham General Hospital and Gloucestershire Royal Hospital. The GHFT's green plan outlines its commitment to sustainable healthcare delivery that improves environmental, economic, and social outcomes[10].

Gloucestershire Health & Care NHSFT is a provider of integrated health services offering care in mental health, physical health and learning disability services to people of all ages across Gloucestershire

Foreword

In the four years that have elapsed since the publication of the Climate Change Committee's Third Climate Change Risk Assessment, our winters have been wetter and warmer and our summers hotter and drier, with increasingly destabilising impacts on agriculture, public health, and the wider economy. Worryingly, the pace of these changes has outstripped the predictions of many climate scientists, suggesting we have historically underplayed the speed at which impacts from global warming and associated climate change will be felt in our everyday lives.

In recognition of these escalating risks, Climate Leadership Gloucestershire (CLG) moved to undertake its own County-Council area wide Climate Risk and Vulnerability Assessment (CRVA), to ensure that no time was wasted in improving our local preparedness for an era of climate turbulence.

I am delighted that we are now able to publish the findings and recommendations of the Gloucestershire CRVA and would like to thank CLG members across local government, the NHS, and the emergency services for their commitment to its delivery.

Delivering this report's recommendations now needs to be undertaken at scale and pace.

With the energy and spirit of collaboration demonstrated thus far, I am confident that we can rise to meet this challenge.

Cllr Sebastian Field – Chair, Climate Leadership Gloucester

As noted in the U.K Health Security Agency's 2023 *Health Effects of Climate Change in the UK* report, our changing climate poses one of the greatest public health challenges we face, with significant threats to everything from the air we breathe to our tolerance for extreme heat and flooding to the security of the food and water we consume.

Gloucestershire will not be insulated from rising global temperature. On the contrary, its ageing population is likely to be impacted disproportionately from the extreme weather events and climatic shifts we will increasingly experience. With clinical vulnerability rising with age, the NHS faces the prospect of significant increases in heat-related ill health, the exacerbation of existing chronic conditions, and a population exposed to new disease vectors such as mosquitoes. Equally, Gloucestershire's uneven wealth and income distribution potentially means poorer health outcomes for deprived household less able to respond to climate change related food shocks and food price inflation.

As challenging the public health risks from climate change are, there is an extensive and growing body of evidence that taking the right adaptative action – through robust emergency contingency planning, improvements to the thermal efficiency of homes, and the widescale deployment of green infrastructure measures – can and will improve health and social outcomes. Not only will this beneficial for individuals and communities, it will also ensure the NHS is able to function with minimal service interruption from extreme weather events.

Gloucestershire NHS partners are therefore proud to have been able to support the work of Climate Leadership Gloucestershire to deliver a Climate Risk and Vulnerability Assessment that asks the questions, poses the challenges, and presents the climate change adaptation solutions today for a healthier Gloucestershire tomorrow.

Cath Leech – Chief Finance Officer, NHS Gloucestershire Integrated Care Board

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Executive Summary

Introduction

Gloucestershire's climate is changing. Faced with increasing risk of flooding, extreme heat, drought and storms and high winds, climate adaptation is needed across the county. Significant events including the summer 2022 heatwave and July 2007 flooding illustrate the potential countywide impacts of extreme weather events, which climate change is worsening.

The Climate Risk and Vulnerability Assessment (CRVA) provides an **evidence base to understand the key climate risks** across the county, demonstrating the impact, likelihood and overall risk posed by climate change across a variety of climate hazards. In tandem with this, **climate adaptation is explored across the county**, outlining existing climate adaptation projects, showcasing best practice and recommending future climate adaptation actions which will continue to bolster Gloucestershire's ability to respond to and withstand the impacts of climate change.

Stakeholder engagement

Understanding the diverse perspectives of stakeholders across Gloucestershire has been critical for understanding the local context of climate risk and adaptation. **The CRVA was co-developed with over 40 stakeholder organisations across the public and private sector including all districts, the county council and the NHS.**

Workshops and select interviews were held between May and July 2025, exploring lived experiences, impacts of climate change and adaptation priorities. This collaborative approach has ensured the integration of local voices in all findings.

Gloucestershire's changing climate

Gloucestershire's climate is becoming hotter, with an increase in temperature recorded since the 1880s and warming accelerating in recent years. Flooding has been commonplace across the county, notably, July 2007 and January 2014. More recent events include the 2022 and 2025 heatwaves experienced across the UK and storm events in 2022 and 2024 which led to disruption and fatalities in Gloucestershire (Figure E.1).

2022

February – Storms Dudley, Eunice and Franklin
>84mm of rainfall in 8 days in Gloucestershire
Amber wind warnings across Gloucestershire and red wind warning on the Severn Estuary

June/July – Heatwaves
53 grassland fire incidents in Gloucestershire
Temperatures reached above 35°C in Gloucestershire

2024

January – Storm Henk
1 fatality in Kemble, road closures, and damage to homes and businesses

November – Storm Bert
GP practices and schools closed due to flooding

2025

June/July – Heatwaves
Amber heat health alert issued
4 heatwaves experienced in the region

Figure E.1 *Timeline of select recent weather events across Gloucestershire*

In future, an increase in extreme weather events is projected by climate models across Gloucestershire. Heatwaves, wildfire events and droughts are projected to increase by the 2050s. Winter rainfall levels are projected to increase also, increasing the risk of both river and surface water flooding events.

Key changes in the climate projected for the 2050s for Gloucestershire are presented in the infographic below.

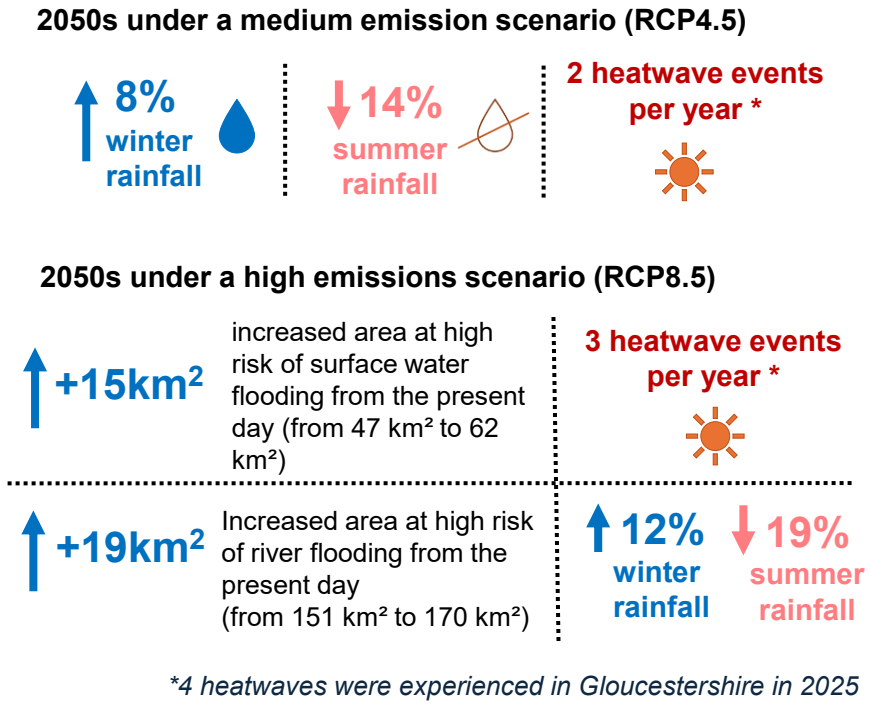


Figure E.2 *Key climate projections for Gloucestershire by the 2050s.*

Executive Summary

Climate Change Risk Assessment of key sectors

Building on the UK Climate Change Risk Assessment defined climate risks, **key climate risks are presented in Table E.1** for Gloucestershire. Key sectors assessed include Health, Built Environment, Business & Industry, Natural Environment, Agriculture and Infrastructure.

Risk scores composed of likelihood and impact of climate hazards are outlined in Table E.1. Most risks increase from a low to medium risk to a medium to high risk by the 2050s under a medium emissions scenario and high emissions scenario. The full evidence base driving risk scoring is outlined in the main body of the report.

Table E.1: *Results of the Climate Change Risk Assessment*

*Qualitative scorings based on expert judgement

	Hazard	Risk	Risk score		
			Baseline	2050s Medium emissions scenario	2050s High emissions scenario
Health	High temperatures	Risks to health and social care delivery from high temperatures	M	H	H
	High temperatures	Risks to public health and wellbeing from high temperatures	M	H	H
	Flooding	Risks to health and social care delivery from flooding	M	M-H*	H
Built Environment	Storm, high winds	Risks to building fabric from moisture, wind, and driving rain	M	M	M
	Drought	Risk of household water supply interruptions	L	M	M
	Surface water flooding	Risks to people, communities & buildings from flooding	M	M-H*	H
	River flooding and sea level rise	Risks to people, communities & buildings from flooding	M	M-H*	H
Business & Industry	Surface water flooding	Risks to business sites from surface water flooding	M	M-H*	H
	River flooding and sea level rise	Risks to business sites from river and tidal flooding	M	M-H*	H
	High temperatures	Employee productivity impacts in heatwaves and from severe weather infrastructure disruption	M	M	M
Natural Environment	Drought	Risks to habitats & wildlife from water scarcity	M	M	M
	Surface water flooding	Risks to habitats & wildlife from flooding	M	M-H*	H
	River flooding and sea level rise	Risks to habitats & wildlife from flooding	M	M-H*	H
	Drought/flooding	Risks to soils from increased seasonal aridity	M	M	M
	High temperatures & wildfire	Extreme weather/wildfire risks to forestry, wildlife & heritage	M	H	H
Agriculture	Drought	Risks to agriculture from water scarcity	M	M	H
	Surface water flooding	Risks to agriculture from surface water flooding	M	M-H*	H
	River flooding and sea level rise	Risks to agriculture from river and tidal flooding	M	M-H*	H
	High temperatures	Risks to soils from increased seasonal aridity	M	M	M
	High temperatures & wildfire	Extreme weather/wildfire risks to farming	M	H	H
Infrastructure	Drought	Risks to public water supplies from drought and low river flows	L	M	M
	Flooding	Risks to infrastructure from river, sea level rise and surface/groundwater flooding	M	M-H*	H
	Surface water flooding	Risks of sewer flooding due to heavy rainfall	M	M-H*	H
	Storm, high winds	Risks to energy, transport & ICT from high winds & lightning	M	M	M
	High temperatures	Extreme heat risks to rail, road, ICT and energy infrastructure	M	H	H

Executive Summary

Opportunities to minimise risks

Ensuring that climate risks are minimised across Gloucestershire requires climate adaptation and resilience to be integrated across communities, assets, infrastructure and businesses.

Existing best practice across Gloucestershire for climate adaptation and resilience is explored, followed by an assessment of future climate adaptation options which could be implemented across the county. A shortlist of potential projects is provided, illustrating the range of adaptations which could be planned for in future.

Existing adaptation actions across Gloucestershire

Organisations across Gloucestershire have implemented a number of **climate adaptation and resilience projects, demonstrating success stories across the county**.

Examples have been identified through stakeholder engagement and wider literature review. These include insulation improvements and enhancement of the natural environment at Forest of Dean Community Hospital and the embedding of climate resilient measures such as water harvesting installation across Bromford Housing Associates' new build homes and Gloucestershire Natural Flood Management Partnership.

Alongside these projects, **climate risk and adaptation has been integrated into key policies and plans**, which help to endorse future projects. Key examples at a county scale include Greener Gloucestershire Adaptation Plan and Gloucestershire Climate Change Strategy. At a local scale all Gloucestershire districts have outlined strategies and plans in regard to climate resilience and the declaration of climate emergencies.

Multi-criteria analysis and priority projects

A longlist of potential climate adaptation projects were identified through stakeholder engagement and wider literature review. **Potential projects were screened** through a multi-criteria analysis assessing potential performance, high level cost and deliverability to provide an understanding of prioritisation.

Based on this prioritisation, a select number of **suggested adaptation projects** are outlined, with further detail on benefits and time frames. An overview of these projects by theme are presented below across the defined sectors and broader education, collaboration and policy and governance categories.

Built Environment

- Built measures to cool buildings such as shutters, awnings, blinds, green or white roofs
- Sustainable Drainage Systems (SuDS)
- Cool spaces in local authority run buildings

Infrastructure

- Road resurfacing with asphalt resilient to extreme heat
- Embed climate adaptation requirements into tenders for infrastructure projects

Business & Industry

- Engagement on climate risk and adaptation through the Growth Hub and GFirst LEP
- Supply chain education on climate resilience and playbook sharing of climate risk and adaptation

Health

- Behavioural guidance for staff and patients during extreme weather
- Climate adaptation education for health professionals aligning with national guidance

Natural Environment

- Natural flood management (NFM)
- Establishing floodplain habitats in the Severn Estuary

Agriculture

- Drought and flood resilient farming techniques and crops

Education & Awareness

- Develop training modules for planners, heritage officers, construction professionals including the sharing of best practice examples in climate adaptation

Cross sector collaboration

- Establish cross-sector networks to understand and map out interdependencies

Policy & Governance

- Align adaptation goals with funding programmes

Next steps

The Climate Risk and Vulnerability Assessment acts as a starting point and evidence base for climate adaptation.

Suggested next steps for Climate Leadership Gloucestershire to agree and progress include:

- Confirm prioritisation of adaptation actions to address key climate risks identified.
- Continually monitor climate risks and keep the Climate Risk and Vulnerability Assessment as a live document.
- Explore funding mechanisms for climate adaptation.
- Explore the implementation of suggested priority projects.
- Draw on the longlist of climate adaptation projects for future planning, notably, lower cost and 'quick win' projects.
- Continue engagement on climate risk and adaptation planning and implementation with diverse stakeholders across Gloucestershire.

1. Introduction

Gloucestershire faces a changing climate, experiencing extreme flooding, heat, drought and storms and high winds. A deeper understanding of climate-related risks in Gloucestershire is needed to understand the areas and policies that should be prioritised for climate adaptation.

Gloucestershire is highly vulnerable to climate change; flood events in 2007 and 2014 caused widespread disruption, whilst heatwaves and water scarcity impacts are becoming more frequent. Temperatures reached above 38°C in Gloucestershire during the UK wide heatwave in 2022[1] and in 2025 alone 4 heatwaves were experienced in Gloucestershire.

As the climate changes, adverse impacts on Gloucestershire will be multi-faceted. People who live, work and visit the county will be impacted, and in particular the most vulnerable groups such as older people, children and those with existing physical and mental health conditions will be most affected. Healthcare facilities may be faced by greater demand for services during extreme heat and flooding events. Infrastructure such as transport and power can be disrupted during extreme weather events. Businesses may be impacted by wider supply chain disruptions or impacts on productivity posed by a changing climate. Gloucestershire's diverse natural environment and biodiversity may experience more frequent flooding, extreme heat, drought and wildfire, changing landscape character and access to green spaces.

This Climate Risk and Vulnerability Assessment (CRVA) sets out a vision for climate adaptation across the county. In this report the case is outlined for adaptation investment, based on the climate risks with the greatest impact on Gloucestershire's communities, infrastructure, assets, natural environment and businesses.

Global and UK context of climate change: adapt to 2°C, prepare for 4°C

The Paris Agreement has set out the need to keep global temperature change below set thresholds; **to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels."** [5]

Abrupt and irreversible changes to the climate system could occur due to climate change, these changes are often referred to as tipping points and could include the slowdown of the Atlantic Meridional Overturning Circulation (AMOC) which would change weather patterns in the UK (a weakening is noted as likely, with medium confidence that a total collapse will not occur by 2100).[6]

The Climate Change Committee's Adaptation Committee has set out advice for strengthening the UK's adaptation objectives. Two key messages are set out[7]:

1. *Objectives should, at a minimum, prepare the country for the weather extremes that will be experienced if global warming levels reach 2°C above preindustrial levels by 2050.*
2. *Reaching 4°C above preindustrial levels by the end-of-century cannot yet be ruled out and should be considered as part of effective adaptation planning.*

This guidance sets a precedent for the urgency of adaptation planning needed across the UK, a key remit for local authorities, health authorities, infrastructure and asset owners and businesses in Gloucestershire.

1. Introduction

Key aims of the Climate Risk and Vulnerability Assessment include:

- Alignment with the **Climate Change Committee's 10 principles for good adaptation**[3], ensuring climate risks are understood across multiple potential future scenarios and adaptation best practice is followed.
- **Co-create the Climate Risk and Vulnerability Assessment** with a diverse group of stakeholders across the county, ensuring buy-in of adaptation priorities and that these are successfully embedded.
- **Provide an understanding of climate risk** across Gloucestershire and **prioritise these risks** in order of likelihood of the risk occurring and the impact it will have on communities, physical infrastructure, the built environment, health and healthcare facilities, the natural environment, agriculture and businesses and industry.
- Set out a **vision for climate adaptation** across the county and a case for adaptation investment.

*"In Gloucestershire, **adaptation is urgently needed due to flood, drought and heat impacts**, occurrences of which we have already seen all too regularly.*

***Adaptation will also be a necessary component within planning for developments** to ensure the resilience of new buildings in Gloucestershire, from both current and future climate change impacts, and to **understand and protect the biodiversity of our future habitats**."*

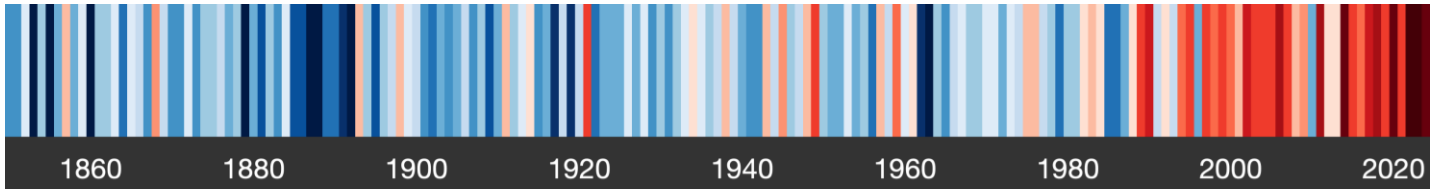
Greener Gloucestershire action plan[2]

Climate risk and adaptation: explainer

Climate risk is defined as the potential for negative impacts caused by climate change.

Climate adaptation is defined as the process of communities making changes and undertaking actions, to become more able to cope with climate change.

This report focusses primarily on climate risk and adaptation, rather than climate change mitigation which focuses on the reduction of carbon emissions. It is important that climate adaptation does not result in increased greenhouse gas emissions, known as maladapting, as set out in the Climate Change Committee's 10 Principles for Good Adaptation, avoiding lock in of carbon emissions through adaptation choices.



Climate stripes for Gloucester, showing temperature change in Gloucester since 1850 relative to average from 1961-2010. Red indicate warmer temperatures above the average, blue indicate cooler temperatures below the average.
Credit: Ed Hawkins #ShowYourStripes[4]

1.1. Climate Change Committee's 10 principles for good adaptation

The UK's Climate Change Committee, an independent body which advises the UK government on reducing emissions and adapting to climate change, have set out **10 principles for good adaptation**[1]. These principles allow for adaptation to be mainstreamed and provide organisations and government with a basis for adaptation reporting.

This Climate Risk and Vulnerability Assessment is centred around these principles, ensuring climate risks are understood across multiple potential future scenarios and adaptation best practice is followed.

1. A vision for a well-adapted UK	Climate Leadership Gloucestershire's vision is to be resilient to the impacts of climate change, where collaborative action ensure climate adaptation delivers co-benefits for all.
2. Integrate adaptation into other policies	Existing policies have been reviewed to advise on entry points for adaptation policies and measures.
3. Adapt to 2°C; assess the risks for 4°C	Climate risk assessment results are shown across two scenarios, +2°C and +4°C compared to pre-industrial levels, in line with best practice guidance.
4. Avoid lock-in	Adaptation measures identified have been reviewed for maladaptation, making sure that none of the options presented inadvertently lead to increases in emissions.
5. Prepare for unpredictable extremes	An assessment of unpredictable extremes has been completed for low likelihood and high impact events such as extreme flooding.
6. Assess interdependencies	Interdependent climate risks have been identified as part of this assessment, across different assets and infrastructure used and managed by key stakeholders across Gloucestershire.
7. Understand threshold effects	Thresholds for climate change impacts on infrastructure and assets are explored within this CRVA, including heatwaves, cooling requirements and risk of impacts on transport infrastructure.
8. Address inequalities	The inequitable impacts of climate change are explored including identifying where vulnerable groups are located and exploring adaptation options which incorporate equity.
9. Consider opportunities	Opportunities presented by climate change are discussed including benefits posed by increasing temperatures such as reduced demand for heating.
10. Funding, resourcing, metrics, research	The CRVA makes the case for investment in adaptation and the need for the integration of climate adaptation into existing policies to support implementation across Gloucestershire.

2. Methodology

The Climate Risk and Vulnerability Assessment is centred around the Climate Change Committee's 10 principles for good adaptation and is broadly divided into two key sections; (**1) Climate Risk and Vulnerability Assessment**, followed by an overview of adaptation through **(2) Opportunities to Minimise Risk.**

Climate Risk Assessment

1. **An overview of observed climate trends and climate projection data** is presented across a suite of climate hazards, along with case studies of extreme projections to understand a 'worst-case' scenario.
2. A **sectoral assessment of climate risk** was completed across a range of risks defined in the UK's Climate Change Risk Assessment 2022 (CCRA3). Sectors include Health, Built Environment, Natural Environment, Agriculture, Business and Industry and Infrastructure.
    - Risk was scored based on a likelihood and impact scoring. **Likelihood scoring** provides an understanding of how frequently climate hazards are occurring. **Impact scoring** provides an assessment of the magnitude of the effect on assets, services and infrastructure due to a climate hazard.
    - **The likelihood and impact scoring are combined to provide an overall risk score for each climate risk.** Multiple climate risks are assessed per sector.

Opportunities to minimise climate risk

To understand what prioritised climate adaptation projects should be put in place across Gloucestershire, a two-step approach was taken.

1. Multi-criteria analysis
A longlist of adaptation projects was derived from stakeholder engagement including interviews and an online workshop, literature review and expert guidance. To prioritise projects, a multi-criteria analysis was completed assessing the **performance/benefits, costs and deliverability of adaptation projects.**

2. Shortlisting of priority adaptation projects
The longlist of adaptation projects were then prioritised based on the overall score of each project. Projects were defined for each of the following 6 themes: (1) Built Environment, (2) Health, (3) Infrastructure, (4) Business & Industry, (5) Natural Environment and (6) Agriculture. One project is defined for each of the following themes: (7) Education & Awareness, (8) Cross-Sector Collaboration and (9) Policy & Governance. These 14 priority projects are outlined in more detail, providing an example of cost implications, effectiveness and high level timescales for implementation.

Full details of the methodology are provided in Appendix C.

3. Stakeholder engagement

Throughout the process of completing the Climate Risk and Vulnerability Assessment, stakeholder engagement was undertaken to ensure that the impacts of climate change within Gloucestershire are well understood, to prioritise climate risks and develop adaptation solutions.

In May 2025, an in-person workshop was held with over 60 individuals at Gloucester Guildhall. In this workshop, the impacts of climate change in Gloucestershire were explored, as well as how vulnerable groups are impacted in the present day and how this may change in the future. The discussion with stakeholders focused on individuals' experiences in their role and how climate change has impacted their respective organisation, service and/or area of interest. In addition, stories of past weather events and the associated financial impacts were discussed alongside prioritisation of impacts across hazards.

Select interviews were held in June and July 2025 with organisations across Gloucestershire. This was to understand the specific vulnerabilities of systems to climate change, and how climate change is managed through adaptation actions.

In July 2025, we held a second online workshop. In this workshop select stakeholders from a range of sectors were engaged. Discussions focused on current adaptation activities and types of adaptation activity needed, along with priorities to minimise the risks of climate change in Gloucestershire. This workshop has been instrumental in determining adaptation options for Gloucestershire.

Stakeholders and Partners

Without engagement from a range of organisations, this assessment would not have been feasible. Therefore, we would like to thank Climate Leadership Gloucestershire for playing an instrumental role in this assessment, in addition to the other stakeholders engaged and individuals' experiences that have shaped this assessment:

- Gloucestershire Climate Leadership Group
- Stroud District Council
- Gloucester City Council
- Tewkesbury Borough Council
- Cheltenham Borough Council
- Forest of Dean District Council
- Cotswold District Council
- Gloucestershire County Council
- Gloucestershire Local Resilience Forum
- Gloucestershire Constabulary
- Gloucestershire Fire and Rescue Service
- Gloucestershire Local Nature Partnership
- Severn Rivers Trust
- Gloucestershire Integrated Care Board
- Gloucestershire Hospitals NHS Foundation Trust
- Gloucestershire Health and Care NHS Foundation Trust
- Hartpury University
- Royal Agricultural University
- University of Gloucestershire
- Gloucester Chamber of Commerce
- Gloucestershire Independent Network
- Gloucestershire Youth Climate Group
- Gloucester Park Forum
- DEFRA
- Southwest Net Zero Hub
- Environment Agency
- Bromford Housing Group
- Inclusion Gloucestershire
- Red Cross
- Wildfowl and Wetlands Trust
- Barnwood Trust
- Multicultural Women's Group
- Gloucestershire Rural Community Council
- Forestry England
- National Energy System Operator (NESO)
- National Grid Energy Distribution
- South- West Infrastructure Partnership
- Business Members Group
- Farming and Wildlife Advisory Group
- Natural England
- BT
- NFU Mutual
- Growth Hub Business Support
- Stroud Chamber of Trade and Commerce

4. Gloucestershire's changing climate

Gloucestershire's observed climate (1981-2010)

Gloucestershire's average monthly rainfall from 1981-2010 was 72mm. The hottest months are June to August with average mean temperatures peaking at 17-18°C[2].

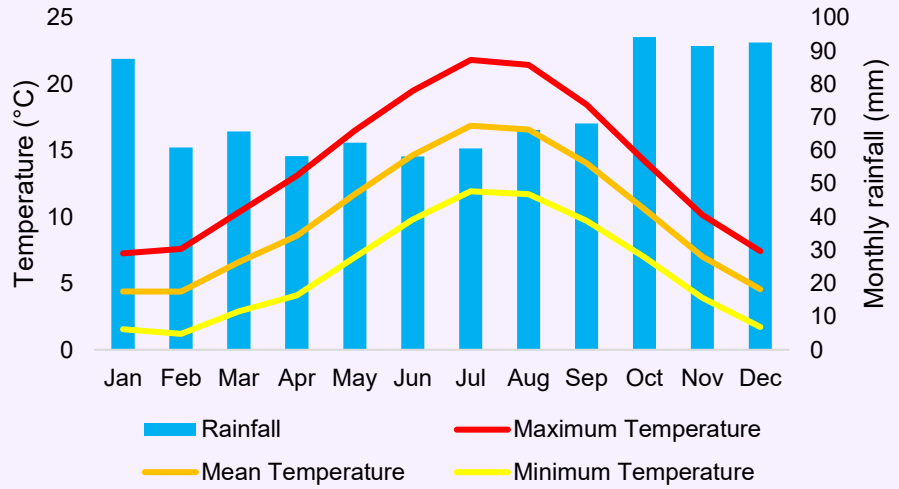


Figure 4.1 *Average annual observed climate (rainfall and temperature) for Gloucestershire in 1981-2010[2]*

Data Sources

Data used to inform the observed climate trends are primarily from the United Kingdom Had-UK Gridded Dataset. HadUK is a collection of gridded climate variables informed by land surface observations. The dataset spans the period from 1836 to the present day.[3]

How the climate is changing

Gloucestershire's climate is changing. Since the 1880s, the temperature has been warming, and this this has accelerated in recent years, with larger increases in temperature being observed across the county (Figure 4.2). In turn, heatwaves are becoming more frequent for Gloucestershire, with summers bringing periods of hot, dry weather and temperatures reaching up to 38°C in 2022.[4]

Gloucestershire has been prone to surface water flooding, tidal and river flooding in the past. Notably, the 2007 flood event driven by an extreme rainfall event led to major county wide impacts.

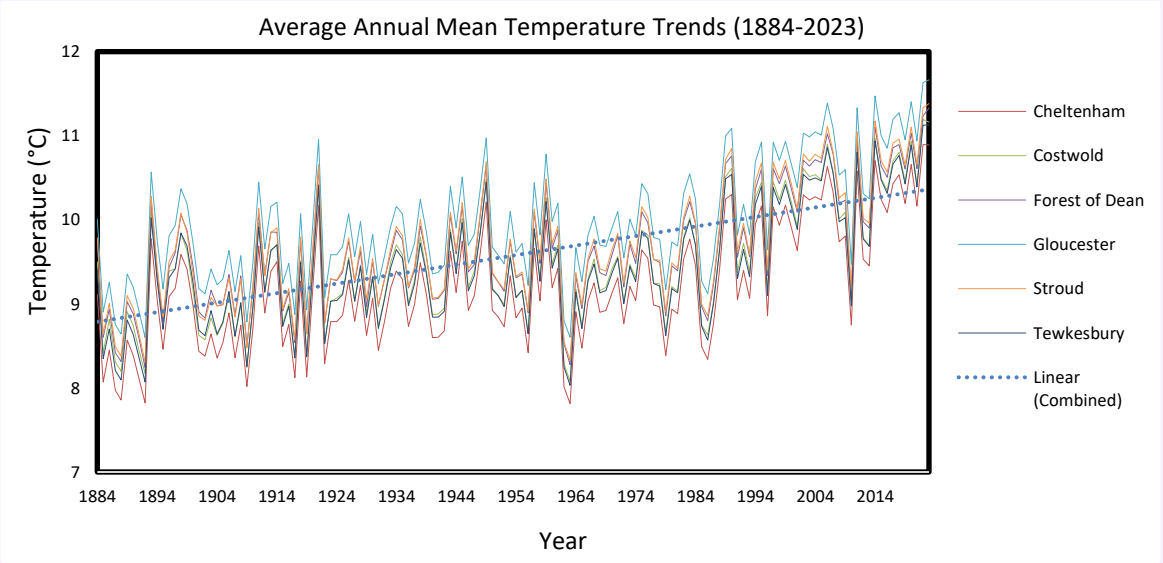


Figure 4.2 *Average Annual Mean Temperature Trends (1884-2023) for Gloucestershire across all district councils[5]*

4.1 Recent history of extreme weather events

2003

June- August, UK-Wide Heatwave

UK wide heatwave impacted all UK regions in 2003, with 2,045 excess deaths in August 2023.[1]
Reported health issues of heatstroke, dehydration, respiratory issues.[1]This heatwave severely impacted Gloucestershire along with the entire of the UK.

2007

July - Fluvial Flooding

140mm of rainfall fell within 24 hours[2].
3 deaths were reported[2]
£50 million damages[2]
5,000 properties damaged, with 825 homes evacuated[2]
Power and water shortages were widespread. Over 135,000 homes were without drinking water for 17 days[2,3].

2014

January - Fluvial Flooding

Heavy rainfall led to rivers overflowing and widespread surface water flooding
Roads and railways were impassable due to floodwaters
Financial losses for residents and local businesses impacted the county[4].

2018

February - Beast from the East

Substantial heavy snowfall, with some areas recording up to 57cm of snow
Many schools were closed for several days, whilst key transport routes such as the A417 and M5 were closed[5]

July- Heatwave and Drought

Maximum temperatures of 29°C[6] recorded across Gloucestershire County.
5th driest summer in England with <5mm of rainfall across SW England[7]

2020

February - Storm Dennis

Heavy rainfall led to River Severn flooding.
Winds of 50mph were reached.[8]

May- Drought

Gloucestershire rainfall in May was 20% of the average from 1991-2020 which was a trend that carried through the summer[9].

August- Heatwave

Gloucestershire reached over 35°C on August 12 in a 3-day long heatwave.[10]
High temperatures led to a loss of productivity.

2022

February- Storms Dudley, Eunice and Franklin

Multiple storms caused >84mm of rainfall in 8 days in Gloucestershire[11]

June- August High Temperatures, Fires and Drought

Consecutive days over 30°C recorded in Gloucestershire . [12]
Gloucestershire Fire and Rescue Service were called out to 53 grassland incidents in August. [13,14]
River flows in Gloucestershire and Southwest England were exceptionally low from June – August. [13,14]

2024

January - Storm Henk

A417 closure, homes and businesses damaged [15]
Loss of one life from high winds in Kemble[16]
River levels at Severn/Avon confluence were highest since 2007 [17]

November -Storm Bert

Lydney Practice closed due to flooding[18]
Many school closures in Gloucestershire
Parts of the A40 and M5[18] were closed.

December - Storm Darragh

Significantly high wind speeds of almost 60mph in Gloucestershire[19]

2025

January- Heavy rainfall and Snow

Several roads including the M50 Eastbound and M5 Southbound were closed.
Train disruption between Bristol and Gloucestershire [20]

June-July Heatwaves

High temperatures across Summer from June –July with amber heat health alert issues by the UKHSA.
4 Heatwaves experienced in the region.
Temperatures reached up to 34°C in August in Gloucestershire[21]

Note: All facts and statistics on the various extreme weather events are relevant to Gloucestershire, with the exception of those included for the 2003 UK Wide Heatwave.

4.2 Future climate of Gloucestershire

Climate change is already impacting Gloucestershire, causing an increase in extreme weather events especially surface water flooding, river flooding, extreme heat, droughts and storms. Across the UK, the Met Office has projected that UK winters will become warmer and wetter whilst summers become hotter and drier. Figure 4.3 presents climate projections across a number of climate indicators for Gloucestershire across a variety of climate change scenarios.

Data Sources

Data used to inform the projected climate trends are primarily from the United Kingdom Climate Risk Indicators Website[4] which models indicators of climate risk across the UK.

	Heatwave Events Three consecutive days with daily maximum temperatures meeting or exceeding the heatwave threshold of 27ºC	Amber-heat health alerts Adverse weather impacts are to be felt across the whole health service	Cold Weather Alerts Considers adverse cold weather and health-sector resilience	Annual maximum Potential Soil Moisture Deficit Balance between rainfall input and losses through evaporation and transpiration	MOFSI Very High Fire Danger Met Office Fire Severity Index combines temperature, humidity, wind and rainfall to estimate days in a given period when fire conditions reach the "Very High" level
2080s High Emissions Scenario	**4 per year**	**<4 per year**	**1 event per year**	**459.2mm**	**78 days per year**
2080s Medium Emissions Scenario	**3 per year**	**<2 per year**	**<2 events per year**	**365.9mm**	**56 days per year**
2050s High Emission Scenario	**3 per year**	**1 per year**	**<2 events per year**	**335.9mm**	**48 days per year**
2050s Medium Emission Scenario	**2 per year**	**<1 per year**	**2 events per year**	**299.2mm**	**39 days per year**
Baseline Period (1981-2010)	**1 per year**	**<1 event per year**	**3 events per year**	**216.5mm**	**21 days per year**

Figure 4.3 *UKCRI Indicators in the baseline period for Gloucestershire. 2050s medium and high emissions scenario and 2080s medium and high emissions scenario [4]*

Explainer: What are emissions scenarios?

- There are a number of potential scenarios in which the climate may change in the future. These scenarios are based on how much greenhouse gas is emitted in the coming decades. These are known as Representative Concentration Pathways (RCPs)[1].
- A medium emissions scenario, assumes that greenhouse gas emissions peak around 2040 and then decline, leading to a moderate level of warming [2]
- A high emissions scenario assumes emissions continue to rise throughout the century resulting in higher levels of warming.

4.2 Future climate of Gloucestershire - Temperature

How hot will a high emissions scenario be?

- Heatwaves are defined by the Met Office in Gloucestershire as **at least three consecutive days when maximum temperatures are equal to or greater than 27°C**[3]. Heatwaves are becoming more frequent as temperatures increase in Gloucestershire (Figure 4.4).In 2025, Gloucestershire recorded four heatwave events in 2025, matching the number projected annually by the 2050s, highlighting that future conditions are already being experienced today.. Heatwaves can cause overheating in buildings, disruption to healthcare services, potential for wildfires and increased health issues, including heat-related mortalities.
- By the **2080s, annual average temperature** change may rise by up to **4°C** in a high emissions scenario (Figure 4.5).
- In addition, as temperatures warm, more amber-heat health alerts are projected (see Figure 4.3). Currently, there are 1 or fewer amber heat health events per year, which will increase to 2 or fewer in 2050s scenarios. These events are tied to heatwave events and are issued in situations where the entire population is at risk, whilst NHS and emergency services are under increased demand.

Cold Spells

Cold spells are categorised as cold weather lasting a period of days or weeks where the temperature falls below a set threshold. As temperatures increase, cold spells are projected to decrease. **Despite the frequency of cold spells decreasing, large intense events may occur due to jet stream and atmospheric changes.**

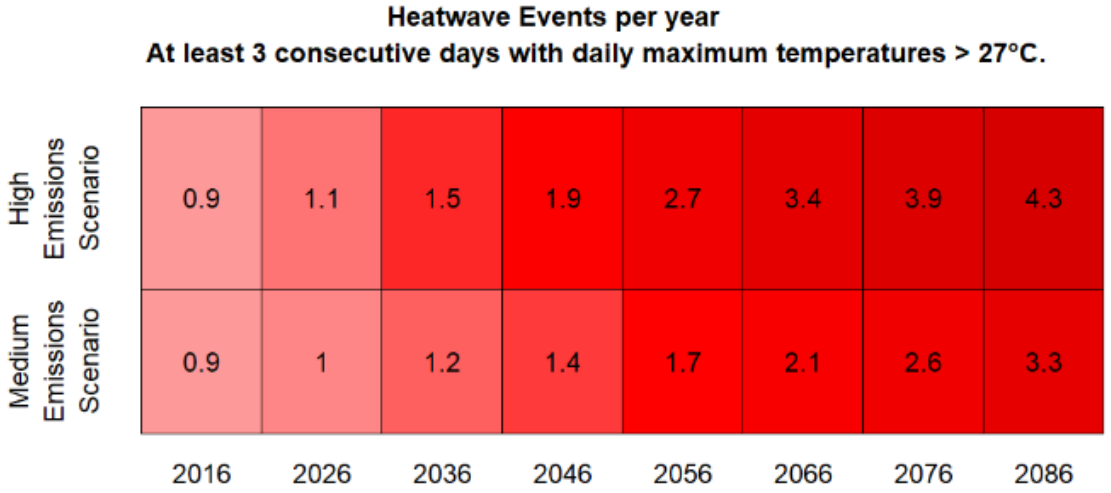


Figure 4.4 *Median Heatwave Events per Year in Gloucestershire*[4]

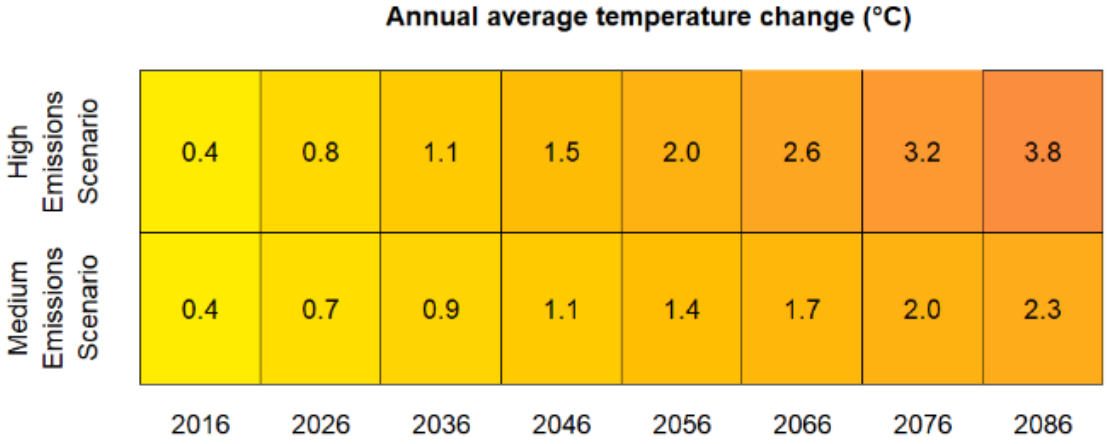


Figure 4.5 *Median Annual Average Temperature Change (°C)*[4]

4.2 Future climate of Gloucestershire - Flooding

Gloucestershire is susceptible to surface water, river and tidal flooding, sea level rise, and as the climate warms, an increase in all flooding types is projected.

Surface Water Flooding

Gloucestershire is already at risk from surface water flooding (Figure 4.6- see Figure B.5 for a larger map), due to overwhelmed drainage systems, low-lying terrain and impermeable surfaces which prevent surface water from soaking into the ground. As the population is projected to grow and the need for further urban development continues, this risk will become more pronounced, especially in urban areas. In particular, Cheltenham, Tewkesbury and Gloucester are prone to surface water flooding due to dense urban development and limited natural drainage. As climate change is exacerbated, the risk of surface water flooding increases.

Risk Category	Present Day Risk Area (km²)	High emissions scenario 2050 Risk Area (km²)
High	47	62
Medium	24	33

Table 4.1. *Area of Gloucestershire at high and medium risk from surface water flooding* [5]

River, Tidal Flooding and Sea Level Rise

As shown in Figure 4.7, the risk of flooding from rivers and seas due to changing rainfall levels and sea level rise, under a high emissions scenario in the 2050s is extensive. The increased risk into the future is centred around the tidal boundary leading into the River Severn and associated tributaries. Gloucester City and Tewkesbury is at particular risk. Communities along the River Severn such as Lydney and Lechlade on the River Thames, which are already at risk will be at higher risk by 2050 with potential for further transport routes to be impacted and business damages in fluvial and sea level rise flooding events.

Risk Category	Present Day Risk Area (km²)	High emissions scenario 2050 Risk Area (km²)
High	151	170
Medium	22	23

Table 4.2. *Area of Gloucestershire at high and medium risk from flooding from rivers and sea level rise*[5]

Data Sources

Data from the Environment Agency's NaFRA2[5] has been used, which looks at the risk from flooding (rivers and sea level rise), as well as surface water flooding, under a high emissions scenario for the present and end of century scenario.

Click Here to see a larger map

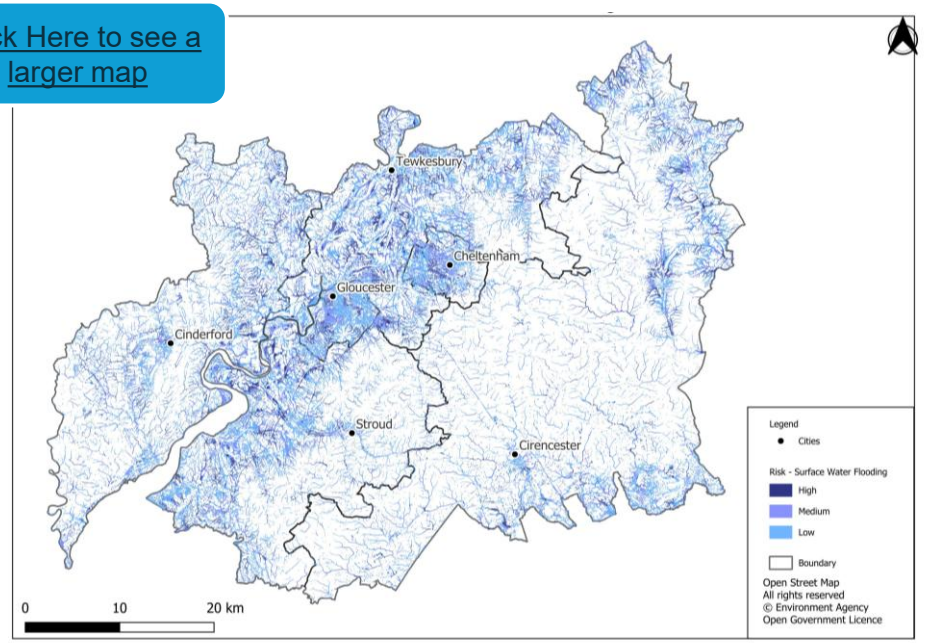


Figure 4.6. *Future risk of Flooding from Surface Water*[5]

13% ↑ **increase** in areas at **high** risk from flooding from rivers and sea level rise

32% ↑ **increase** in areas at **high** risk from surface water flooding

4.2 Future climate of Gloucestershire – River flooding and sea level rise

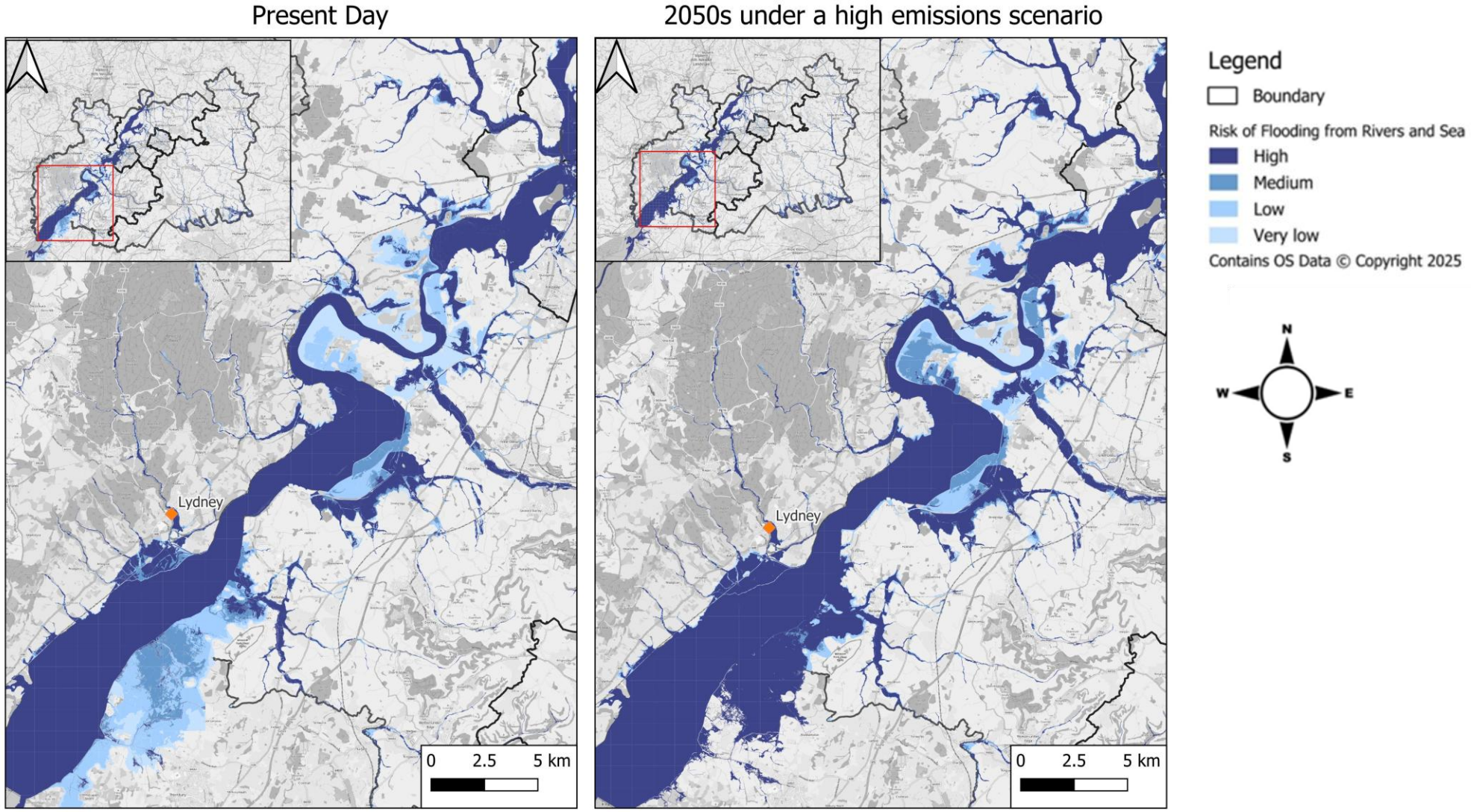


Figure 4.7. *Risk of Flooding from Rivers and Seas under Climate Change driven by rainfall and sea level rise (high emissions scenario 2050s)*[5]

4.2 Future climate of Gloucestershire – Coastal erosion, high winds and storms and wildfires

Coastal Erosion
Coastal erosion is influenced by tidal processes and sea level rise, along with the geology of the land. Coastal erosion is localised in areas around the tidal boundary in Gloucestershire, with areas such as Beachley Peninsula, Gloucestershire's Science and Technology Park and Berkeley Power Station, at risk from coastal erosion by 2055. In addition, by 2055 under a high emissions scenario with Shoreline Management Plans in place, such as the Seven Estuary Shoreline Management Plan, the banks along the River Wye and Severn Estuary will also be at risk.

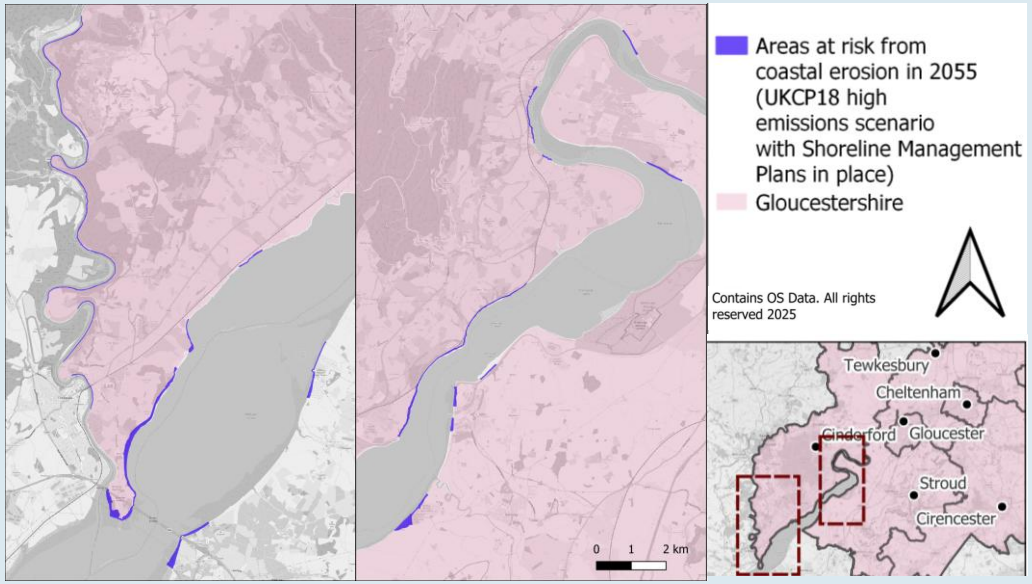


Figure 4.8 *Areas at risk from coastal erosion in 2055 under a high-emissions scenario with Shoreline Management Plans in place*[6]

High Winds and Storms
Trends in storms are difficult to detect, however, evidence for the UK suggests that there has not been an increase in storminess from 1980-present. Projections for the future show that on balance the UK, and Gloucestershire, will see a small increase in the frequency and severity of storms and high winds, in particular in winter. With winter rainfall projected to increase (see Figure 4.12), the potential of storms to cause disruption is expected to escalate

Wildfires
Wildfires are uncontrolled fires that spread rapidly through vegetation such as grasslands, heathlands and agriculture. Wildfires can be man-made or natural. As the climate warms, changes to temperature, humidity, and wind impact the potential for wildfires. By the 2080s, the number of days rated as "Very High" Fire danger on the Met Office Fire Severity Index is projected to rise to 56 days in a medium emissions scenario and 78 days in a high emissions scenario. Highest impacts are seen to the north of the county in Tewkesbury, to the south of the Cotswold District and Forest of Dean. These areas are primarily rural with farmland, woodland and shrubland at particular risk.

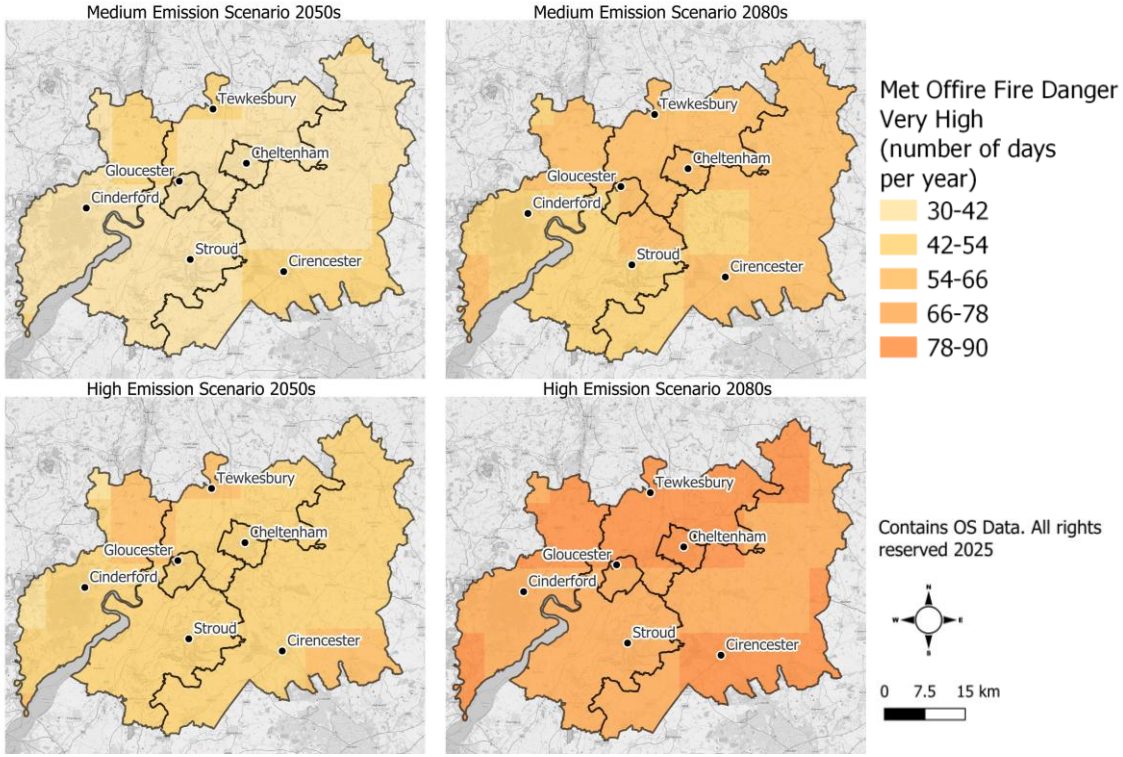


Figure 4.9 *Projected changes of the Met Office 'Very High' Fire Danger in Gloucestershire*[4]

4.2 Future climate of Gloucestershire – Drought and subsidence

Drought
Droughts are projected to occur more often in Gloucestershire as summer rainfall is projected to decrease by the 2050s (see Figure 4.11) under a medium and high emissions scenario. Drought will place pressure on water supplies, adding additional pressure to most sectors in Gloucestershire as well as increasing subsidence risk. Drought can exacerbate subsidence as the soil moisture content decreases, drying out the soils, shrinking the soils and can cause the ground to move unevenly[7,8].

Under a high emissions scenario, soil moisture deficit is projected to increase by as much as 55% by the 2050s. These changes will be pronounced (as shown in Figure 4.10) around the south and east borders of the Cotswolds, north of Tewkesbury borough and to the north of the Forest of Dean District.

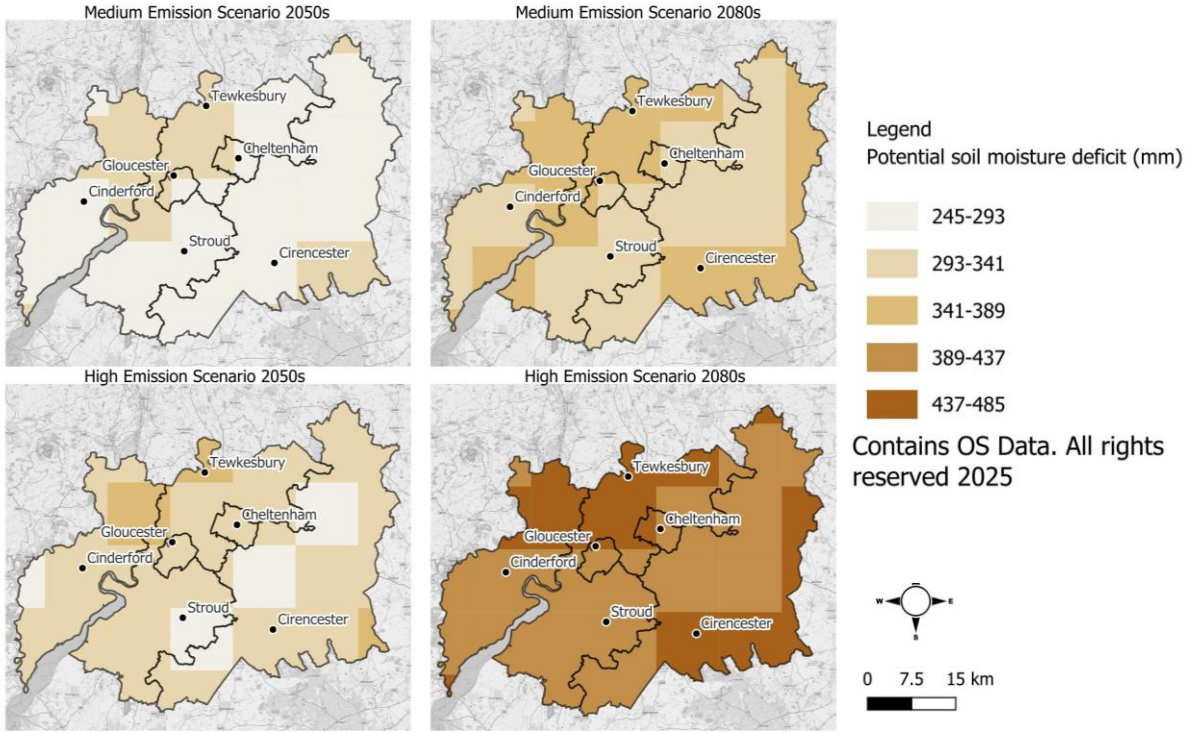


Figure 4.10. *Projected changes in Potential Soil Moisture Deficit in Gloucestershire [4]*

Summer Rainfall Change (%)

	2016	2026	2036	2046	2056	2066	2076	2086
High Emissions Scenario	-2.3	-5.6	-8.6	-12.7	-19.0	-24.0	-29.0	-35.7
Medium Emissions Scenario	-1.8	-4.0	-6.3	-9.1	-13.5	-16.8	-19.8	-23.9

Figure 4.11 *Change in summer rainfall in relation to the baseline period 1981-2010 [4]*

Winter Rainfall Change (%)

	2016	2026	2036	2046	2056	2066	2076	2086
High Emissions Scenario	2.7	5.3	6.8	9.1	11.9	15.7	20.0	24.2
Medium Emissions Scenario	2.4	4.5	5.3	6.6	8.0	10.2	12.5	14.7

Figure 4.12. *Change in winter rainfall in relation to the baseline period 1981-2010 [4]*

4.3 Extreme futures and surface water flooding

Flooding in Gloucestershire is a key climate hazard, with particularly large flooding events in 2007 and 2014 leading to widespread disruption. As the climate changes in future, extreme rainfall events are projected to increase across the UK, leading to more flooding events. This analysis outlines:

- **How Gloucestershire will be impacted by the most extreme flooding events;**
- **Assessment of what rainfall events storm drainage infrastructure will need to be designed to**, to cope with these extreme events;
- Where it is not plausible to manage the impact of extreme flooding events through design**, which proactive management methods can be planned** before and after an event to aid recovery.

Past extreme events

To set the scene for past extreme flooding events in Gloucestershire, the July 2007 flooding event is used as a case study of rainfall which led to severe impacts. **Rainfall intensity, or hourly rainfall, during the July 2007 flooding peaked at 21.2 mm/hour in Brize Norton** to the west of the Gloucestershire border in West Oxfordshire[1]. This statistic is used to understand the extent of flooding impacts if these extreme events become more frequent.

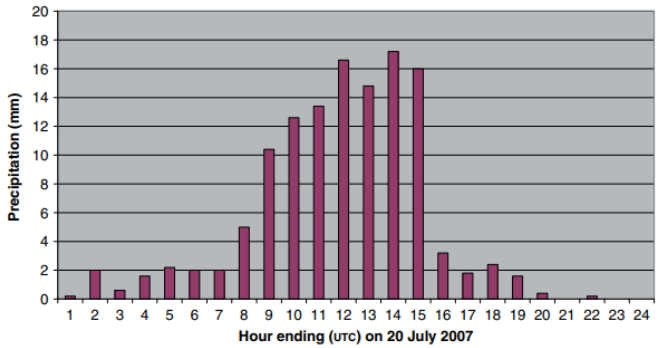
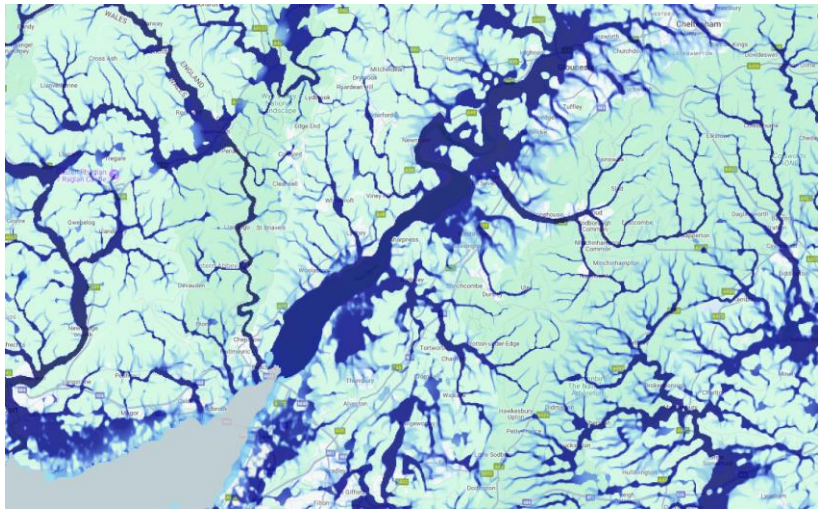


Figure 4.13. *Hourly rainfall totals (rainfall intensity) at Brize Norton during the 2007 flood event.* [1]

The **Fast Flood App**[2] was used to simulate the extent of flooding and depths associated with the 2007 event, this provides an understanding of what a currently 'extreme flood' extent will be, which may become a more common storm. **This exploratory tool of rainfall levels and hazard extents demonstrates how flooding extents can be viewed for extreme events such as 2007 occurring across the county compared to a "normal" heavy rainfall event (Figure 4.14).**

2007 event: 21mm/hr 7-hour duration



'Average' heavy rainfall: 4mm/hr 2-hour duration

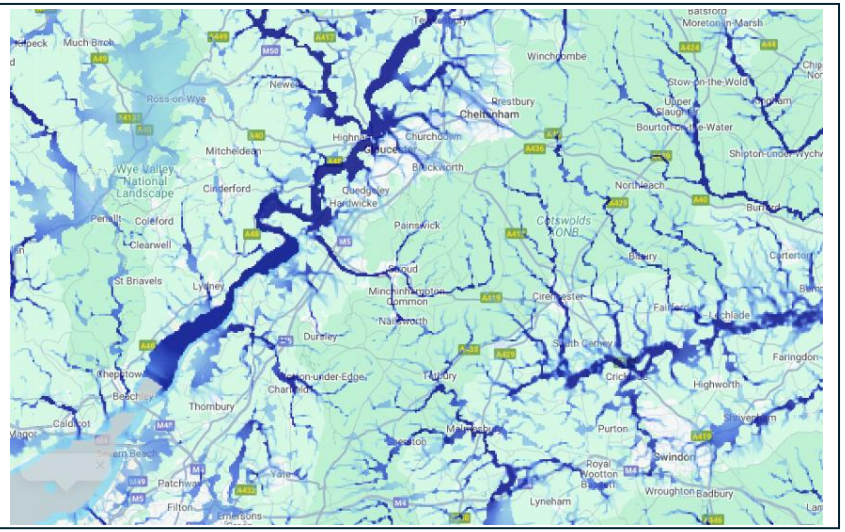


Figure 4.14. *Rainfall extents under an extreme rainfall event (the July 2007 flooding event in Gloucestershire) and an average heavy rainfall event,* [2]

4.3 Extreme futures and surface water flooding

Designing drainage infrastructure to cope with heavy rainfall

Storm drainage infrastructure will need to be designed or retrofitted to cope with more extreme events in future. The **Future Drainage project** presents recommended rainfall uplifts for designers to apply to drainage designs to better cope with future extreme rainfall events[3]. These are presented across **different return periods** of a storm event (e.g. 1 in 100 year flood is a 1% chance of this storm event occurring each year) and **different durations** of storm events from 1 hour to daily durations (e.g, 24 hours).

The uplifts provided are estimates for a high emissions or worst-case scenario (RCP8.5) for the 2050s and 2070s against a baseline period of 1981-2000. The data has been provided by a Newcastle University led consortium involving the Met Office, JBA Consulting, Loughborough University[4].

Table 4.1 *Gloucestershire County Council Future Drainage Uplifts[4]*

		2050s (% drainage uplift)		2070s (% drainage uplift)	
Event duration	**Return Period**	*50th Percentile*	*95th Percentile*	*50th Percentile*	*95th Percentile*
1 hour	1 in 2 year	19.1%	30.0%	23.4%	35.0%
	1 in 30 year	20.0%	35.0%	25.0%	35.2%
	1 in 100 year	19.8%	35.0%	20.0%	35.6%
12 hours	1 in 2 year	12.1%	22.4%	16.8%	29.9%
	1 in 30 year	15.8%	30.1%	23.3%	38.3%
	1 in 100 year	19.6%	34.6%	25.0%	42.2%
24 hours	1 in 2 year	11.7%	23.9%	15.8%	30.9%
	1 in 30 year	15.0%	30.8%	20.1%	38.2%
	1 in 100 year	15.4%	35.2%	21.2%	41.3%

These uplifts show that drainage design should increase to be able to manage storm flood water across sub-daily (e.g. 1 hour) to daily durations (e.g. 24 hours). As the storm duration increases from 1 hour to 24 hours, drainage design must be increased to manage greater volumes of water (Table 4.1). As the return period increases, more extreme events will require an increase in drainage capacity. In the future (2050s and 2070s), drainage uplifts increase, indicating heavier rainfall and a need to design drainage to manage more frequent rainfall.

Management of heavy rainfall events

As heavy rainfall events become more frequent, preparing, anticipating and responding to these events will be key. Opportunities to minimise risks are explored in detail later in this report. Figure 4.15 illustrates how extreme heavy rainfall may overwhelm drainage systems and suitable management strategies which will be required to adapt to these rainfall events. These figures may be conservative and should be a starting point to define future management approaches.

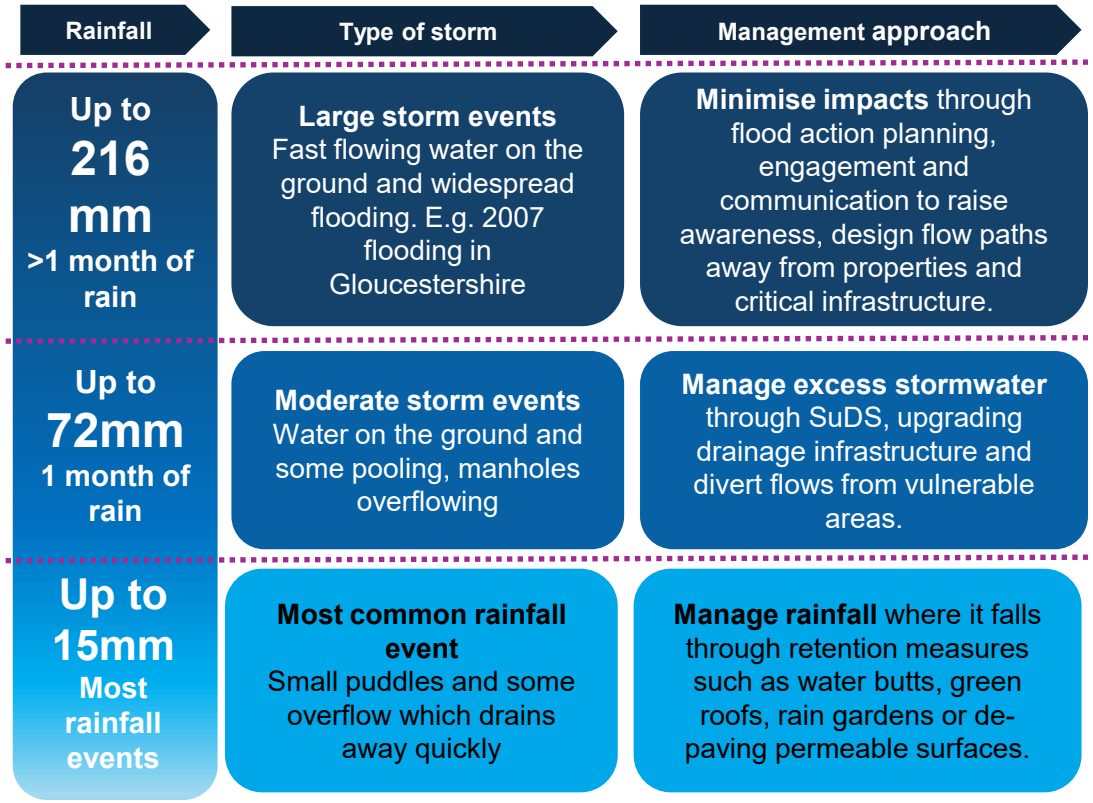


Figure 4.15. *Management of extreme heavy rainfall events. Adapted from the London Surface Water Strategy and updated with known Gloucestershire rainfall figures[5]*

4.4 Vulnerability of Gloucestershire's people to climate change

The impacts of climate change are not experienced equally, and certain groups within Gloucestershire are more vulnerable than others. This can stem from limited resources, reduced mobility, or systemic inequalities that affect their ability to prepare for, respond to, and recover from climate impacts. Common vulnerable groups include **low-income households, elderly individuals, children and infants, people with disabilities or chronic illnesses, ethnic minority groups and those who live in deprived or isolated rural communities.**

Present day land surface temperatures overlain with the most 20% most deprived areas indicate that **areas of higher deprivation in Gloucestershire are vulnerable to risks from overheating** (Figure 4.16). A large concentration of deprived areas are in Cheltenham, Tewkesbury and Gloucester. Deprived areas in the Forest of Dean are at less urban locations and therefore the risks from overheating are lower[1].

Rising temperatures and more frequent heatwaves increase the risk of overheating, particularly for vulnerable groups. This includes **ethnic minority communities** who may not speak English as a first language and therefore may have limited access to information about climate risks and how to stay safe during extreme heat events. **Elderly people** may also struggle to adequately support themselves during heatwaves, leading to dehydration and other adverse health impacts. It is key for local authorities to consider communications that reach all audiences in a variety of formats and languages with regards to extreme weather[2,4]. Heatwaves and increasing temperatures also result in heat stress, lower productivity and heat-related mortality, with **outdoor workers** at risk to the impacts of extreme heat[3].

Marginalised communities are more vulnerable to the effects of climate change. This includes groups that may be systematically excluded from society due to race, sexual orientation, religion, etc. **LGBTQIA+** individuals may face higher risks of **homelessness and unstable housing**, which will increasingly become a challenge as storms intensify, flooding becomes more likely, and temperatures rise.[10,11] In response to this in the Forest of Dean, the LGBTQIA+ community have created a Community Climate Action Plan.

Relocation due to flood damage in homes can cause **mental health impacts**, while some vulnerable groups (those in poor health, physically disabled or elderly), may struggle with preparing and responding to flood events. They may struggle to lift sandbags and exiting their property due to mobility issues[2]. Moisture ingress can cause damp and mould, which may impact **those with pre-existing health conditions**.

Long-term impacts on properties (such as damp and mould from flooding or structural damage from high winds and storms) may affect the **recovery of low-income groups to climate-related events**, who may struggle to fund repairs[2]. **Community buildings** (places of worship, community centres and schools) may remain **closed impacting education and morale of vulnerable groups. Climate anxiety** may also become prevalent due to repeated episodes of flooding creating **mental health impacts**. Tewkesbury, one of the most deprived areas in Gloucestershire (Figure 4.17) was heavily impacted by the 2007 flooding. Overall, 38% of homes and 43% of businesses in Gloucestershire were affected by flooding during the 2007 flood event.[8]

POOR HEALTH

4.3% of the population are in bad or very bad health. Forest of Dean has the largest proportion of people who have poor or very poor health (5.5%).[5]

ELDERLY POPULATION

22.1% of Gloucestershire's population is aged 65+ and often are more vulnerable to the impacts of extreme heat and flooding.[6] In comparison, the national proportion of those aged 65+ at 18.7%. Over the next few years, the proportion of frail elderly population in Gloucestershire is projected to increase[9].

SOCIAL RENTING

Across Gloucestershire **13.1%** of the population socially rent and are less able to make adaptations to properties, as they do not own their homes.[7] This is in line with the regional average, but lower than the national average.

DISABLED UNDER THE EQUALITY ACT

Across Gloucestershire **16.8%** of the total population are disabled under the Equality Act compared to 17.3% in England, with Gloucester City (17.4%) and Forest of Dean (19.2%) higher than the region's average.[5]

4.4 Vulnerability of Gloucestershire's people to climate change

This section focuses on vulnerability of Gloucestershire's people to climate change relevant to various sectors. These sectors are set out in more detail in Chapter 5 Climate Risk Assessment.

Health

- Elderly and disabled individuals may struggle to access help that they rely on due to mobility limitations, which may prevent them from reaching emergency services.[2,4]
- Access to medical care may be disrupted during extreme events, affecting those with chronic or existing medical conditions.
- Older people, people with existing medical conditions, pregnant people are more vulnerable to overheating and heat stress during heatwave events.
- Heatwaves and flooding can exacerbate health issues, particularly for vulnerable groups.
- Emergency responders may face long-term health impacts from events such as flooding and wildfires, including mental health challenges and carcinogen risks.

Natural Environment

- Communities near the Severn Estuary are at risk from flooding and coastal erosion.
- Residents in wildfire-prone areas, such as the Forest of Dean and Cotswold grasslands, face increased exposure to fire hazards.
- Urban ethnic minority groups may have limited access to green spaces, reducing their ability to access shade and refuge during heatwaves.

Business & Industry

- Business owners near the Severn Estuary and other flood risk areas are vulnerable to repeated flooding, risking closures and income loss. Repeated flood events may also cause mental health impacts.
- Outdoor workers are exposed to extreme heat, increasing risks of dehydration and heat-related illness.[3]

Built Environment

- Renters may not be able to adapt their home to prepare for the effects of climate change such as reducing heat exposure.
- Many schools are located in flood-prone areas, disrupting children's education. See Chapter 5.2 for more information.
- Low-income households may face financial challenges in recovering from flood or storm damage.[2]
- Migrants and ethnic communities may live in urban areas, which are more exposed to overheating.
- Homeless individuals are directly exposed to extreme weather and are often unable to access information on weather warnings[12]

Infrastructure

- Public transport users may be disproportionately affected by disruptions caused by flooding and heatwaves.
- Women, who are more likely to rely on public transport, may face greater challenges to reaching key services during extreme events.[14]
- Rural communities may be more at risk from water, ICT and electricity networks being cut off and/or being isolated due to flooding and strong winds

Agriculture

- Climate change directly impacts crop yields and livestock productivity making farmers livelihoods vulnerable to climate change. Farmers may have to expend more labour and time to prepare for flooding and storm events such as relocating cattle and sheep to high ground.
- Rural communities and businesses may rely on local food produce, and therefore affected by the impacts of climate change on agriculture

4.4 Vulnerability of Gloucestershire's people to climate change

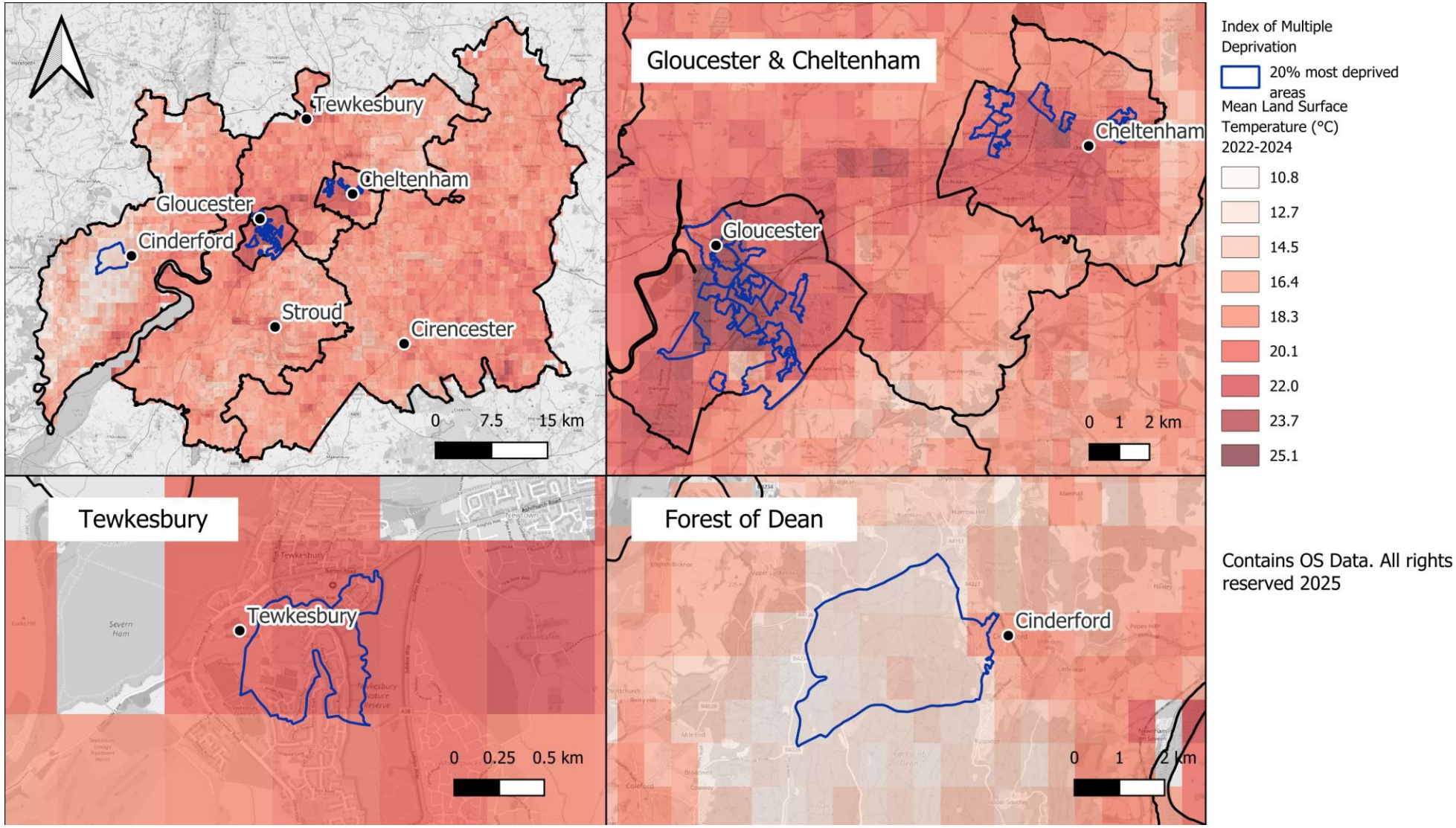


Figure 4.16. *20% most deprived areas in the UK in Gloucestershire and mean land surface temperatures from 2022-2024.*[9]

4.4 Vulnerability of Gloucestershire's people to climate change

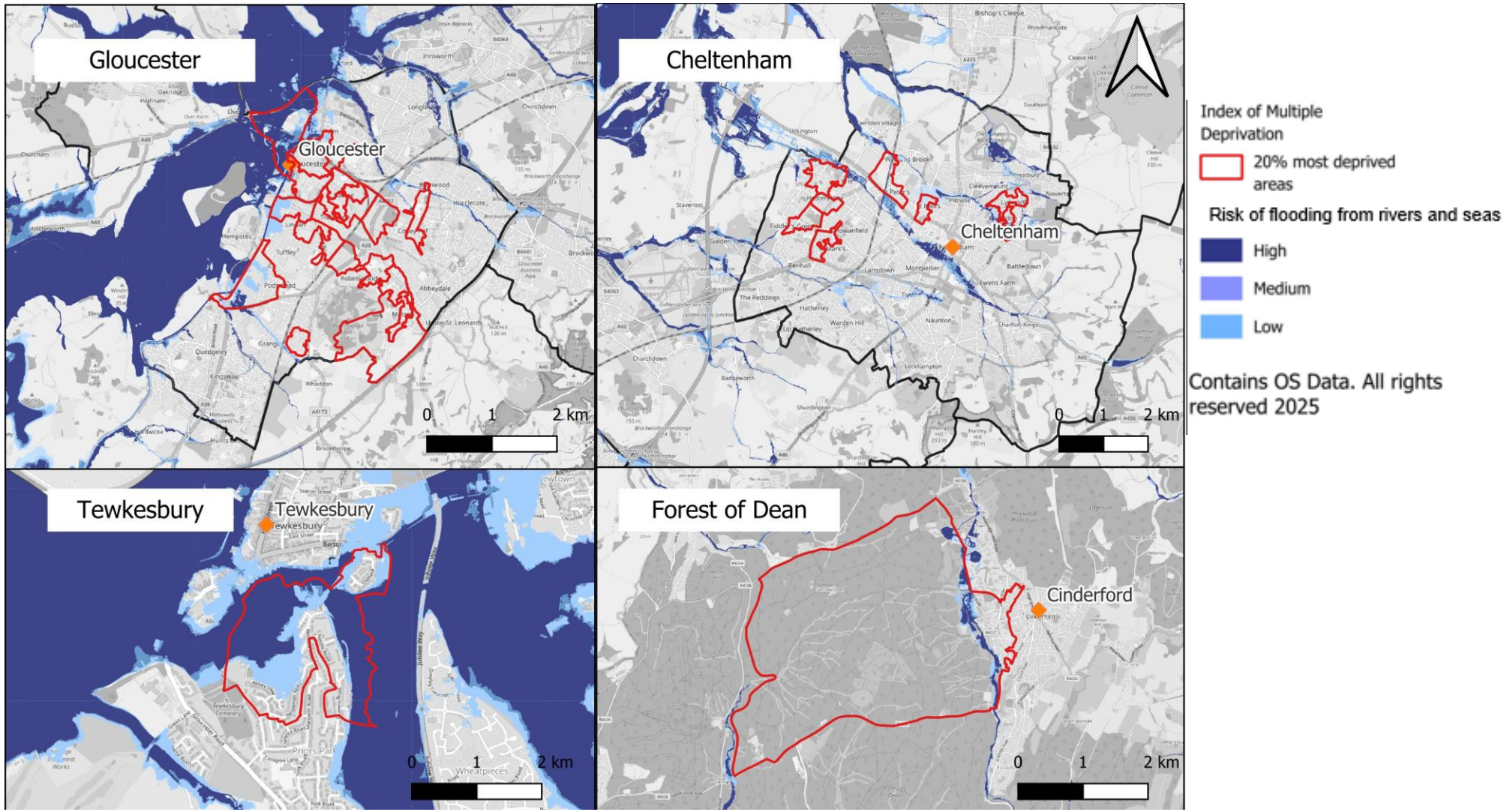


Figure 4.17. *20% most deprived areas in the UK in Gloucestershire and risk from flooding from rivers and seas in the 2050s under a high emissions scenario*

5. Climate Risk Assessment of Gloucestershire's key sectors

Sector specific climate change risk assessments are essential to ensure a comprehensive understanding of the most likely and impactful climate hazards for different organisations and communities.

Six key sectors are presented in this report. These sectors broadly align with those of the UK's CCRA3[1] and were identified as key to Gloucestershire throughout the stakeholder engagement process. The six themes are outlined below with a guide to select relevant organisations and stakeholders across Gloucestershire. It should be noted however that there is cross over between themes and all results should be reviewed for a full understanding of Gloucestershire's climate risks. In addition to the organisations and stakeholders listed below, members from across Gloucestershire County Council, Stroud District Council, Tewkesbury Borough Council, Cotswold District Council, Forest of Dean District Council, Gloucester City Council and Cheltenham Borough Council were also engaged with for each sector. Engaged representatives included specialists from housing, planning, transport, environment, public health, facilities and operations, community services, and emergency planning

Sector	Description	Select relevant organisations and stakeholders
Health	Health impacts from climate change and on health and social care delivery.	Gloucestershire Hospitals NHS Foundation Trust, Gloucestershire Health and Care NHS Foundation Trust and Gloucestershire Integrated Care Board, Primary Care and Ambulance Service,
Built Environment	Buildings including residences, education centres and community facilities.	Housing Associations, universities, volunteer groups
Business & Industry	Supply chain resilience, distribution networks and business sites and locations.	Gloucester Chamber of Commerce, Growth Hub Business Support, Business Members Group.
Natural Environment	Terrestrial and freshwater habitats and species, soil health and agriculture and forestry productivity.	Gloucestershire Local Nature Partnership, Environment Agency, Severn Rivers Trust, Natural England and Forestry England
Agriculture	Agricultural industry including crops, dairy farming, beef pastures and orchards.	Gloucestershire Local Nature Partnership, Farming and Wildlife Advisory Group and NFU Mutual
Infrastructure	Water, energy, transport, ICT networks.	BT, National Highways, Gloucestershire Fire and Rescue, water companies, National Grid, UK Power Networks and South West Infrastructure Partnership

5.1.Health – Climate Risk Assessment

Key risks

Climate change and extreme events are already placing a significant burden on healthcare in Gloucestershire. This assessment provides an analysis of key risks and their impacts, to inform the healthcare services delivered by Gloucestershire Health and Care NHS Foundation Trust, Gloucestershire Integrated Care Board, Gloucestershire Hospitals NHS Foundation Trust and South Western Ambulance Service NHS Foundation Trust.

Table 5.1. *Healthcare Risks to Gloucestershire County Council*

Hazard	Risk
Surface water flooding	Risks to health and social care delivery from surface water flooding
River, sea level rise and tidal flooding	Risks to health and social care delivery from river, sea level rise and tidal flooding
High temperatures	Risks to health and social care delivery from high temperatures
High temperatures	Risks to public health and wellbeing from high temperatures

Likelihood

Heatwaves in Gloucestershire have impacted individuals' health and healthcare delivery, including the summers of 2018, 2020, 2022 and 2025 heatwaves (see section 4.1). High temperatures and heatwave events are projected to increase in the 2050s and 2080s, increasing these risks to health and social care delivery along with public health and wellbeing (Figures 4.4 and 4.5). In the 2050s, the probability of heatwave events increases from up to 2 events a year under a medium emissions, to up to 3 events a year under a high emissions scenario. Similarly, amber-heat-health-alert events per year increase from less than 1 event per year in 1981-2010 to 1 per year in the 2050s under a high emissions scenario. Under a high-emissions scenario by the 2080s, average annual temperatures in Gloucestershire are projected to increase by up to 4.3ºC compared to a 1980-2010 baseline period.

Increases in heavy rainfall will lead to more frequent surface water flooding, with the potential for rainfall extremes to significantly disrupt both healthcare infrastructure and provision[1]. Winter rainfall is expected to increase under both medium (+8%) and high (+12%) emissions scenarios, increasing the frequency of river flooding in the absence of further protection measures, coupled with sea level rise (up to 20-30cm by 2050). Contingency planning for how to ensure continued delivery of critical healthcare services should incorporate such extreme flood scenarios.

Who we engaged with:

NHS Gloucestershire Hospitals

One Gloucestershire – Transforming Care, Transforming Communities

NHS Gloucestershire Health and Care NHS Foundation Trust

Gloucestershire County Council

Impacts

Climate change impacts both physical and mental health. It is recognised as an important driver of excess mortality, admission to hospitals and reduction in quality of life[2] – both through the impact of extreme events, as well as interactions with other health-related drivers such as air quality, and chronic conditions. For example, heatwaves increase the concentration of ground-level ozone and fine particulate matter increasing air pollution, posing additional risks, in particular for those with respiratory conditions[3] which can lead to people being admitted to hospital.

Key impacts include both damage to healthcare facilities from extreme weather (e.g. floods and storms), as well as significant weather-related increases in demand for healthcare services, in particular during periods of extreme heat and cold. Responding to climate change therefore requires a combination of measures to increase the resilience of healthcare facilities, alongside programmes to enhance community resilience and response, and reduce peak demand on services.

Table 5.2. *Excess Deaths in Gloucestershire due to extreme heat.*[4]

Year	Excess deaths in Gloucestershire due to heat	Number of heat periods	Number of days in a heat period
2020	31	3	19
2021	80	2	12
2022	96	4	42

High temperatures and extreme heat can lead to overheating of homes and physical health conditions such as heat stress, dehydration and heart attacks[5]. In particular, vulnerable individuals such as the elderly and those with pre-existing conditions are at risk from heat stress and dehydration during heatwaves[6]. These impacts can lead to a significant rise in admissions to hospitals and GP practices in and following climate-related events. See section 4.3 on more information of impacts to vulnerable communities.

5.1 Health – Climate Risk Assessment

Impacts

Flooding Impacts on Health and Social Care Delivery

Figure 5.1 shows the impact of flooding on GP practices and hospitals, within Gloucestershire. Sites at risk from river, sea level rise and tidal flooding in a high emissions scenario by 2050 include; Lydney Health Centre, Stroud Locking Hill Surgery, Winfield Hospital and Tewkesbury Community Hospital. Healthcare sites are likely to be exposed to flooding in the future as the likelihood of flooding increases across all emissions scenarios. As demonstrated in Table 5.3, there is an 60% increase in GP surgeries at high risk from flooding from rivers and sea by the 2050s under climate change. Facilities in Tewkesbury, Berkley and Cheltenham are at risk from increases in river flooding (see Figure 5.1).

The increase in sites exposed to surface water, river, sea level rise and tidal flooding is likely to cause greater physical damage to buildings during flood events. Water supplies could be cut off, and ambulances or healthcare vehicles may be unable to reach vulnerable individuals if roads are disrupted. Flooding can further hinder healthcare delivery by preventing staff from accessing facilities and delaying the transport of essential medical supplies. Elderly and disabled individuals are particularly at risk, as they may struggle to access the help they rely on, either due to disruption of at-home services or mobility limitations that prevent them from reaching emergency centres.

Displacement from homes and the financial burden of repairs can lead to significant mental health impacts, adding pressure on healthcare services.[7] Access to healthcare may be restricted, with operations postponed. For example, in May 2025, flooding at Cheltenham General Hospital caused major disruption, including the cancellation of medical scans due to damage requiring repairs.[8]

NHS Gloucestershire stakeholder engagement impacts

The NHS in Gloucestershire have experienced impacts from all types of flooding but mostly surface water flooding. The following impacts were discussed during workshops and interviews:

- As a result of previous flooding events, catering and cleaning costs increased.
- Following flood events, some hospital sites have experienced a surge in patient numbers, leading to increased demand for treatments. To meet the demand, many individuals subsequently had to be transferred to nearby hospital sites for treatment and discharge.
- In addition, district nurses were unable to travel to homes and healthcare staff struggled to travel to work during the floods due to damages and transport links impassable or not in operation[7].

High Temperatures Impacts on Health and Social Care Delivery

Multiple impacts on the health sector in Gloucestershire have been experienced, in particular during the heatwaves of 2022-2023. These events significantly impacted hospital operations, causing key surgeries to be postponed, whilst medicines had to be disposed of due to storage conditions (temperature thresholds) being exceeded[7].

Public health and wellbeing

Overheating impacts vulnerable groups, for example, elderly people are particularly susceptible to the health impacts of overheating. Outdoor workers are highly exposed to extreme heat[9] and are at risk of dehydration and conditions, such as sunstroke without adequate breaks and sun protection. This may result in a greater demand for healthcare services due to severe dehydration, heat stroke, dizziness and mental health impacts[10] increasing ambulance calls and medical visits. For more information see section 4.4 on Vulnerability of Gloucestershire's people to climate change

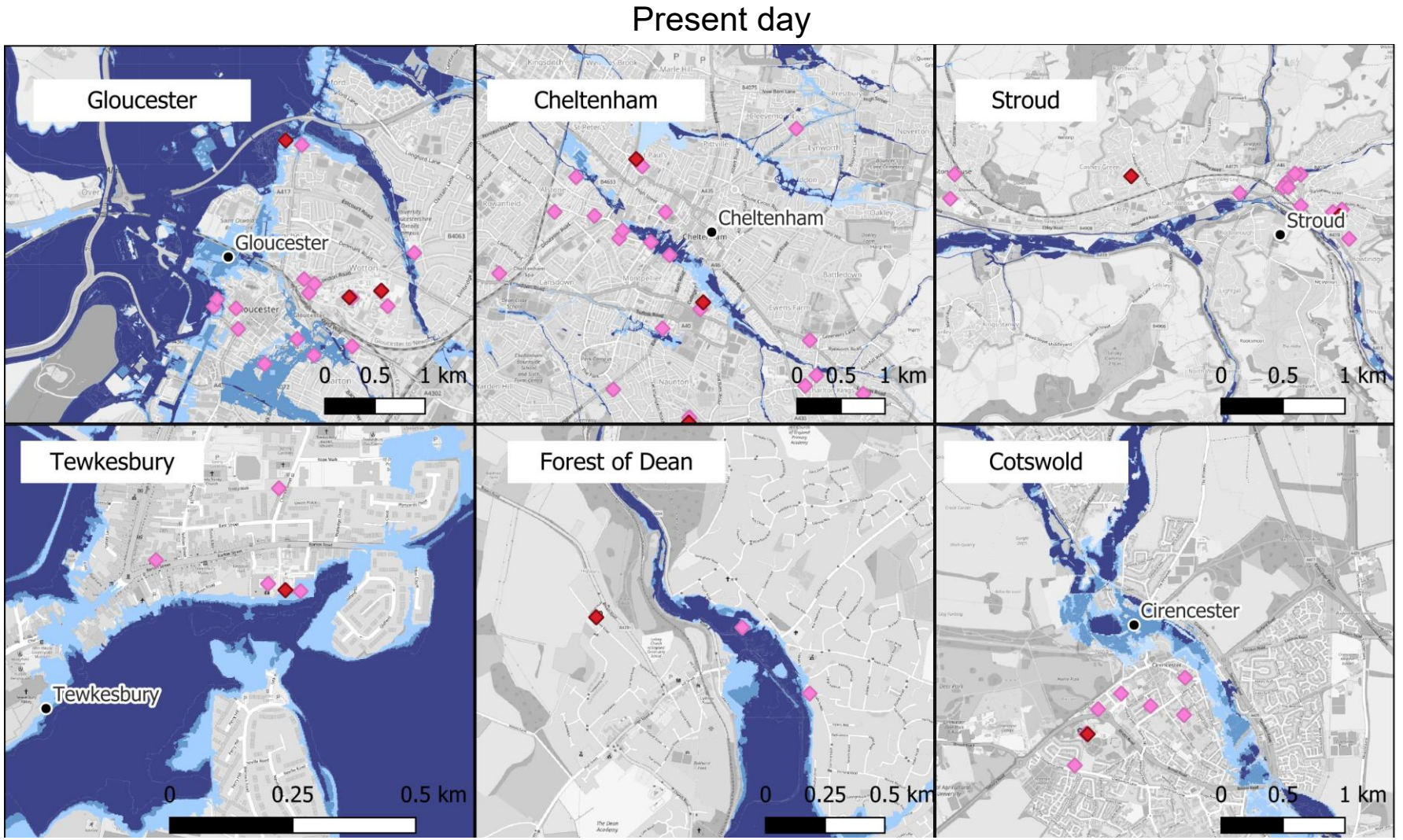
***Table 5.3**. Number of hospitals and GP surgeries at risk from flooding (surface water and rivers and seas) under a high emissions scenario in 2050 in Gloucestershire*

Flooding type	Type	Present flooding	2050s high emissions scenario	Overall change	% increase
		High likelihood (>3.3% chance of flooding each year)			
Surface water	Hospitals (count)	3	3	0	0%
	GP surgeries (count)	2	3	+1	+50%
Rivers and seas	Hospitals (count)	0	0	0	0%
	GP surgeries (count)	5	8	+3	+60%

Vulnerable Groups:

- Pregnant women
- People with disabilities
- People with chronic illnesses
- Elderly population
- Ethnic minorities

5.1 Health – Climate Risk Assessment



Key Locations at Risk:

- Lydney Health Centre
- Stroud Locking Hill Surgery
- Winfield Hospital
- Tewkesbury Community Hospital

Figure 5.1. *Impact of flood risk from rivers and seas (including sea level rise) on hospitals and GP practices in the present day[11]. For changes in present day and future risk to river, tidal flooding and sea level rise see section 4.2. For all of Gloucestershire see Figure B.6*

5.1 Health – Climate Risk Assessment

Risk Outcome

In the baseline there is a medium risk to health and social care delivery and public health and wellbeing from high temperatures. The risk to health and social care delivery increases to high in a medium emissions and high emissions scenario by the 2050s. Both risks have serious impacts to individuals relating to health and livelihoods, as evidenced through the number of excess deaths due to heat in section 5.1. Risk scoring is driven by both scoring of likelihood and impact presented in Appendix A.

The risks to health and social care delivery to all types of flooding (river, tidal, sea level rise and surface water) is medium in the baseline and increases to a high risk under a high emissions scenario in the 2050s. As lives and individuals' health are at risk from climate change, the healthcare sector must be a priority sector for adaptation moving forwards. A medium emissions scenario is currently unavailable, with Environment Agency Flood risk mapping only provided for a high emissions scenario, therefore, a qualitative assessment of medium- high is used between the baseline and high emissions scenario.

Table 5.5 *Risk Matrix for Health Sector in Gloucestershire*

Hazard	Risk	Baseline	2050s	
			Medium Emissions Scenario	High Emissions Scenario
High temperatures	Risks to health and social care delivery from high temperatures	Medium	High	High
River, Tidal flooding and sea level rise	Risks to health and social care delivery from flooding	Medium	Medium - High	High
Surface water flooding	Risks to health and social care delivery from flooding	Medium	Medium - High	High
High temperatures	Risks to public health and wellbeing from high temperatures	Medium	High	High

Note: Speckled ratings are based on qualitative data and expert judgement

Adaptive Capacity

Adaptive capacity is defined as an organisations' ability to adjust to potential damage, to take advantage of opportunities, or to respond to consequences of climate change[12]. During select interviews, stakeholders from the healthcare sectors in Gloucestershire outlined their organisations' adaptive capacity. Key findings include:

What is already happening?

- There is a gap in embedding adaptation within all healthcare activities which is key to ensuring adaptation is consistently considered in actions and ensures that behaviour change is a priority within organisations.
- There are limited funding mechanisms which act as a blocker to implementing adaptation actions.
- Communications are provided to local communities on climate change awareness and this is a co-ordinated effort across healthcare partners. This enables local communities to be aware of climate change and the potential impacts on their health

What is recommended?

- Climate adaptation plans are needed for specific healthcare sites within Gloucestershire, along with the vulnerable areas of population situated within the County to understand how climate change will impact these communities. This will help healthcare commissioners and providers to be able to plan and respond effectively.
- Collaborating to learn from one another's best practice to improve adaptive capacity and help the healthcare sector to better respond to extreme events and/or reduce these impacts.
- Creating partnerships to enable collaboration in the healthcare sector can be used to share knowledge on best practice in increasing sustainability in wider supply chains. Joined up concerted efforts can also be a springboard for action and increasing sustainability and climate resilient considerations within the wider supply chain.

5.2 Built Environment

Key risks

The Built Environment includes residences, education centres and community facilities across Gloucestershire, and faces a number of climate risks including the risk of disruptions to water supplies, the impact of surface water, river and tidal flooding on people, communities and buildings and risks to building fabric during storm and high wind events.

Table 5.6 Built Environment Risks to Gloucestershire County Council

Theme	Hazard	Risk
Built Environment	Drought	Risk of household water supply interruptions
	Surface water flooding	Risks to people, communities & buildings from surface water flooding
	River, tidal flooding and sea level rise	Risks to people, communities & buildings from river, sea level rise and tidal flooding
	Storm, high winds	Risks to building fabric from moisture, wind, and driving rain

Likelihood

Household water supply interruptions may increase in future. Gloucestershire has experienced a number of drought periods which have placed pressure on water supply, including the droughts of summer 2018 and 2022.

Droughts place significant stress on water supplies with competing pressures across homes and communities, agriculture and businesses for water. Summer precipitation across Gloucestershire is projected to decrease in the 2050s by 13.5% and 19.0% across medium and high emissions scenarios respectively. As populations increase in Gloucestershire in future, there will be a greater demand on water supplies. Gloucestershire's population is projected to increase by 17% from 663,558 to 738,482 from 2018 to 2043, which will further increase pressure on water resources[1].

Who we engaged with:

Bromford. Forest of Dean District Council. Cotswold District Council. Tewkesbury Borough Council. Cheltenham Borough Council. Gloucester City Council. Stroud District Council.

Surface water flooding is associated with periods of heavy rainfall coupled with impermeable environments which do not allow for adequate drainage, and as such are a particular risk for urban and built environments. The area at high risk from surface water flooding (>3.3% chance of occurring in any given year) across Gloucestershire is projected to increase by 15km^2 by the 2050s compared to the present day (from 47km^2 in the present to 62km^2 in the 2050s), even without accounting for any development-driven increase in impermeable areas.

River flooding and sea level rise tends to occur in a smaller area than surface water flooding, primarily along river channels such as the River Severn and River Wye, but can have more severe impacts. River flooding and sea level rise is projected to increase in future as winter rainfall increases in Gloucestershire by 8 to 12% under a medium and high emissions scenarios respectively[2], increasing the area exposed to a high river flooding and sea level rise (>3.3% of occurring in any given year) in the 2050s by 19km^2 compared to the present day.

Tidal flooding events are associated with the Rivers Severn and Wye, and are projected to increase in future, increasing the risk of tidal flooding and coastal erosion.[3]

Gloucestershire has been impacted by a number of storms and high wind events in recent years. **Wind driven rain** associated with storm events **is** projected to increase by the end of the century under a medium (+2ºC) and high (+4ºC) warming scenarios. Wind-driven rain is expected to be greatest for buildings which are oriented south-west, in line with UK weather patterns (Figure 5.2).

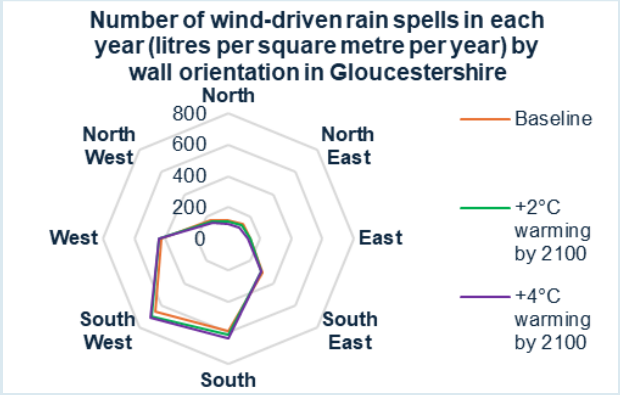


Figure 5.2 *Wind-driven rain spells in Gloucestershire in the present day, +2 ºC and +4 ºC warming scenario by 2100*

5.2 Built Environment

Impacts

Water supply interruptions

Interruptions in water supply to buildings will affect the ability of households, services such as schools and education centres and community facilities to be able to operate. Water supplies were cut off to households during the 2007 flooding, which led to the displacement of people from homes and lack of access to drinking water. As drought periods in summer and flooding events in winter are projected to increase in future, a greater number of households are likely to be impacted by water supply interruptions.

Flooding and storms and high winds

The Built Environment is likely to be more exposed to all flooding types in future as populations grow and there is a greater demand for housing and services such as education in Gloucestershire. For example, In the 2007 flood, 390 schools were affected across Gloucestershire and Worcestershire[4]. As demonstrated in Table 5.7, buildings in Gloucestershire are most exposed to surface water flooding and an increase in the number of both buildings and schools to all types of flooding is projected by the 2050s.

Flooding type	Type	Present flooding	2050s high emissions scenario	Overall change	% increase
		High likelihood (>3.3% chance of flooding any given year)			
Surface water	Buildings*	6,285	11,392	**+5,107**	**+81%**
	Schools	12	25	**+13**	**+108%**
Rivers and sea level rise	Buildings*	2,989	4,857	**+1,868**	**+62%**
	Schools	4	5	**+1**	**+25%**

**Building outlines e.g. multiple terraced houses are represented as one building*

Table 5.7 *Number of buildings and schools at risk from surface water flooding and flooding from rivers and seas in a high emissions scenario by 2050 relative to the present day[5]*

Vulnerable Groups:

- Renters
- School children
- Low-income households
- Migrants/ ethnic communities
- Homeless individuals

Flood events cause major damage to the built environment and have a large economic impact. The median house price across Gloucestershire ranges from £123,000 to £1,000,045 (Figure 5.3).[6] Damages to housing from flooding can be extensive and lead to long-term financial implications due to the displacement of people from homes during repairs. The average residential claim during the 2007 flooding for one residence was £30,000.[7]

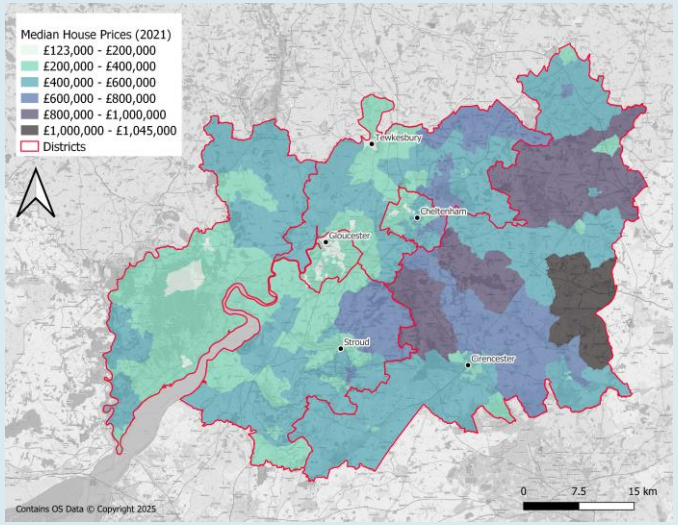


Figure 5.3 *Median House prices in Gloucestershire*

Storms Dudley, Eunice and Franklin in 2022 led to high spring tides and a large storm surge in the south-west of England. Coastal protection measures prevented severe coastal flooding in the Severn Estuary, helped by the fact that the storm surges did not coincide with high tide.[8] Winter windstorms are likely to increase in number and intensity in future, albeit, with higher uncertainty in climate model projections.[9] This may increase the likelihood of tidal flooding from storm surges in future, leading to consequential impact on buildings sited on the Severn and Wye estuary without adequate coastal protection.

Moisture ingress into buildings from both storms and wind-driven rain, and as a result of flooding can cause an increase in mould and damp and is linked to respiratory problems. This is especially impactful to vulnerable communities which are less able to make adaptations to their homes or have the financial means to remove and prevent damp conditions, for example, through pre-existing home insurance in place which overs flood damage.

5.2 Built Environment

Risk Outcome

In the Built Environment sector in the baseline there is a medium risk from surface water, and river, sea level rise and tidal flooding, and a low risk of drought leading to household water supply interruptions, and storms and high winds impacting building fabric through moisture ingress, wind and driving rains. The risk scoring is driven by both scoring of likelihood and impact presented in Appendix A. By the 2050s, risk of household water supply interruptions is projected to increase to a medium risk as the likelihood of drought in the region increases slightly but there remains a low likelihood of severe drought causing water supply interruptions. This risk should be monitored in future as populations increase in Gloucestershire and water demand increases.

The risk from flooding to people, communities and buildings is currently considered medium across Gloucestershire, and will increase under both a medium, and high emissions scenario, under which it increases to a high risk in the 2050s. A medium emissions scenario is currently unavailable, with Environment Agency Flood risk mapping only provided for a high emissions scenario, therefore, a qualitative assessment of medium-high is used between the baseline and high emissions scenario.

Finally, risks to building fabric from moisture, wind and driving rain are currently a medium risk. There is more uncertainty over changes to storminess and wind-driven rain in the future, however, it is noted that winter windstorms are likely to increase in number and intensity in future. Due to the uncertainty in changes in storms and high winds, this risk is assessed as a medium risk in 2050s for both high and medium emissions scenarios. Storms already cause significant impacts and will need to be adapted to despite key gaps and uncertainty in climate data.

Table 5.8 *Risk Matrix for Built Environment Sector in Gloucestershire*

Hazard	Risk	Baseline	2050s	
			Medium Emissions Scenario	High Emissions Scenario
Drought	Risk of household water supply interruptions	Low	Medium	Medium
Surface Water Flooding	Risks to people, communities & buildings from surface water flooding	Medium	Medium - High	High
River, tidal flooding and sea level rise	Risks to people, communities & buildings from river and tidal flooding	Medium	Medium - High	High
Storms and high winds	Risks to building fabric from moisture, wind, and driving rain	Medium	Medium	Medium

Note: Speckled ratings are based on qualitative data and expert judgement

Adaptive Capacity

During select interviews, stakeholders from the Built Environment outlined their organisations' adaptive capacity. Key findings include:

What is already happening?

- Public and private collaboration provides more successful outcomes for climate adaptation and improving adaptive capacity.

What is recommended?

- Resource and capability are required to unlock funding for climate adaptation. Without these in place it can be difficult to source funding.
- Access to funding and awareness of where to find funding to finance climate adaptation remains a challenge.
- A greater sharing of information on successful climate adaptation and addressing climate risks would be helpful to align with best practice and ongoing work across Gloucestershire.
- The need for a less reactive approach to responding to extreme heat and storms.

5.3 Natural Environment

Key risks

The natural environment includes areas used for forestry and/or natural and green spaces supporting wildlife. Gloucestershire's natural environment is unique. Its landscape is home to large swathes of grasslands in the Cotswolds, wetlands in the Severn Vale and woodlands in the Forest of Dean. The Forest of Dean supports many birds such as robins, finches, doves and many more, whilst the grasslands shelter a number of insects and invertebrates such as caterpillars, butterflies, beetles and spiders[22,23]. The natural environment provides a range of services such as supporting biodiversity and ecosystems, and provision of access to green and spaces which promote physical activity and reduce mental health impacts. The natural environment is at risk from multiple climate related hazards, with the focus being drought, wildfires, high temperatures and all types of flooding.

Table 5.9 Natural Environment Risks to Gloucestershire

Theme	Hazard	Risk
Natural Environment	Drought	Risks to habitats and wildlife from water scarcity
	Surface water flooding	Risks to habitats and wildlife from surface water flooding
	River and tidal flooding and sea level rise	Risks to habitats and wildlife from river and tidal flooding and sea level rise
	High temperatures	Risks to soils from increased seasonal aridity
	High temperatures & wildfire	Extreme weather/wildfire risks to habitats, forestry & wildlife

Likelihood

Rising temperatures, surface water, river flooding and sea level rise along with droughts have the potential to impact Gloucestershire's habitats, landscapes, and local wildlife. **Temperatures** are increasing. By the 2050s, in a medium emissions scenario, average annual temperatures in Gloucestershire are projected to increase by up to 2°C. As temperatures rise, the balance of ecosystems can be disrupted, causing disturbance to biodiversity and altering habitats. Soils are prone to becoming more arid with the increase of high temperatures, and heat stress can affect plant growth[1].

Who we engaged with:

glos nature · Natural England · Severn Rivers Trust · Forestry England · Environment Agency

Droughts are likely to increase in the future. Gloucestershire has experienced numerous droughts in the last decade, which can stress the natural environment, posing water scarcity risks to wildlife[2]. Summer precipitation across Gloucestershire is projected to decrease in the 2050s by **13.5%** and **19.0%** across a medium and high emissions scenario respectively, negatively impacting plant growth.

Soil moisture deficit measures the gap between the soil's current moisture level and its field capacity[3]. High levels of soil moisture deficit indicate dry soil and drought stress. Soil moisture deficit and water scarcity are projected to increase, and summer deficits could increase by **between 38% and 55% by the 2050s** in a medium and high emissions scenario (Figure 5.5) increasing stress both on natural environments across Gloucestershire. Northeastern areas of Gloucestershire in the Forest of Dean, along with southwestern areas of the county in the Cotswold District will see the greatest decreases in soil moisture, albeit all regions show a decrease in soil moisture.

Gloucestershire already experiences regular floods from surface water, river and tidal flooding and sea level rise, affecting soil health and wildlife. Surface water flooding is often exacerbated by dry land where water cannot penetrate the surface and can be most severe when heavy rainfall follows drought. The combination of increased likelihood of drought, along with heavy rainfall is likely to increase flooding of forests and green spaces. The Severn Vale contains many rivers and tributaries and is home to wetland bird nesting sites and water voles[24]. This area is increasingly vulnerable to river flooding and sea level rise, which is projected to increase in future as winter rainfall increases in Gloucestershire **by 8 to 12%** under a medium and high emissions scenarios respectively and sea level is projected to rise by 20-30cm by 2050.

Gloucestershire's natural environment is already at risk from wildfires. Increased high temperatures are **heightening the risk of wildfires**, which can lead to destruction of the natural environment and distress wildlife. Wildfires are expected to increase in the future as high temperatures continue to rise and soil moisture decreases. Met Office Fire Severity 'Very High' Danger is projected to increase from **21 days per year** currently to **48 days per year** by the 2050s under a high emissions scenario. In particular, the Forest of Dean, grasslands and valleys across Gloucestershire are most at risk.

5.3 Natural Environment

Impacts

High temperatures are projected to increase, which may result in **increased pests and invasive species**[7]. As warmer temperatures prevail in winter, colonies of pests survive throughout the season creating larger populations in the following summer[14]. Invasive species **can often outcompete native ones,** creating "winners and losers", whilst also altering habitats, making them **unsuitable for native plants and wildlife**. In particular water hyacinth may become more prevalent across the UK as temperatures increase[16]. Effective monitoring and reporting of new and invasive species is critical to effectively manage the risk[15]

Increases in temperatures may cause changes in wildlife populations. Changes in temperatures are **impacting populations of insects**. Subsequently, **serotine bats are moving** north and west **into Gloucestershire** due to the wider availability of large insects as food and the milder climates. Serotine bats need to be protected and maintained as they are a priority species under the UK Post 2010 Biodiversity Framework and protected under the Wildlife and Countryside Act 1981 showing their ecological importance UK.[17,18] High temperatures can also **reduce nectar availability**, as flowers can become stressed during high temperatures. Subsequently, bee populations struggle to pollinate[6].

Additionally, high temperatures are likely to **impact bird populations**, which are supported by the Severn Estuary. Species such as Berwick's swans may arrive earlier or stay for shorter periods in Gloucestershire as they no longer need to migrate as far to reach ice-free wetlands[19]. In addition ,due to rising temperatures, the **population of waders** notably Grey Plovers and Dunlins are **showing significant declines** in the Severn Estuary[20]. In turn, reduced foraging activity from waders may **reduce nutrient cycling** and **invertebrate populations may increase.**

High temperatures and heatwaves are causing a **rise in fungal diseases** on plants such as increased rates of **Dutch Elm Disease**, which can be deadly to Elm trees[6,12]. A rise in ash dieback has significantly impacted the Forest of Dean making trees on roadsides unsafe, as **unstable trees** are **more likely to collapse** onto roads causing disruption and injuries, this may be exacerbated by climate change creating ideal conditions for disease and pests which cause dieback[8].

High winds and storms may also cause tree uprooting such as in Storm Darragh. In the Cotswolds, local reports highlighted fallen trees[10]. Fallen trees not only impact habitat connectivity and wildlife but also pose a risk to human life and property also. A stakeholder interviewee noted a fallen tree caused by one storm event cost **approximately £30,000 for tree maintenance[6].**

Vulnerable Groups:

- Ethnic minorities living in urban environments
- People living on the Severn Estuary
- People living in wildfire-prone areas

Figure 5.4 *Dutch Elm Disease in Gloucestershire*[19]

Droughts have widespread impacts across ecosystems, associated with increased temperatures and shifts in rain patterns, causing low river flows. This has consequential impacts on aquatic species in rivers and soils. Low river flows can lead to the **loss of aquatic species** such as trout which are found in the River Coln in the Cotswold. Loss of fish species impacts wildlife and the wider food chain within Gloucestershire[4,5]. Key sites of special scientific interest that may be impacted by drought include Ashleworth Ham in Tewskesbury, and Dymock and Collins Park Woods, located in the Forest of Dean (Figure 5.5).Soil moisture deficit can also put additional stress on habitats, cause dehydration in wildlife and affect breeding grounds which can lead to widespread biodiversity loss

Wildfires are already impacting Gloucestershire's natural landscape, in the Forest of Dean, the Cotswolds and Valleys in Stroud District. Wildfires not only destroy the plants but also **threaten habitats and cause distress to wildlife**. In March 2025, wildfires broke out in the Slad Valley causing devastation to Juniper Hill Fields and Juniper Hill which is a Site of Special Scientific Interest[25]. Nesting birds, mammals and reptiles that reside there were also affected. Grassland fires are also uncommon to the region of Gloucestershire – in August 2022 alone there were 53 incidents related to grassland fires.[11]

Surface water flooding, river flooding and sea level rise have the potential to **damage woodland** by causing waterlogged soils leading to plant stress and increased potential vulnerability to diseases[9]. In 2011 due to increases in rainfall and water run-off, an outbreak of phytophthora ramorum (water mould) affected larch and sweet chestnut trees within the Forest of Dean causing fallen trees[6]. Floodwaters from all types of flooding can deposit sediments and pollutants on soil quality causing an inability for woodland to regrow again.

Rising sea levels and increased coastal erosion around the Severn Estuary threaten vital mudflat sandflat and saltmarsh habitats, which serve as essential feeding, roosting and resting areas for numerous seabird and waterbird species—putting their populations at risk of decline. These intertidal habitats also host many invertebrates which in turn provide an important food source for fish species in this area[21]

5.3 Natural Environment

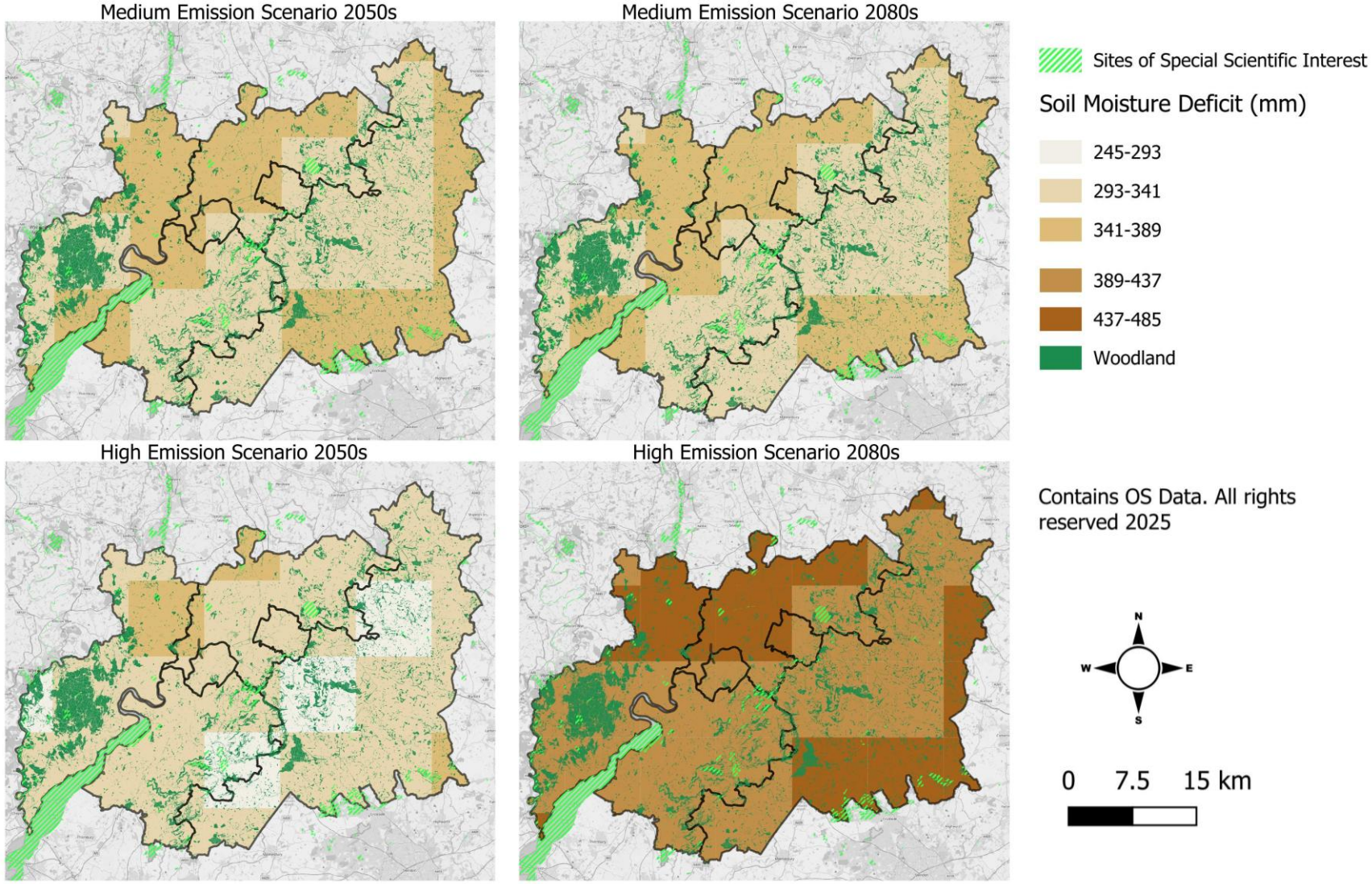


Figure 5.5 *Soil Moisture Deficit, woodland and Sites of Scientific Interest in a medium emissions scenario (RCP 4.5) and high emissions scenario (RCP 8.5) in the 2050s and 2080s in Gloucestershire*[20]

5.3. Natural Environment

Risk Outcome

Across the natural environment, there is a medium risk of surface water, river and tidal flooding and sea level rise affecting natural and green spaces, biodiversity, and wildlife, increasing to a high risk in the 2050s under a high emissions scenario. A medium emissions scenario is currently unavailable, with Environment Agency Flood risk mapping only provided for a high emissions scenario, therefore, a qualitative assessment of medium-high is used between the baseline and high emissions scenario.

There is a medium risk to wildlife from water scarcity from drought in the 2050s under a medium and high emissions scenario. Changes in moisture levels in soils due to drought and/or flooding is currently a medium risk and will stay as a medium risk under a high emissions scenario for 2050s. The risk scoring is driven by both scoring of likelihood and impact presented in Appendix A. Risks to wildlife and forestry from high temperatures and wildfire is a medium risk currently, which increases to a high risk in the 2050s as extreme temperatures and wildfires can lead to habitat loss and therefore displacement of wildlife.

Although not quantified in the below risk score card, it is also noted that as temperatures rise and likelihood of flooding increases, there will be inevitable risks to the natural landscape in Gloucestershire as well as a rise in pests and invasive species. Monitoring of these risks should be undertaken to understand how the natural environment is impacted as the climate changes.

Table 5.10 *Risk score card for the Natural Environment Sector in Gloucestershire*

Hazard	Risk	Baseline	2050s	
			Medium Emissions Scenario	High Emissions Scenario
Drought	Risks to habitats and wildlife from water scarcity	Medium	Medium	Medium
Surface water flooding	Risks to habitats and wildlife from surface water flooding	Medium	Medium - High	High
River and tidal flooding and sea level rise	Risks to habitats wildlife from river and tidal flooding and sea level rise	Medium	Medium - High	High
Drought	Risks to soils from increased seasonal aridity	Medium	Medium	Medium
High temperatures and wildfire	Extreme weather/wildfire risks to forestry, habitats wildlife and heritage	Medium	High	High

Note: Speckled ratings are based on qualitative data and expert judgement

Adaptive Capacity

During select interviews, stakeholders from the Natural Environment outlined their organisations' adaptive capacity. Key findings include:

What is already happening?

- Public and private collaboration with water management bodies and landowners to drive successful climate adaptation action.

What is recommended?

- Access to funding and awareness of where to find funding to finance climate adaptation remains a challenge.
- Resource and capability are required to unlock funding for climate adaptation. Without these in place it can be difficult to source funding. Specifically funding related to public relations campaigns to communicate the future of climate change and sea level rise and producing solutions with local communities is a gap identified
- Consideration and regular review of wildfire risk, particularly in the Forest of Dean where broadleaf trees are situated.
- Sharing of best practice and adaptation actions to other similar landowners and champion the benefits of adaptation action conducted.
- Further guidance required on tree planting species which can cope with climate change impacts.

5.4 Business and Industry

Key risks

Business and Industry includes large scale businesses, industries, small medium- enterprises and major technology parks, with key climate risks including the risk to business sites from river, surface water and tidal flooding, disruption to supply chains and employee productivity reductions in high temperatures.

Table 5.11. *Business and Industry Risks to Gloucestershire*

Theme	Hazard	Risk
Business & industry	Surface water flooding	Risks to business sites from surface water flooding
	River and tidal flooding and sea level rise	Risks to business sites from river and tidal flooding and sea level rise
	High temperatures	Employee productivity impacts in heatwaves and from severe weather infrastructure disruption
	Cascading	Risks to business from disruption to supply chains

Likelihood

Surface water flooding is associated with heavy rainfall periods and impermeable environments such as concrete surfaces which occur in urban and built environments, where many businesses in Gloucestershire are located. The area at risk of high surface water flooding is projected to increase by up to 32% from 47km^2 to 62km^2 by the 2050s compared to the present day. This increases the likelihood of businesses being exposed to surface water flooding in the 2050s.

River and tidal flooding and sea level rise occur at a local level around key rivers, tributaries and tidal zones and is projected to increase in Gloucestershire where an additional 19km^2 (from 151 km² in the present day to 170 km² by 2050) is at high risk of flooding from rivers and sea. Tidal flooding is also associated with storm surges within the Severn and Wye Estuary[1]. Tidal flooding events are projected to increase, subsequently increasing coastal erosion and tidal flooding risk.

High temperatures are projected to increase in the future. By the 2050s temperatures are projected to rise by up to 2ºC in a high emissions scenario compared to the present day, exposing more outdoor workers more frequently to high temperatures. By the 2050s it is projected that there will be up to 3 heatwave events per year compared to 1 heatwave event per year currently in Gloucestershire. As shown in Figure 5.7, under a medium and high emissions scenario by the 2050s and 2080s the increase in maximum temperatures will rise uniformly across Gloucestershire, and therefore all businesses and industries need to be prepared to climate change.

Who we engaged with:

THE GROWTH HUB

FARMING & WILDLIFE ADVISORY GROUP SOUTH WEST

NFU Mutual

Impacts

Business sites are more likely to be exposed to surface water flooding, river flooding and tidal flooding and sea level rise in the future. As shown in Table 5.12, the number of small and medium business enterprises at risk from high rivers and sea flooding is projected to increase by 58% in a 2050s high emissions scenario compared the present day.

The increase in business sites at risk of flooding is likely to drive insurance premiums up, causing higher costs for businesses. Higher costs to businesses are also likely through lost working days and physical damage to sites from water damage[2]**.** On average in the UK, a serious flood event results in 50 lost working days amounting to £80,000, whilst small businesses say it would take at least 3 months to recover from a disaster[3].

Gloucestershire's Science and Technology Park located on the River Severn was impacted by Storm Bert in November 2024, flooding roads and blocking off access to the Science and Technology Park[4].

Table 5.12 *Small Medium Enterprises at risk from flooding from Rivers and Seas[5]*

Flooding type	Likelihood	Present flooding	2050s high emissions scenario	Overall change	% increase
Rivers and seas	High*	53	84	+31	+58%
	Medium**	46	55	+9	+20%

*High likelihood denotes a greater than 1 in 30 annual chance (>3.3% probability) of flooding from rivers and seas
**Medium likelihood indicates a 1 in 100 to 1in 30 annual chance (1% to 3.3% probability) of flooding from rivers and seas

5.4 Business and Industry

Impacts

Employee productivity is impacted during extreme heat due to decreasing concentration, lower energy levels and more severe health effects such as heat rash and heat exhaustion. Outdoor workers are at an increased risk, due to lack of refuge and air conditioning[6].

As seen in Table 5.13, Gloucestershire has experienced significant loss in output between 2019 and 2021, particularly in 2020, when two heatwave events affected the region. In 2020 Gross Value Added (GVA) loss due to heat events was particularly high in Cheltenham and Cotswold districts (£30-35m)[7] (Figure 5.6). Given that 2020 marked the height of the COVID-19, it is likely that this pandemic also contributed to losses across this time period. With increasing maximum temperatures and heatwave numbers, productivity and health impacts from heat are likely to increase, emphasising the need for adaptation to heat extremes across Gloucestershire.

Table 5.13 *Output Loss (Gross Value Added) in Gloucestershire without Adaptation measures*[7]

Year	Gross Value Added Loss (£)
2019	84,186,762
2020	146,365,803
2021	29,585,294

Supply chain disruption is a cascading risk, which means that impacts at one part of the supply chain can be felt across the entire supply chain. Impacts to transport infrastructure due to damage from extreme weather events may cause upstream and downstream delays and cancellations which disrupt supply chains. As 14.9% of Gloucestershire's workforce is employed in the agriculture and food sector[8], extreme weather adversely impacting the production of food can have profound impacts on the food supply chain. For example, perishable goods may spoil faster if delays to deliveries are caused by transportation impacts during extreme weather events. For further information on impacts on agricultural output, see Chapter 5.5 Agriculture.

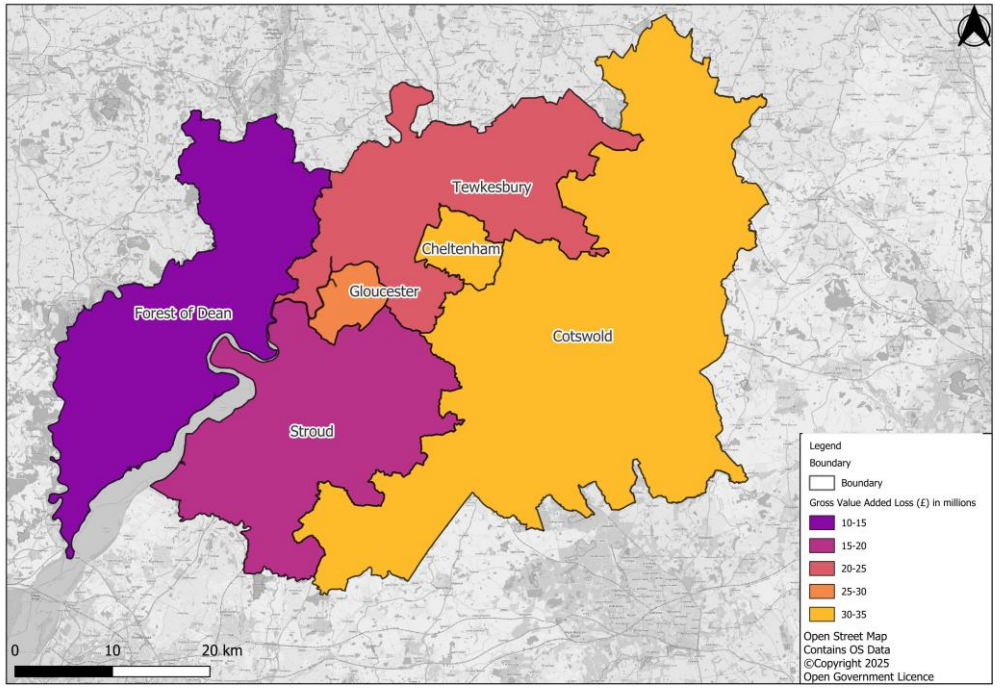


Figure 5.6 *Gross Value Added Loss from Heat Events in 2020 across local authorities in Gloucestershire*[7]

Vulnerable Groups:

- Business owners along the tidal boundary and flood risk zones
- Outdoor workers exposed to extreme weather

5.4 Business and Industry

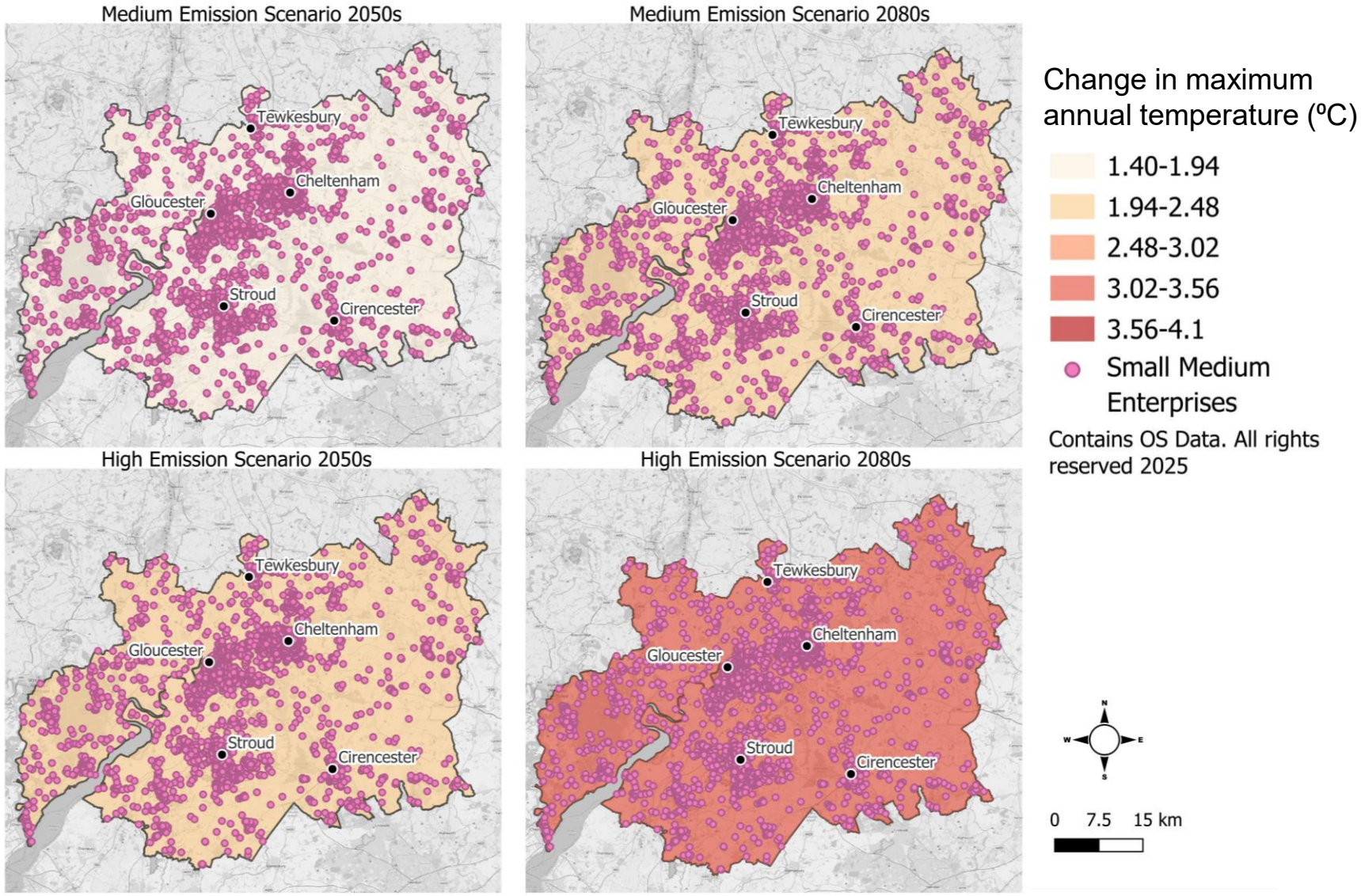


Figure 5.7 *Maximum high temperatures and small medium enterprises in a medium emissions scenario (RCP 4.5) and high emissions scenario (RCP 8.5) in the 2050s and 2080s in Gloucestershire*[9]

5.4 Business and Industry

Risk Outcome

Across Gloucestershire, there is considered to be a medium risk of surface water, river and tidal flooding to businesses and industries. The risk scoring is driven by both scoring of likelihood and impact presented in Appendix A.

By the 2050s, risks to business sites from all types of flooding is projected to increase to a high risk under a high emissions scenario as the likelihood of all types of flooding in the region increases. A medium emissions scenario is not currently available, with Environment Agency flood risk mapping provided only for a high emission scenario. Therefore, a risk level of medium-high is considered for a medium emissions scenario based on expert judgement.

There is a medium risk of high temperatures and severe weather impacting employee productivity. This risk remains a medium risk under both a medium and high emissions scenario in the 2050s, driven by a low impact score.

The risk to supply chains from climate change is explored further in in Chapter 5.6 Interdependent risks, exploring interdependent risks due to climate change.

Hazard	Risk	Baseline	2050s	
			Medium Emissions Scenario	High Emissions Scenario
Surface water flooding	Risks to business sites from surface water flooding	Medium	Medium - High	High
River and tidal flooding	Risks to business sites from river and tidal flooding	Medium	Medium - High	High
High Temperatures	Employee productivity impacts in heatwaves and from severe weather infrastructure disruptions	Medium	Medium	Medium

Note: Speckled ratings are based on qualitative data and expert judgement

Table 5.14 *Risk Matrix for Business and Industry Sector in Gloucestershire*

Adaptive Capacity

During workshops, stakeholders from Business and Industry outlined their organisations' adaptive capacity. Key findings include:

What is recommended?

- A greater need for co-ordination across all sectors to create successful outcomes for climate adaptation and improving adaptive capacity.
- Additional guidance to prepare businesses and industries for heatwaves and droughts is required.
- Supporting businesses (mostly small and medium) to evaluate supply chain criticality to become resilient to climate change events.
- Awareness raising and further education for all businesses and industries on adaptation actions, potential adaptation efforts businesses can implement and how to prepare better for major climate events.

5.5 Agriculture

Key risks

Table 5.15 Agriculture Risks to Gloucestershire

Theme	Hazard	Risk
Natural Environment	Drought	Risks to agriculture from water scarcity
	Surface water flooding	Risks to agriculture from surface water flooding
	River and tidal flooding and sea level rise	Risks to agriculture from river and tidal flooding and sea level rise
	High temperatures	Risks to soils from increased seasonal aridity
	High temperatures & wildfire	Extreme weather/wildfire risks to farming

Gloucestershire is a predominantly agricultural county known for its dairy farming, beef pastures and orchards. In 2019 it was reported that Gloucestershire's farming, food, drink and rural economy sector was valued at £1.5 billion gross value added, accounting for 8.8% of the local economy. Gloucestershire's agriculture industry directly supports around 6,000 jobs and covers 193,000 hectares (equivalent to 2.1% of England's total farmed area)[20]. The rich agricultural landscape forms a key part of Gloucestershire's economy is at risk from a range of climate related hazards.[18]

Likelihood

Rising temperatures, surface water, and river flooding and sea level rise along with droughts and wildfires have the potential to impact Gloucestershire's farms. **Temperatures** are rising. By the 2050s, in a medium emissions scenario, average annual temperatures in Gloucestershire are projected to increase by up to 2°C. Rising temperatures can subject crops to heat stress, leading to reduced yields. Soils are prone to becoming more arid with the increase of high temperatures, and heat stress can affect yields and productivity[1].

Droughts are likely to increase in the future, which can stress the agricultural landscape. Droughts can pose water scarcity risks which can limit the growth of pasture and forage crops for cattle farming and cause dehydration and heat stress to cattle (Figure B.1)[2]. Summer precipitation across Gloucestershire is projected to decrease in the 2050s by **13.5%** and **19.0%** across a medium and high emissions scenario respectively, negatively impacting crop yields.

Who we engaged with:

FARMING & WILDLIFE ADVISORY GROUP FWAG SOUTH WEST

NFU Mutual

High levels of soil moisture deficit indicate dry soil and drought stress. **Soil moisture deficit** and water scarcity are projected to increase, and summer deficits could increase by between 38% and 55% by the 2050s in a medium and high emissions scenario (Figure 4.10) increasing stress on agricultural environments across Gloucestershire. Agricultural land areas on the outskirts of the Cotswold district and in Tewkesbury will see greater decreases in soil moisture in the future under a medium and high emissions scenario (Figure B.4)

Wildfire risk is expected to increase in the future as dry weather conditions make vegetation highly flammable as soils dry out. The number of days with Met Office Fire Severity 'Very High' Danger is projected to increase from 21 days per year currently to 48 days per year by the 2050s under a high emissions scenario..

Gloucestershire already experiences regular floods from **surface water, river and tidal flooding and sea level rise,** with significant impacts on farmland and agricultural yields. Dry, compacted soils limit water absorption, worsening surface water flooding when intense rainfall follows drought. This combination of prolonged dry periods and heavy rain is expected to heighten flood risk for agricultural land.

Impacts

Wildfires were experienced in Gloucestershire in 2022, impacting farmland. In Cherington in the Cotswolds a wildfire occurred during the hot and dry conditions of August 2022, which spread across 50 acres of farmland.[3] Wildfires can destroy standing crops as well as grass for grazing and stored feed. In addition, livestock and animals can be at risk from heat stress or burn injuries also. As shown in Figure 5.8, north Tewkesbury, eastern Cotswolds and northern agricultural land in Forest of Dean are most at risk from wildfires

5.5 Agriculture

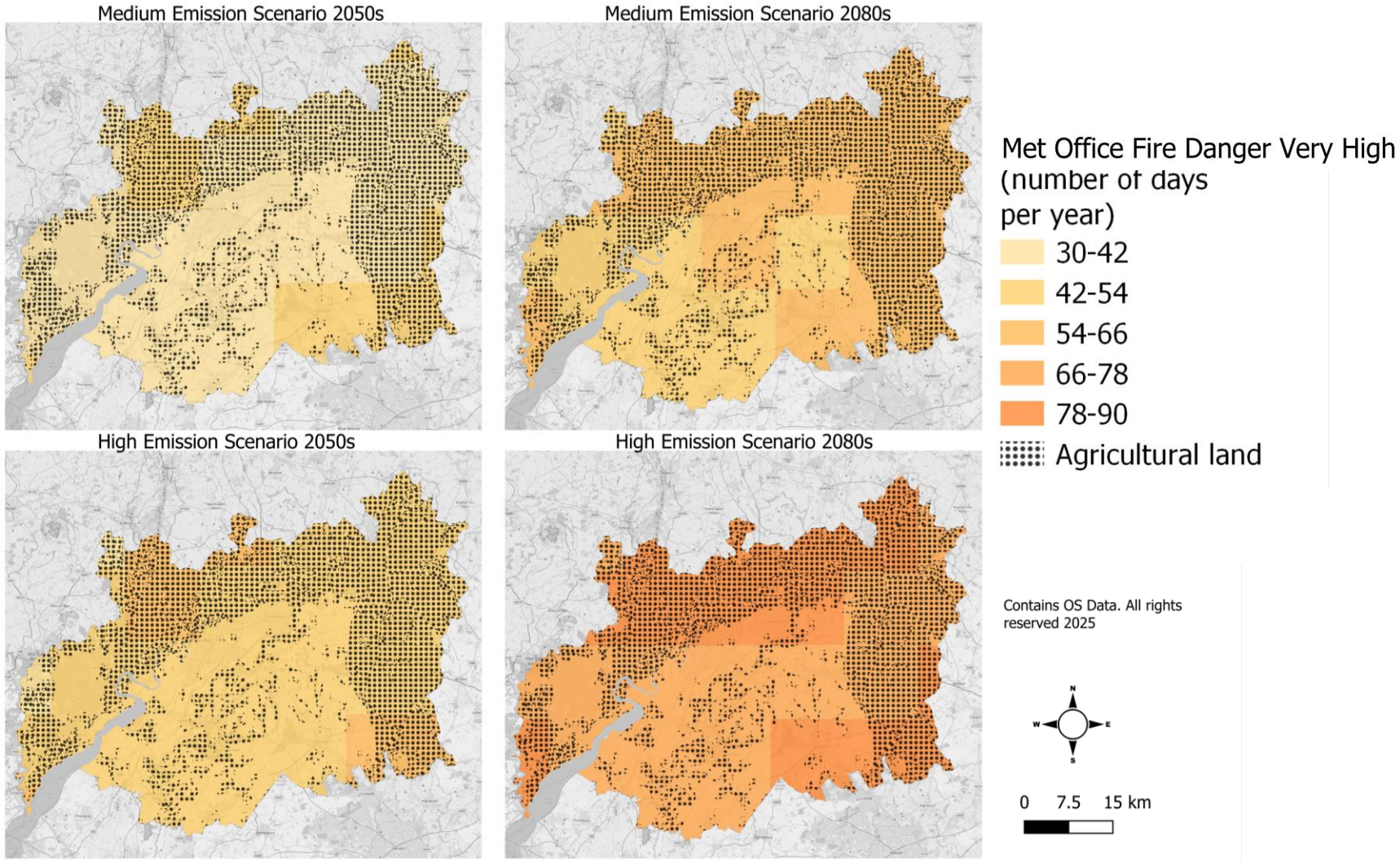


Figure 5.8. *Met Office Fire Danger Very High number of Days and agricultural land in a medium emissions scenario (RCP4.5) and high emissions scenario (RCP8.5) in the 2050s and 2080s in Gloucestershire*[20]

5.5 Agriculture

Vulnerable Groups:

- Outdoor workers
- Rural communities
- Small-scale farmers
- Food insecure households

Impacts

Gloucestershire's agriculture sector was valued at £102m Gross Value Added (GVA) in 2017, framing the sector as a key economic driver[7]. Therefore, extreme weather impacts affect the livelihoods of farmers and the wider economy.

Drought has the potential to **impact agricultural yields**, altering or shortening growing seasons and impacting crop quality. In the Cotswolds, where the topsoil is already thin, the risk of decreased soil quality is likely to increase as periods of drought are projected to become more frequent[4]. The availability of silage for livestock decreases due to droughts, creating a knock-on impact on cattle farming. In summer 2025, dry weather caused farmers to face an additional £1,000 monthly bill for animal feed[5,6]. Stakeholder interviews noted that the growing season has been stunted with reporting of 30% loss of 200,000 trees planted due to an 8-week dry period[4].

High temperatures are projected to increase, which may result in increased pests and invasive species[8]. As warmer temperatures prevail in winter, colonies of pests survive through winter creating larger populations in summer[16]. Influxes of pests can disrupt natural balances of native insects affecting wider ecosystem balance and may disrupt crop production. High temperatures and humidity can cause heat stress to dairy cattle[9], which in turn reduces milk yield on heat stress days (Figure B.1). The number of heat stress days is projected to increase to up to 80 days under a high emission scenario by the 2050s, which has potential to place stress on dairy cattle, reducing milk yield and income for farmers.

Surface water flooding, river flooding and sea level rise have the potential to damage crops by causing waterlogged soils leading to crop stress[10]. Floodwaters from all types of flooding can deposit sediments and pollutants on soil quality causing an inability for crops to regrow again. Surface water and river flooding can lead to the runoff of excess pesticides into agricultural land, potentially damaging crops[11]. Soil degradation due to surface water flooding can cause soil erosion and further loss of topsoil, impacting long term fertility[12]. In 2024 during Storm Henk, heavy rainfall caused the River Severn to overflow, flooding farmland, meaning that sowed grass seeds and wheat were submerged, whilst livestock had to be moved to higher grounds across Gloucestershire's farms.

The 2007 flooding and impacts on agriculture

In the July 2007 flood event, floodwaters from the River Avon and River Severn severely disrupted agricultural systems, damaging farmland and reducing soil quality, while runoff from fields increased water pollution and threatened crop productivity.[14] Swathes of agricultural land was waterlogged and crops lost due to the floods.

Following the event farmers were interviewed and select farms were assessed for flood loss estimation based on flood and waterlogging impacts. Across the West Midlands, Gloucestershire and Worcestershire, 10,923 hectares of land was flooded, with most flooded farmland containing grass cereals, vegetables and maize[15].

Crop yield and quality were impacted, in addition to loss of income from livestock deaths and the expense associated with debris clearing. Temporary disruption to water supplies incurred additional costs to secure water for farming.[15]

On average, the total flood damage for agricultural land was estimated at £1,207/hectare. Scaled up across Worcestershire and Gloucestershire this equates to £13 million[15].

Local and Global Dimension

As the climate warms, **new invasive pests and species** may be able to survive in the UK, posing additional threats to both crop production. Effective monitoring and reporting of new and invasive species is critical to effectively manage the risk[17].

Changes in climate and extreme weather events globally and locally may **affect supply chains**, leading to crop shortages, driving food insecurity and increased costs. Risks associated with food safety and security highlight the need for adoption of adaptive farming practices and improved supply chain resilience.[19]

5.5 Agriculture

Risk Outcome

Across agriculture, there is a medium risk of surface water, river and tidal flooding and sea level rise to agriculture, increasing to a high risk in the 2050s under a high emissions scenario. A medium emissions scenario is currently unavailable, with Environment Agency Flood risk mapping only provided for a high emissions scenario, therefore, a qualitative assessment of medium-high is used between the baseline and high emissions scenario.

There is an increasing risk to agriculture from water scarcity and drought, due to the combination of decreasing rainfall and increased rates of evapotranspiration. The risk is greatest under a high emissions scenario, but is still higher than at present even under a medium emissions scenario. As droughts periods are projected to increase and the likelihood of flooding is projected to increase, this risk should be monitored along with soil health, as it can significantly impact crop health and yield production. The risk scoring is driven by both scoring of likelihood and impact presented in Appendix A.

Risks to farming from extreme weather related to extreme high temperatures is a medium risk currently, which increases to a high risk in the 2050s due to the disruption extreme temperatures and wildfires can have on the natural environment.

Hazard	Risk	Baseline	2050s	
			Medium Emissions Scenario	High Emissions Scenario
Drought	Risks to agriculture from water scarcity	Medium	Medium	High
Surface water flooding	Risks to agriculture from surface water flooding	Medium	Medium - High	High
River and tidal flooding and sea level rise	Risks to agriculture from river and tidal flooding and sea level rise	Medium	Medium - High	High
Drought	Risks to soils from increased seasonal aridity	Medium	Medium	High
High temperatures and wildfire	Extreme weather/wildlife risks to farming	Medium	High	High

Note: Speckled ratings are based on qualitative data and expert judgement

***Table 5.16** Risk score card for the Agriculture Sector in Gloucestershire*

Adaptive Capacity

During workshops, stakeholders from agricultural backgrounds outlined their organisations' adaptive capacity. Key findings have been adapted below:

What is recommended?

- A greater need for co-ordination across agricultural stakeholders, local authorities and environmental bodies to create successful outcomes for climate adaptation and improving adaptive capacity.
- Additional guidance to prepare farmers for heatwaves and droughts is required, including best practice for soil conservation, crop management and livestock care.
- Co-ordination with local and national Government on policies relating to water storage for farmers to adequately cope with the impacts of drought and heatwaves.
- Awareness raising and further education for all farmers and industries on adaptation actions, potential adaptation efforts businesses can implement and how to prepare better for major climate events.

5.6 Infrastructure

Key risks

Six key climate risks are identified for Gloucestershire's infrastructure including water, energy, transport and ICT networks. Cascading infrastructure failures are explored in Chapter 5.6 Interdependent risks. Climate risks to infrastructure in Gloucestershire include risks to water and wastewater systems such as public water supply from drought and sewer flooding. Across all infrastructure, flooding, sea level rise, storms and high wind and extreme heat are highlighted as key risks.

Table 5.17. *Business and Industry Risks to Gloucestershire*

Theme	Hazard	Risk
Infrastructure	Drought	Risks to public water supplies from drought and low river flows
	Flooding	Risks to infrastructure from river, surface/groundwater flooding and sea level rise
	Surface water flooding	Risks of sewer flooding due to heavy rainfall
	Storm, high winds	Risks to energy, transport & ICT from high winds & lightning
	High temperatures	Extreme heat risks to rail, road, ICT and energy infrastructure
	Cascading	Risks of cascading infrastructure failures across interdependent networks

Likelihood

Multiple water companies operate water supplies in Gloucestershire, including Severn Trent Water, Wessex Water, Thames Water and Welsh Water, which utilise water sources from groundwater, rivers and reservoirs[1]. These water suppliers rely on regular rainfall to ensure a consistent water supply. **Public water supplies are likely to be affected by drought and low river flow**, driven by a projected decrease in summer rainfall in the 2050s by 13.5% and 19.0%, across a medium and high emissions scenario respectively.

River, surface water and groundwater flooding, sea level rise and risks of sewer flooding due to heavy rainfall are likely to increase in future. This will place all types of infrastructure at increased risk of flooding including roads, digital and telecoms, water supply and wastewater and energy networks.

In recent years a number of storms have occurred including Storms Dudley, Eunice and Franklin. **High winds and lightning during storm events** are a key risk for infrastructure. There is higher uncertainty in future projections of storm events.[2] It is projected with high uncertainty that winter windstorms are likely to increase in number and intensity in future. **Extreme heat is projected to become more common and intensify in future**, including by the 2050s there is projected to be up to 3 heatwave events per year under a high emissions scenario compared to 1 heatwave event per year currently. Summer maximum temperatures are projected to increase by 6ºC by the 2080s compared to the 1981-2010 baseline, exposing more infrastructure to the impacts of extreme heat [3].

Impacts

Public water supplies in Gloucestershire are highly dependent on water stores in the south-west and Midlands including reservoirs, groundwater and rivers. **Drought and low river flows have wide-reaching implications on public water supplies**, resulting in the need for a series of actions by water companies limiting the public's use of water.[4] These actions can range from hosepipe bans through to standpipes for public water access during the most extreme droughts.[5]

Drought Management Level	Operational Strategy and Actions
Normal Operation	Normal Operation and cost saving strategy. Background Water Efficiency, metering and leakage activity. Normal seasonal water efficiency messaging to customers and retailers.
Level 1a	Move towards resource saving strategy and review of outage programme. Increase water efficiency campaigns and leakage control.
Level 1b	Further enhance water efficiency campaign and leakage control. Additional transfers from neighbouring companies and use of standby sources coupled with further system optimisation.
Level 2	Least environmentally damaging drought permit options Temporary Use Bans
Level 3	Non-essential use bans and high-profile water efficiency campaign Moderate/Most environmentally damaging drought permit options
Emergency Plan	Emergency drought orders (e.g. standpipes/rota cuts)

Figure 5.18 *Wessex Water Drought Management* [6]

Restrictions on the use of water can have socio-economic impacts such as impacts on businesses being able to operate due to lower availability of drinking water or for manufacturing or agricultural purposes. Mental health impacts can be felt in the event of very extreme drought, for example, when water supplies are cut off to homes or affect businesses, resulting in increased feelings of stress. Physical health impacts may also be felt during extreme drought periods due to dehydration and difficulty in maintaining hygiene routines if household water supplies are reduced.

Gloucestershire hosts a number of **data centres**, and the demand for these facilities is increasing to support digital innovation and artificial intelligence use. These facilities require substantial water for cooling, which could **intensify pressure on local water resources**—particularly during drought periods when supplies are already constrained.

5.6 Infrastructure

Impacts

River and sea level rise and surface water flooding is projected to impact a greater number of infrastructure assets. Across Gloucestershire an additional 116km and 161km of the road network is projected to be exposed to a high likelihood of surface water flooding and river and tidal flooding and sea level rise respectively (Table 5.16, Figures B7 and B8). A greater exposure of the transport network to both types of flooding may result in travel disruption across private and public transport, with knock on impacts on businesses and ability for day-to-day activities such as reaching schools, hospitals and public services.

Prolonged periods of drought can weaken soil moisture, whilst all types of flooding (river, surface water and tidal) can saturate soil and destabilise slopes. Both of these dynamics increase the risk of landslips on railway embankments which occurred on the railway line between Lydney in Gloucester, affecting public transport, causing widespread travel disruption. For more information, see this Case Study.

Table 5.16 *Number of rail stations and kilometres of railway tracks and roads at risk from surface water flooding and rivers and seas in a high-emissions scenario in 2050*

Flooding type	Type	Present flooding	2050s high emissions scenario High likelihood (>3.3% chance of flooding each year)	Overall change	% increase
Surface water	Rail stations (count)	8	9	+1	+13%
	Roads (km)	321	437	+116	+36%
	Railway tracks (km)	23	29	+6	+27%
Rivers and seas	Rail stations (count)	0	0	0	0%
	Roads (km)	186	288	+161	+37%
	Railway tracks (km)	2	4	+6	+51%

Inundation of transport, energy and water networks has large economic implications, both directly increasing the cost of maintenance and recovery by local and national infrastructure providers, and the wider knock-on effects of service disruption. This can lead to reputational damage during service closures or interruptions. The 2007 flooding caused a major sub station in Tewkesbury to be inundated.

Case study: A417 Maisemore flooding

The A417 is an important strategic route, and links the north-west of the country to Gloucester, and Cirencester and Swindon beyond. The section of the road between Gloucester and Ledbury suffers from surface water flooding and tidal flooding from the River Severn, causing road closures and congestion on nearby alternative routes. The road is a key transport infrastructure route, which has been closed for up to 2 weeks per year in recent years. The impact of road closures can cause major disruption, causing diversion to the M50, M5, A40 and B4215. This is estimated to cost £45 million over a 60-year period in 2010. Taking into account inflation this amounts to £71 million pounds over 60-year period in 2025.

Table 5.17. *Annual estimated flooding costs at Maisemore. Source:* A417 Maisemore flood resilience scheme | Highways.

	Days of Disruption per Year	Cost (60-year assessment period estimated using 2025 prices)
Days of flooding of A417 per year	14	£24,493,393.88
Days of congestion on the B4215	10	£20,511,880.80
Days of congestion on the A40	10	£4,117,014.47
Vehicle operating costs	N/A	£17,451,191.21
Clean Up	2	£1,857,609.12
School Bus Diversions	10	£2,312,723.35
	Total	**£70,743,812.84**

5.6 Infrastructure

Impacts

Sewer overflows due to heavy rainfall may become more frequent as the frequency of heavy rainfall events increases. Heavy and prolonged rainfall can overwhelm drainage systems lead to combined sewer systems overflowing, affecting water courses, bathing water and even residences[7]. While investment is planned to reduce overflows, significant improvements are required to avoid future increases. If heavy rainfall is coupled with dry preceding weather, sewers can also become susceptible to blockages leading to water to back up behind this leading to flooding[8].

Figure 5.10 *Sewer flooding incident in 2012 in Stroud[10]*

The health implications from sewer flooding in homes can be acute, causing distress and long-term mental health impacts, alongside the physical health risks of contact with sewerage. **Stroud has experienced sewer flooding events**, due to the existing trunk sewer following the River Frome, flooding open spaces and field and in proximity to Stroud town centre[9].

Storms and high winds can impact energy, transport and ICT infrastructure due to high winds and lightning. Energy infrastructure can be impacted by high winds, damaging power lines and causing tree fall on to power infrastructure, whilst lightning strikes can disrupt electricity transmission networks[11]. Falling debris, such as trees or increased leaf fall, on to roads and railway lines during storm events, may also result in transport disruption. Leaf fall can result in trains being unable to accelerate and brake effectively. Power cuts can have knock on impacts on ICT networks also, particularly in rural areas[12].

Extreme heat can have adverse impacts on energy, transport and ICT infrastructure also. In the July 2022 heatwave, data centres in London suffered outages during the 40ºC temperatures experienced[13]. As extreme heat is projected to increase, Gloucestershire may also be faced by these events.

Vulnerable Groups:

- Population travelling via public transport
- Rural communities at risk from isolation

Extreme heat can result in road surfaces softening, rutting and melting. Road maintenance across the UK during the 2003 heatwave resulted in approximately £40.6 million in additional road maintenance costs[14]. Buckling of rail lines occurred during the July 2022 heatwave causing significant disruption across the UK, due to the need to slow train speeds or cancel services, resulting in passengers across Gloucestershire encouraged to use their tickets on alternative days[15]. These extreme heats are projected to increase in future, placing energy, transport and ICT infrastructure at higher risk (Figure 5.11).

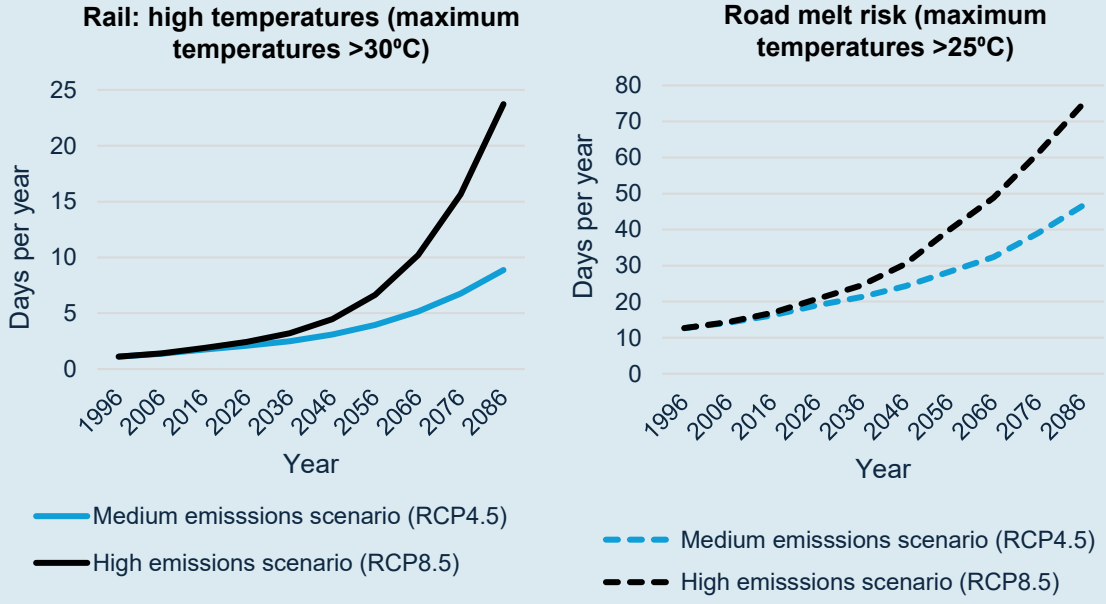


Figure 5.11 *Projections in high temperatures and maximum temperatures affecting rail and road melt risk in a medium emissions scenario and high emissions scenario in Gloucestershire[16]*

Many infrastructure networks are interlinked and depend on one another. In the event of extreme weather events (caused by flooding, storms, high winds and/or heatwaves), digital systems – such as communication networks and data centres- are more vulnerable to cyberattacks during outages or recovery periods. Further detail on interdependent risks is outlined in Chapter 5.7.

5.6 Infrastructure

Landslips

What are landslips?
Landslips are downward movement of soil, rock and debris on a slope due to gravity. As the climate changes, landslips can occur more frequently[18].

Causes of Landslips
Extreme rainfall is projected to increase in winter by up to 11.9% in a high emissions scenario by 2050s .The projected increases in extreme rainfall in Gloucestershire can trigger landslips. As rainwater from extreme rainfall infiltrates the ground, it can become more prone to slipping and sliding. The saturated soil can add additional weight in the soil, causing stress in slopes and cause downward movements. Water also has the potential to weaken the slopes' structure and undermine the slope base[19].

In Gloucestershire, droughts are projected to increase in frequency, particularly in summers where soil moisture deficit is projected to increase. In Gloucestershire, an increase in soil moisture deficit is projected in the 2050s under a high emissions scenario by up to 55%. Prolonged drought conditions can cause soils to shrink and crack, allowing rapid water infiltration in periods of heavy rainfall, weakening slopes. Dry conditions can also alter the soil structure and stresses existing vegetation, reducing root strength which stabilises the soil[20].

Case Study: Landslips on the Railway Line between Lydney and Gloucester
The railway line between Lydney and Gloucester runs along the Severn Estuary. These conditions have meant that this stretch of the rail line has been regularly impacted by landslips, causing disruption to public transport, freight trains and 'Tesco trains' that transport essential supplies to supermarkets.[21]
As a result, Network Rail have been focused on improving the resilience of a three-mile slope on the railway line. As of summer 2025, Network Rail have removed 15,000m^3 of fallen rock and earth and installed 45,000m^2 of netting and 5000 rock bolts to improve the stability of the slope and ensure the land is less prone to slips and falls[21].

Figure 5.12. Resilience works on slope between Lydney and Gloucester. Credit: Network Rail Operations

5.6 Infrastructure

Risk Outcome

Infrastructure across Gloucestershire, including energy, water and ICT assets are at risk from a changing climate. In the baseline there is a medium risk across risks to infrastructure from all types of flooding, sea level rise, risk of sewer flooding due to heavy rainfall and risks posed to all infrastructure from high winds and lightning and extreme heat. There is a low risk to public water supply in the baseline driven by a lower likelihood of low river flows. The risk scoring is driven by both scoring of likelihood and impact presented in Appendix A.

By the 2050s under a high emissions scenario, all flooding and extreme heat risks increase from a medium risk to a high risk. This increase is driven by an increase in the likelihood of all types of flooding and extreme heat under a high emissions scenario. Uncertainty in future projections of high winds and lightning is noted and should be caveated when interpreting these results. Risks to public water supplies are likely to only be affected in a severe drought, therefore, the risk increases to a medium across both scenarios in the 2050s.

Hazard	Risk	Baseline	2050s	
			Medium Emissions Scenario	High Emissions Scenario
Drought	Risk to public water supply from drought and low river flows	Low	Medium	Medium
Flooding	Risks to infrastructure from river, surface/groundwater flooding and sea level rise	Medium	Medium - High	High
Surface water flooding	Risks of sewer flooding due to heavy rainfall	Medium	Medium - High	High
Storms and high winds	Risks to energy, transport & ICT from high winds & lightning	Medium	Medium	Medium
Extreme heat	Extreme heat risks to rail, road, ICT and energy infrastructure	Medium	High	High

Note: Speckled ratings are based on qualitative data and expert judgement

Table 5.18 *Risk Matrix for Infrastructure Sector in Gloucestershire*

Adaptive Capacity

During select interviews, stakeholders from infrastructure organisations in Gloucestershire outlined their organisations' adaptive capacity. Key findings include:

What is recommended?

- Understanding the impacts of climate change is a gap, especially interdependencies.
- More partnerships are needed across organisations to address climate risk, such as cross sector networks between multiple sectors due to the cross-cutting nature of infrastructure.
- Inconsistent policy across governance and regulation is often a blocker to progressing solutions.
- Short-term time frames of political cycles can change direction of policy making implementing adaptation difficult.
- A greater understanding of the funding available for climate adaptation would be helpful, more efficient planning on this would be helpful in building capacity.
- Good guidance on performing risk assessments and how to make the best use of climate data available.

5.7 Interdependent risks

Human and physical systems are highly interconnected, resulting in wide reaching impacts from a changing climate. Gloucestershire's physical infrastructure, buildings, natural landscapes, business and industry and healthcare systems are reliant on interconnected infrastructure systems such as the power grid and transport network.

During key strategic interviews with organisations across Gloucestershire, interdependent risks were identified as a result of flooding, extreme heat, storms and high winds, low temperatures, including: supply chain disruption, power supplier and network disruption, water supply outages and disruption and damage to transport infrastructure.

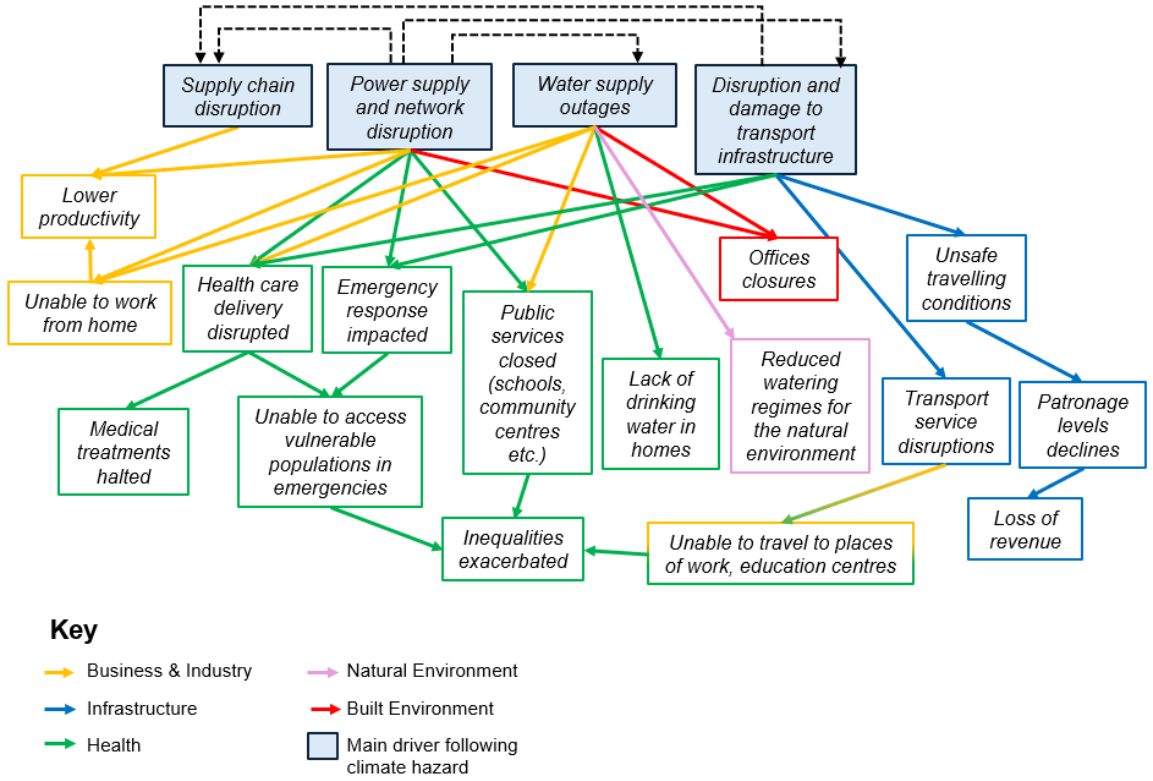


Figure 5.13 *Interdependent climate change risk linkages across Gloucestershire*

Criticality of power infrastructure

Power outages were referenced by key healthcare and infrastructure stakeholders. A failure in power not only impacts homes and businesses but also other infrastructure such as roads, rail, water supplies and wider supply chains.

Hospitals were highlighted as particularly vulnerable during power cuts which result in the need for prioritisation of services. The July 2007 flooding resulted in a loss of power to local pumping stations resulting in hospitals having no access to water with severe impacts, limiting healthcare services.

Water supply outages

Water is a critical component to ensure that healthcare and public services can operate across Gloucestershire and access to drinking water and household use is maintained. Water supply outages due to climate hazards such as drought and flooding can have adverse impacts.

Water outages have occurred in Gloucestershire due to leakages across the mains systems. Healthcare services are particularly vulnerable, and prioritisation of services can be necessary in these events, such as acute care hospitals.

Transport network reliance

Interruptions and damage to roads and rail from climate change can have knock on impacts on accessibility to key services such as healthcare, day-to-day activities such as travelling to work and access to education.

If impacted roads require lengthy diversions, rural communities and those without access to cars may be disproportionately impacted.

The cancellation of public transport may also result in loss of revenue for transport operators and leave those most vulnerable without the ability to travel during extreme weather events placing greater pressure on emergency response.

Supply chains

Infrastructure supports services across Gloucestershire including food and goods supply chains which communities and businesses rely on.

Where transport networks are disrupted due to events such as extreme heat or flooding, the delivery of supplies can be impacted and employees and contractors may be unavailable to reach their areas of employment, slowing the distributions of supplies.

6. Opportunities to minimise risks

Adaptation to climate change is defined as the "process of adjustment to actual or expected climate and its effects". Adaptation is essential to reduce the risks posed to key sectors across Gloucestershire by climate change outlined in Chapter 5.

This Chapter outlines how Gloucestershire will need to adapt to climate change. The chapter sets out (**1) an understanding of how adaptation is embedded across Gloucestershire currently with key success stories, (2) which key adaptation actions will be the most effective across Gloucestershire** and **(3) potential funding mechanisms for adaptation.**

This Chapter presents recommendations which organisations across Gloucestershire should review and look to integrate into key strategies and policies, including recommendations for priority projects across Gloucestershire. The following steps are taken with the outcome of a longlist of adaptation options, selected shortlist projects showcased in more detail and proposed next steps.

1. Outline of adaptation integration in existing policies and plans
2. Existing adaptation actions across Gloucestershire and key case studies
3. Longlist of adaptation projects
4. Short list of adaptation projects
5. Next steps

Explainer: Adaptation and Mitigation synergies

This report focusses primarily on climate risk and adaptation, however, it is important that adaptation actions do not also increase GhG emissions. For example, proposing the increased use of air conditioning to adapt to extreme heat has a knock-on impact on increasing energy use and as a result carbon emissions. This ties back to the Climate Change Committee's 10 Principles for Good Adaptation, avoiding lock in of carbon emissions through adaptation choices.

An overview of adaptation versus mitigation activities is shown below, highlighting crossover between adaptation actions and reducing carbon emissions through mitigation measures.

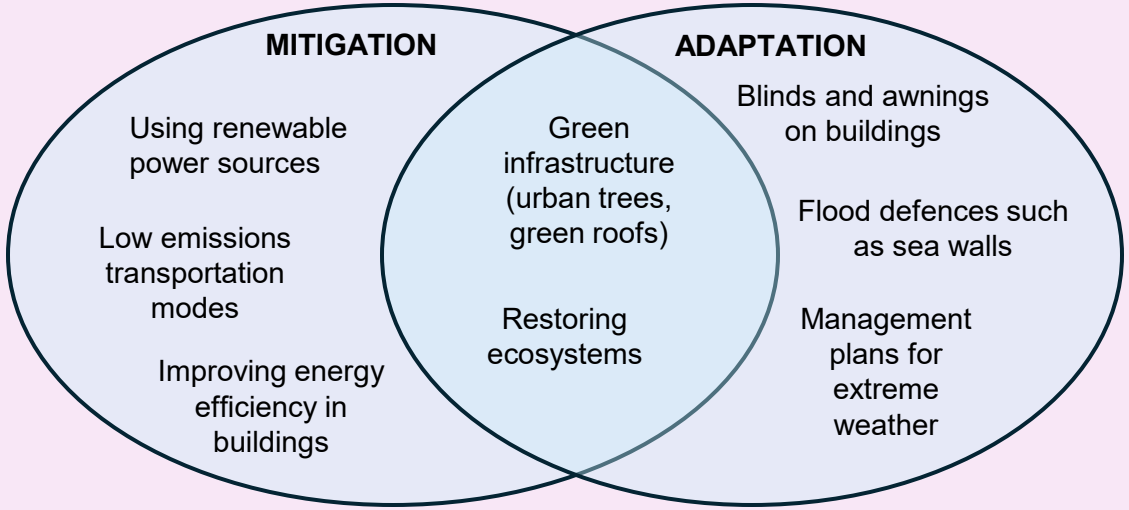


Figure 6.1 *Adaptation and Mitigation Synergies and Differences*

6.1 Adaptation integration in existing policies and plans

Gloucestershire County Council has taken significant steps to ensure that climate risk and adaptation is integrated into existing local policies and plans. The development of these plans and policies has been undertaken at various system-levels, from county-wide strategies, district-level initiatives and collaborative efforts across teams and councils. A summary of plans and policies that consider adaptation is given here.

Greener Gloucestershire Adaptation Plan – Gloucestershire County Council

The Climate Change Committee's third independent report states that "the gap between the level of risk we face and the level of adaptation has widened. Adaptation action has failed to keep pace with the worsening reality of climate risk.'[1]

Gloucestershire County Council recognises that adaptation is urgently needed due to flood, drought and heat impacts. The Greener Gloucestershire Adaptation Plan focuses on preparing the county for the inevitable impacts of climate change, regardless of mitigation efforts. The plan takes a holistic approach, aiming to integrate climate risk within the Climate Leadership Group and to adopt the Climate Change Committee's ten principles for good adaptation.[2] See Chapter 1.1 for more information on these principles.

Gloucestershire Local Transport Plan 2020-2041- Gloucestershire County Council

Gloucestershire's vision of transport is: "***A resilient transport network that enables sustainable economic growth by providing travel choices for all, making Gloucestershire a better place to live, work and visit"*** To take action towards their vision for transport, Gloucestershire County Council have developed their local transport plan.[3] The Gloucestershire Local Transport Plan sets out the strategic transport vision to 2041. The plan embeds adaptation through Policies PD 0.1, 0.4 and 4.2. As part of these commitments set out in the plan, Gloucestershire County Council plan to implement and strengthen the Climate Change Strategy by embedding principles that promote the transition towards a circular economy and deliver transport related recommendations. They also have planned an array of activities to increase their network resilience such as identifying vulnerable areas of their highway network and support multi-functional blue green infrastructure providing functions for flood risk management and adaptation.[3]

Strategic and Local Plan (SLP) - Cheltenham Borough Council, Gloucester City Council and Tewkesbury Borough Council *Emerging Local Plan*

Cheltenham Borough Council, Gloucester City Council and Tewkesbury Borough Council are currently in a phase of engagement for the new Strategic and Local Plan.[18] This engagement period runs until June 2026 and adoption of the SLP is subject to the Planning Inspectorate.

Climate change is recognised as an emerging driver for changes to the Joint Core Strategy (JCS). A new Strategic Flood Risk Assessment will be published for comment and the SLP will align with changes to the National Planning Policy Framework (NPPF) in 2024, which outlines that undeveloped land can also perform functions such as wildfire, flood risk mitigation and cooling/shading, which can help towards climate adaptation activities.

Local Plan – Stroud District Council *Emerging Local Plan*

The Stroud Local Plan[19] is currently in examination with the Planning Inspectorate. Adapting to a changing climate is listed as a priority issue, including key objectives for maintaining and enhancing green infrastructure networks. The Severn Vale Mini Vision key guiding principle includes development targeted outside the flood plain to increase resilience of the district to climate change.

***Figure 6.2** Key policies and plans by Gloucestershire County Council that integrate adaptation.*

Gloucestershire Climate Change Strategy – Fifth Annual Report Gloucestershire County Council

Gloucestershire County Council (GCC) presented an update on carbon emissions in their most recent Climate Change Strategy. The strategy states their goal to achieve 80% reduction in carbon emissions by 2030, striving towards 100% carbon offsetting by the same date. Although the strategy predominantly focuses on GCC's carbon emissions reduction efforts, there is recognition given to adaptation and the need for key actions in both mitigation of carbon emissions and adaptation to climate change.[4]

6.1 Adaptation integration in existing policies and plans

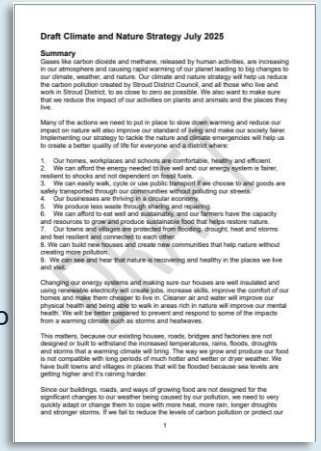
Climate and Nature Strategy - Stroud District Council

Stroud District Council published a new Council Plan that emphasises the importance of reducing our impacts on climate and nature and building resilience and adaptation.

This includes updating the existing 2030 strategy to produce a new Climate and Nature Strategy which reframes the current approach to the climate and nature emergencies. The new Climate and Nature Strategy contains specific ambitions for emissions reduction but also new specific ambitions for adaptation planning- restoring nature, prioritising nature-based solutions that tackle both the climate and nature emergencies together. This new strategy recognises that our climate is already changing rapidly, creating challenges and impacts to our everyday lives, our businesses and the natural environment.

SDC's aim is that **"our towns and villages are protected from flooding, heat and storms and feel resilient and connected to each other"**

Specific Objectives for adaptation in the strategy include AD01 through to AD05. These objectives are focused on supporting partners and affected communities to adapt and plan for sea level rise along the Severn Estuary. An adaptation plan will be established and implemented to build resilience within the most vulnerable communities and infrastructure in the District. It also aims to ensure that the Local Development Plan maximises the potential to help existing and new communities adapt to all climate risks.


Draft Climate and Nature Strategy July 2025

Summary

Gases like carbon dioxide and methane, released by human activities, are increasing in our atmosphere and causing rapid warming of our planet leading to big changes to our climate, weather, and nature. Our climate and nature strategy will help us reduce the carbon pollution created by Stroud District Council, and all those who live and work in Stroud District, to as close to zero as possible. We also want to make sure that we reduce the impact of our activities on plants and animals and the places they live.

Many of the actions we need to put in place to slow down warming and reduce our impact on nature will also improve our standard of living and make our society fairer. Implementing our strategy to tackle the nature and climate emergencies will help us to create a better quality of life for everyone and a district where:

1. Our homes, workplaces and schools are comfortable, healthy and efficient.
2. We can afford the energy needed to live well and our energy system is fairer, resilient to shocks and not dependent on fossil fuels.
3. We can easily walk, cycle or use public transport if we choose to and goods are safely transported through our communities without polluting our streets.
4. Our businesses are thriving in a circular economy.
5. We produce less waste through sharing and repairing.
6. We can afford to eat well and sustainably, and our farmers have the capacity and resources to grow and produce sustainable food that helps restore nature.
7. Our towns and villages are protected from flooding, drought, heat and storms and feel resilient and connected to each other.
8. We can build new houses and create new communities that help nature without creating more pollution.
9. We can see and hear that nature is recovering and healthy in the places we live and visit.

Changing our energy systems and making sure our houses are well insulated and using renewable electricity will create jobs, increase skills, improve the comfort of our homes and make them cheaper to live in. Cleaner air and water will improve our physical health and being able to walk in areas rich in nature will improve our mental health. We will be better prepared to prevent and respond to some of the impacts from a warming climate such as storms and heatwaves.

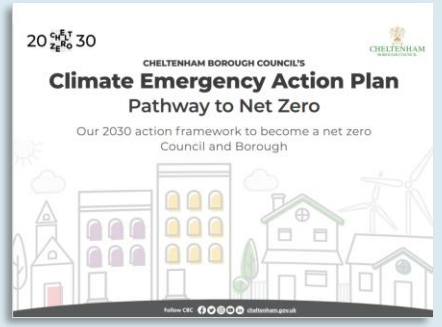
This matters, because our existing houses, roads, bridges and factories are not designed or built to withstand the increased temperatures, rains, floods, droughts and storms that a warming climate will bring. The way we grow and produce our food is not compatible with long periods of much hotter and wetter or dryer weather. We have built towns and villages in places that will be flooded because sea levels are getting higher and it's raining harder.

Since our buildings, roads, and ways of growing food are not designed for the significant changes to our weather being caused by our pollution, we need to very quickly adapt or change them to cope with more heat, more rain, longer droughts and stronger storms. If we fail to reduce the levels of carbon pollution or protect our

1

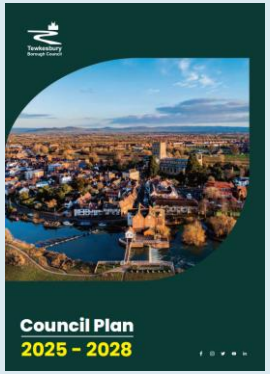
Climate Emergency Action Plan- Cheltenham Borough Council

Cheltenham Borough Council have outlined their intention to be a net-zero council in the 2030 action framework. Part of this plan focuses on reducing carbon emissions across its operations. The council is also focused on a number of climate adaptation initiatives such as the 'Cheltenham Standard'. This will be a climate-focused planning document to aid decision making and encourage the use of natural flood management techniques.
In 2024, the council invested in climate-resilient infrastructure measurements, including sustainable urban drainage systems, rain gardens, and green roofs.
The council has made significant progress to embed adaptation across its various sectors.[7].



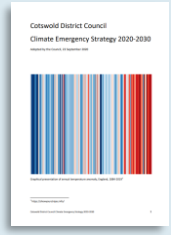
Tewkesbury Borough Council Plan 2025-2028

Tewkesbury Borough Council declared a climate emergency in 2019, which extended to a climate and ecological emergency in 2023.
Subsequently, climate action has become a key area of focus for the district council. Within their Council Plan, TBC plan to adopt and deliver a borough-wide Climate and Ecological Emergency Framework to enhance biodiversity and build climate resilience. The council have identified that nature and climate are interlinked and how the climate is crucial to supporting nature recovery, restoring habitats and protecting wildlife.[6]
As part of their commitment to climate change and adaptation, the council plan to improve their Climate Action scorecard position and build an evidence base on climate and ecological sustainability to inform the development of the future planning policy.



Climate Emergency Strategy 2020-2030 – Cotswold District Council

Cotswold District Council presented their Climate Emergency Strategy in 2020 highlighting the need for adaptation to manage the 'physical, economic and social impacts of climate disruption'. The council recognise the need to raise awareness of rising temperatures and the potential impacts to human health. The council also plan to undertake training of staff on the science of climate change and deliver a climate communications strategy[8].



6.1 Adaptation integration in existing policies and plans

Gloucestershire Community Risk Register 2022 Gloucestershire Local Resilience Forum

The Local Resilience Forum (LRF) is a multi-agency partnership with representatives from the emergency services, NHS, Environment Agency and others. The organisation aims to co-ordinate emergency management arrangements in Gloucestershire to ensure the county can prepare for, respond to and recover from emergencies.[10]

The LRF carried out a risk assessment in 2022 to identify the range of risks present in the community, assess the likelihood of their occurrence and understand the health, social, economic and environmental impacts that would occur in the event of the risks happening.[10]

Flooding and extreme weather were highlighted as a top risk in Gloucestershire. Actions that individuals can take are outlined within the Community Risk Register (prepared by the LRF) as well as links to guidance, weather warnings and winter preparedness. Similarly, guides and actions to prepare for flooding are also shared in the register.[10]

The register supports adaptation planning by informing local resilience strategies and ensures that residents and businesses are prepared for emergencies in Gloucestershire.

Climate Change Strategy – Gloucester City Council

In 2023, Gloucester City Council published their Climate Change Strategy. Their strategy highlights their commitment to delivering net-zero emissions by 2030 whilst simultaneously recognising the impact of extreme weather events. In recognition of this, the district council conducted a climate risk assessment.[11]

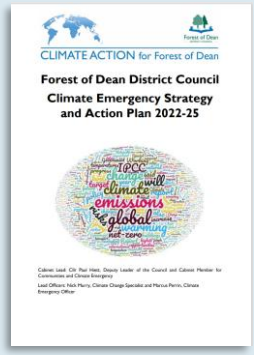
Through the risk assessment, priority risks and opportunities were identified for Gloucester City . A suite of adaptation actions fell out of this strategy, across a range of areas that Gloucester City Council can undertake to adapt to climate change. Some of these actions include[11]:

- Awareness raising focusing on those with climate anxiety
- Extreme weather follow-up schemes
- Fire and rescue community wildfire education programme
- Community support for retrofitting
- Climate Cafes
- Overheating Respite Area Creation
- Increasing connectivity of blue-green infrastructure
- Rewilding
- Multi-Agency Extreme Weather Plans

Climate Emergency Strategy and Action Plan 2022-2025- Forest of Dean District Council

Forest of Dean District Council have committed to consider the impact on climate change in all of its decision-making with a vision to embed climate change thinking as a long-established issue.

Similarly to Tewkesbury Borough Council, the council are committed to ensuring natural environment remains a top priority in combatting climate change. The council plan to carry out a review of council buildings to climate change impacts and adapt the buildings accordingly. The council aim to realise co-benefits through adaptation and mitigation efforts through the specific actions set out in their action plan[9]



Draft Local Nature Recovery Strategy

Gloucestershire Local Nature Partnership and Gloucestershire County Council are developing a Local Nature Recovery Strategy. This strategy recognises that climate change will impact the natural environment and species that inhabit it.

The strategy will include details of how climate change affects nature and how to respond accordingly, ensuring that habitats and species most vulnerable to climate change are protected. In addition, the strategy will outline how nature can also help to adapt to climate change (namely to drought flooding, extreme heat and increased fire risk. A number of potential measures will be outlined to adapt to climate change such as woodland climate adaptation and floodplain reconnection

6.1 Adaptation integration in existing policies and plans

Green Plan– Gloucestershire Hospitals NHS Foundation Trust

Gloucestershire Hospitals NHS Foundation Trust's ambition is to become a leader in sustainable healthcare. Resultantly, the trust recognises the challenge that climate change presents to its patients, colleagues and communities.[12]

Adaptation is a core area of focus, with plans outlined to ensure that adaptation remains embedded within the organisational culture. To ensure the trust is prepared for climate change, their green plan states that they will conduct a climate change risk assessment and adaptation plan to support key infrastructure. These actions will ensure the trust is well equipped to also respond and recover from climate change [12].

Figure 6.3 *Heath plans across Gloucestershire that integrate adaptation.*

Green Plan 2022-2025 – One Gloucestershire

One Gloucestershire Integrated Care System takes on a legal and social responsibility to address climate change, especially due to the inextricable links between climate change and human health[13].The plan outlines how climate hazards, such as flooding, drought and extreme temperatures can exacerbate health issues. Subsequently, adaptation is considered a sustainability priority. As a result, the organisation commits to developing a climate change adaptation plan outlining interventions to reduce the impact of risks[13].

Gloucestershire Health and Care NHS Foundation Trust (GHCNHSFT)

GHCNHSFT published their three-year Green Plan to outline how they plan on reducing their emissions between 2022 and 2025. The plan outlines their achievements to date which ensure that they reach net-zero by 2040. Some of these implemented interventions include solar panels and EV charging points.[14]

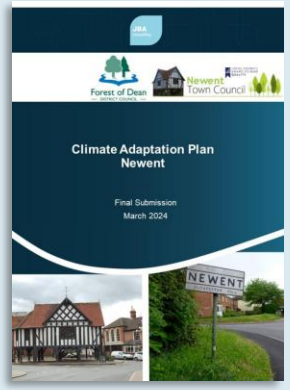
In their mission in delivering sustainability beyond net-zero, wider sustainability measures have been implemented across Gloucestershire. For example, swales and trees planting at the North Cotswold Hospital, enhancing resilience to flood events.[14]

The plan references the organisations' objectives and actions to increase their resilience against climate-related severe weather events. This includes development of a climate adaptation plan and conducting a climate risk assessment to ensure climate change and adaptation features on the Trust's risk register[14]

6.1 Adaptation integration in existing policies and plans

Forest of Dean Town Risk Assessments and Adaptation Plans

The Forest of Dean District Council supported the Town and Parish Councils in developing climate adaptation plans for integration into local strategies. The project was funded by the UK Shared Prosperity Fund and delivered with JBA Consulting. The project delivered local scale climate risk assessments to understand how climate is going to change in the future under a medium and high emissions scenario for the Forest of Dean, and the towns within the district, namely Cinderford, Coleford, Lydney and Newent. Risk assessments assessed temperature increases, rainfall changes and changes in the number of heatwaves in the 2050s, 2070s and 2100 under a medium and high emissions scenario.[15]

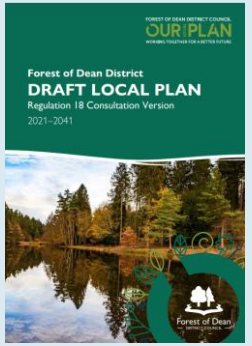


Following on from the results of the risk assessments, adaptation plans were developed. These plans considered local measures that build resilience, as well as outlining how the town can support adaptation over long-term periods for people and the natural environment. For each town, a longlist of adaptation measures, alongside time periods, costs, funding mechanisms and barriers to implementation were outlined. These plans allow the relevant local town council to use these documents to guide policies and implement adaptation actions

Forest of Dean Draft District Local Plan 2021-2041

The Forest of Dean District Council (FoDDC) are developing a Local Plan which is currently under draft. The purpose of the Local Plan Is to guide change that benefits the local area. Within the local plan, a number of policies are being developed to ignite change and benefit the local population within the district. [16]

In the FoDDC's Local Plan climate change is embedded throughout the document in several policies. Specifically, under Policy LP.1, new sustainable developments must be designed to "*reduce the vulnerability to and provide resilience from the impacts arising from a changing climate.*"[16]

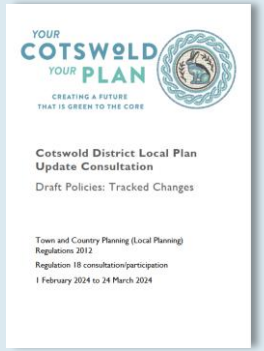


In addition to Policy LP.1, Policy LP.3 focusses on climate adaptation, ensuring that new developments must include and show effectiveness of a number of measures. Some of these measures are aimed to contribute towards building climate resilience. These include outdoor spaces and use of vegetation to provide shade, open water features, enablement of airflow throughout buildings[16]

Cotswold District Draft Local Plan

Similarly to the Forest of Dean District Council, the Cotswold District Council are drafting their local policies that will sit in their local plan. Climate change adaptation is embedded throughout the policies in the draft local plan.
Policy SD.2 is focussed on the climate and ecological emergencies. The policy states that policies that incorporate adaptation measures, improve connectivity of blue and green infrastructure network in the district and avoid placing development in areas at risk of flooding will be actively supported. These policy measures ensure that the Local Plan is made "green to the core"[17]

In addition to Policy SD2, SD3 is outlines the Cotswold Design Code. The Cotswold Design Code ensures that the area maintains its distinct character. As part of this policy, the design code references the need to ensure that designs also meet the challenge of climate mitigation and adaptation[17]



6.2 Adaptation: influence, partnerships and control

Adaptation across Gloucestershire requires action from a wide range of organisations, working in partnership. The county and district councils have an important leadership role to play, but it is important to be clear about the areas over which county and district councils have direct control, and those where councils can convene and influence, but rely on others to implement adaptation on the ground.

Spheres of adaptive influence: a county and district council perspective

Direct Control – "We have direct control over our buildings and estate, and the services which we operate. This means we can use our buildings to pilot approaches to resilience (for example cool spaces), and seek to integrate resilience within our services."

Indirect Control – "The council is a significant buyer of services, and we can use our procurement processes to encourage resilience (e.g. targeting social value to community adaptation measures)."

Place shaping – "A key lever we have is to use local plans to control how development and regeneration takes place. Where possible we will ensure that developments are both resilient in themselves, and support wider resilience in our communities (e.g. reducing heat island effects, or surface water flooding)."

Enabling and Engaging – "We can convene and support the partnerships needed for resilience across the county. Our role is to set the tone, demonstrate and reward good practice, and facilitate the space needed for innovation and collaboration."

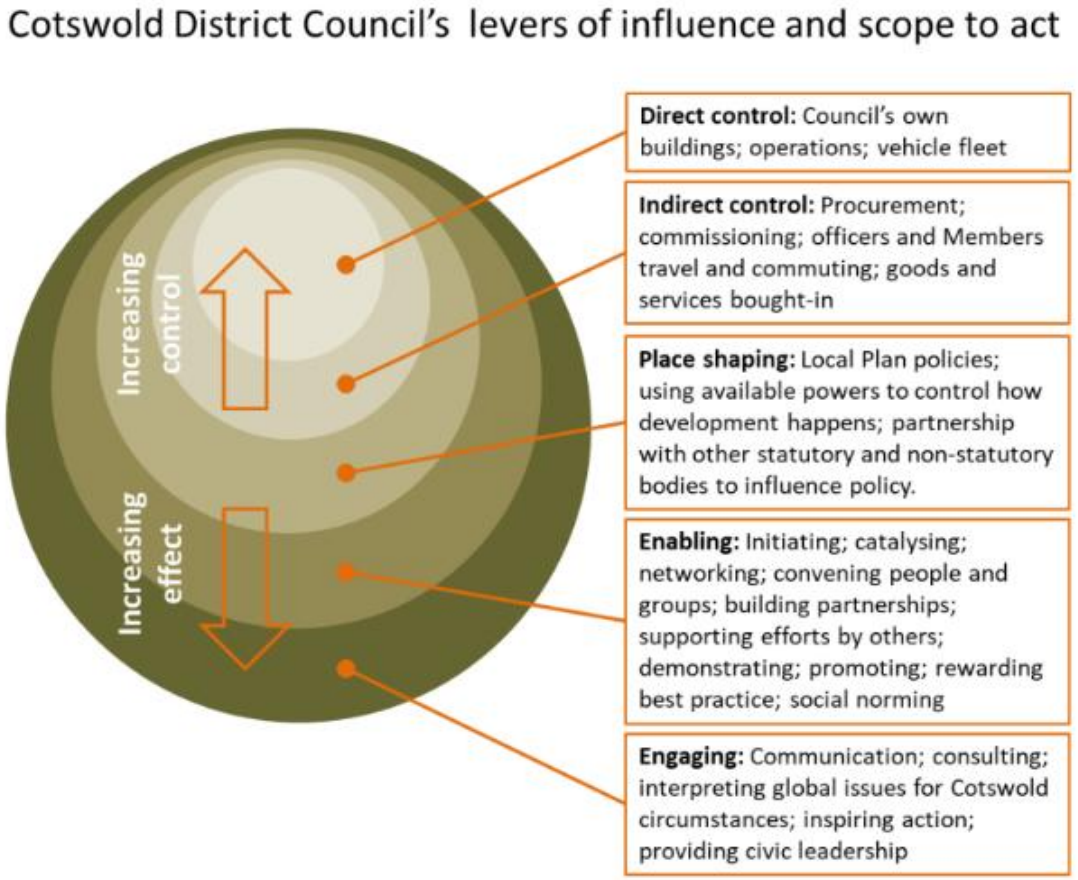


Figure 6.4 *Cotswold District Council's spheres of Influence, as set out in the Climate Emergency Strategy 2020-2030.*

6.3 Existing adaptation actions in Gloucestershire

Gloucestershire is already taking action to adapt to climate change through a range of initiatives. Together, these programmes help build climate resilience across the county's landscape, infrastructure, and communities. Through our engagement with stakeholders, a compiled list of existing adaptation action undertaken by various organizations is shown below:

Business and Industry

- Business engagement has been facilitated through the Growth Hub which includes a series of **climate adaptation workshops.** These workshops aimed to **enhance preparedness and response to climate change.** Building on this success, similar **future workshops are proposed for parish councils**
- **Capacity building** and the broader relevance of **climate adaptation—beyond emergency planning**—have been demonstrated using the Local Government Association's Adaptation Toolkit.
- **Forest of Dean Climate Action Partnership** brings together communities, organisations and businesses to work together and build a net-zero and climate resilient Forest of Dean. The group is connecting actors to work on climate, creating networks, and sharing lessons learned across the business.

Healthcare

- New **community hospital developments** are being designed with climate resilience in mind.
- **The Forest of Dean Hospital** exemplifies best practice, incorporating features such as **Sustainable Drainage Systems (SuDS), passive cooling, solar-resistant glazing, green spaces**, and sound insulation. These measures enhance resilience to hazards including cold spells, heatwaves, and surface water flooding.
- Hospital sites have established **emergency response plans** for **extreme weather events**. These plans include measures such as backup generators, emergency supplies, and the use of 4x4 vehicles to ensure continuity of operations during disruption.
- **Public health** campaigns have been implemented to promote **adaptive behaviours** among residents. Notably, communications on staying safe during heatwaves have contributed to a reduction in heat-related hospital admissions compared to similar events two decades ago.

Built Environment

- **Gloucestershire County Council** is **leveraging regeneration projects** to deliver climate adaptation outcomes. Projects include **tree planting, creation of cool spaces, Sustainable Drainage Systems (SuDS), and improved ventilation**.
- **Cotswold District Council** has published **online guidance** to help traditional buildings become more climate-resilient. This resource is now being adopted by other local authorities.
- **The Green Open Home programme** is under development to promote **energy retrofits,** supporting **household-level adaptation** to climate risks.
- Adaptation is being prioritised within the **Green Skills Strategy**, with emerging roles in **natural flood management and urban greening** identified as key areas for workforce development.
- **The Barnwood Trust** is commissioning research to explore **optimal funding approaches for climate action**, integrating both mitigation and adaptation. This includes embedding adaptation within funded initiatives, such as **retrofitting and accessibility improvements**.
- Towns are planning to **install public water fountains** to **reduce overheating risks** in urban areas.
- **Tewkesbury Borough Council's Garden Communities Masterplan** is incorporating **adaptation measures** to ensure **new developments are resilient** to heat, cold, and drought.

6.3 Existing adaptation actions in Gloucestershire

Natural Environment

- The **Forest of Dean woodland** serves as a leading case study in climate adaptation. Measures include drought and flood resilience, tree species diversification to combat climate-related disease, natural flood management, and the reintroduction of beavers to enhance ecosystem resilience.
- The **Stroud Valleys Natural Flood Management Project** is a community-led initiative using nature-based solutions—such as tree planting, wetland creation, and river reconnection—to reduce flood risk and boost biodiversity.
- Cheltenham Borough Council is reviewing **tree species selection in parks** and open spaces to improve resilience to drought and flooding.
- The **Gloucestershire Natural Flood Management Partnership** is delivering landscape-scale interventions through cross-sector collaboration, taking a holistic approach to climate resilience.
- The **Local Nature Recovery Strategy**, mandated under the **Environment Act 2021**, will identify **spatial opportunities for biodiversity and habitat** enhancement. Due in 2026, the strategy will promote nature-based solutions to mitigate drought and flood risks helping to shape a **climate-resilient vision** for Gloucestershire.[1]
- Public campaigns on **fire risk** and **flood preparedness** have been delivered in partnership with emergency services.
- The **Environment Agency** continues to engage with communities following **flood events** to gather insights and **improve future response and warning systems.**

Infrastructure

- **Severn Trent Water** has implemented **customer-facing programmes** to improve **water efficiency**, including the distribution of **water butts** in areas **vulnerable to flooding and drought**. The organisation assesses current and future climate risks and is retrofitting high-risk assets to enhance resilience. Other adaptation measures include increasing **backup generator capacity** at key sites and using **nature-based solutions to improve biodiversity**—supporting water retention, quality, and flow regulation.
- **National Grid** is developing an adaptation policy to guide climate-resilient asset design. The organisation is conducting iterative risk assessments and testing new materials and methods, including retrofitting assets, to strengthen infrastructure resilience.
- The **Southwest Infrastructure Partnership** is fostering a shared mindset around climate adaptation, influencing leadership across sectors. It has co-developed a route map with adaptation as a key pillar and is promoting collaboration across supply chains to unlock value through joint workshops and initiatives.
- **Gully clearing** has proven effective in reducing localised flooding, notably during the 2007 flood events.

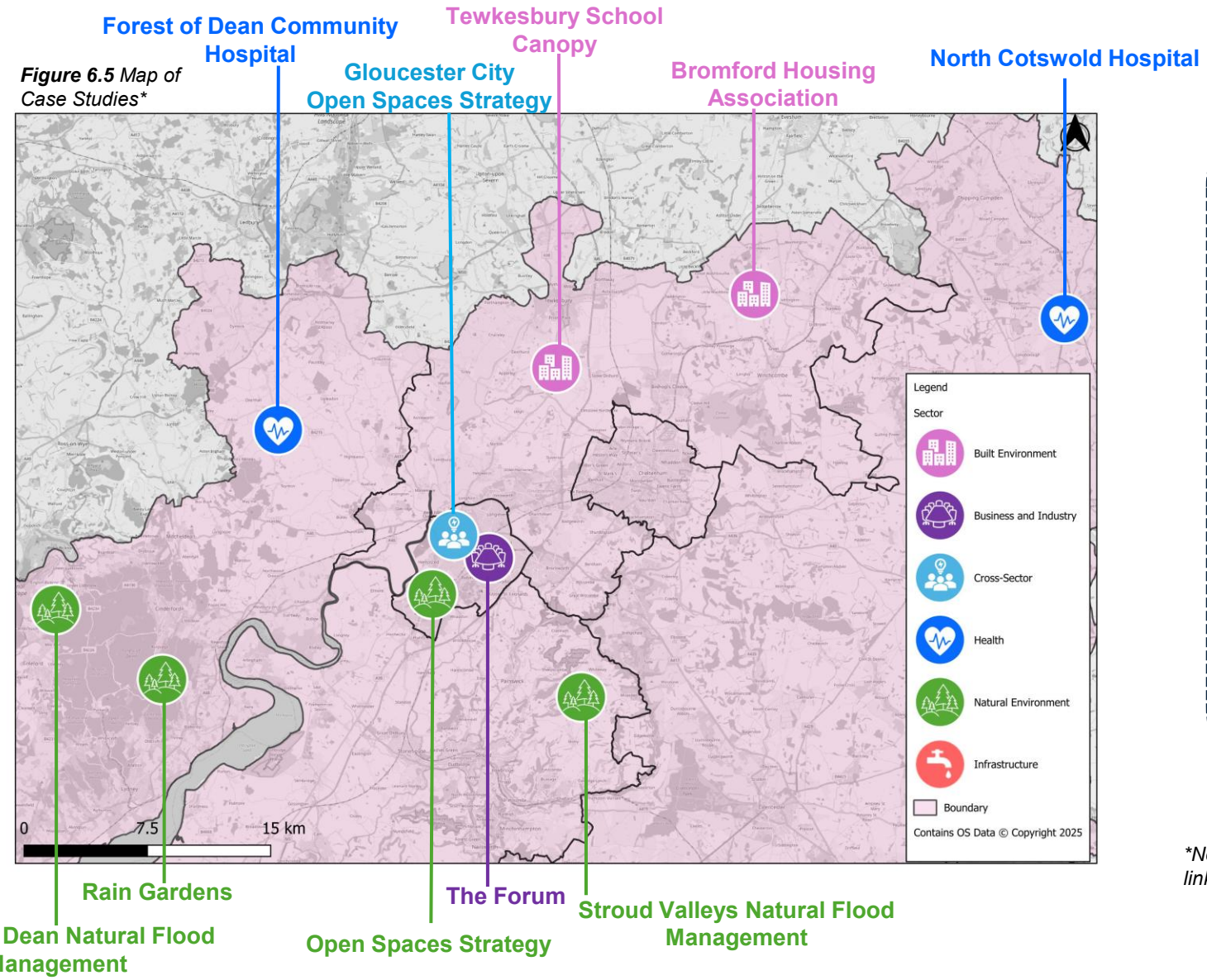
Agriculture

- **Farmer Facilitation Funds** are being used to support **agricultural stakeholders** in adapting to climate change.

6.4 Case studies of climate adaptation and resilience

Across Gloucestershire, there are a number of examples that showcase adaptation and resilience. This section explores these case studies in further detail. A summary of the case studies that will be explored are shown below.

Figure 6.5 *Map of Case Studies**



Regional and National Case Studies

In addition to the case studies shown in Figure 6.4, a number of case studies that feature adaptation and resilience measures span regionally and even nationally. These are summarised here:

- Gloucestershire Local Resilience Forum
- Gloucestershire Natural Flood Management Partnership
- Cheltenham and Gloucester Waterscapes
- South West Infrastructure Partnership
- Severn Trent Adaptation Measures
- National Grid Building Resilience

**Note: Locations of case studies shown in Figure 6.5 are not exact but are linked to the corresponding district*

6.4 Case studies of climate adaptation and resilience

Forest of Dean Community Hospital

The Forest of Dean Community Hospital was completed in 2024. Located in Cinderford, the project has embedded sustainable principles into its design and day-to day operations. The hospital has been designed to achieve BREEAM Excellent certification, showcasing features that make it a model of sustainability. The building has implemented an array of measures to reduce energy use and make the building climate resilient.[1]

To save energy, the building features thick insulation in its walls and roof reducing energy required for heating and cooling. This makes the property resilient to climate change in the face of cold spells and heatwaves. The hospital relies solely on electricity and uses air-source heat pumps, mechanical ventilation recovery systems and on-site renewable energy sources, driving down energy consumption.[1]

The hospital has also used sustainable materials which are easily recyclable when they come to their end-of-life. In addition, the surrounding site preserves and enhances local ecology and biodiversity.
Consideration to wildlife, such as dormice and bats have been incorporated onto the wider site, in addition to the planting of 100 trees increasing biodiversity further. The hospital has also taken surface water flooding and drainage into account in its design.[1]

***Figure 6.6** . Forest of Dean Community Hospital[2]*

North Cotswold Hospital

Gloucestershire Health and Care NHS Foundation Trust completed work on the site to make the North Cotswold Hospital site more sustainable and resilient to climate change. The organisation implemented extensive ornamental gardens with some semi-naturalised copses.
In addition, swales and bog plants were created to make the site more resilient to surface water flooding. The grounds were designed with rehabilitation in mind, benefitting the mental and physical health of patients and visitors.[28]

A total of 246 NHS forest trees have been planted since 2012, which improves the resilience to heat and flooding, as well as promoting biodiversity. The site was commended at the NHS Forest Conference Awards in 2014.[28]

Cheltenham and Gloucester Waterscapes

Waterscapes are a nature-based solution for flooding. Over the past two years, the Gloucestershire Wildlife Trust and Intact Insurance have implemented a number of nature-based solutions to limit the impact of flooding and boost biodiversity.

So far, the team have removed paving to let the rain soak into the ground and installed rain gardens which capture and slow rainwater. In addition, swales and scrapes have been created to manage surface water, reducing the risk of surface water flooding and built leaky dams to help 'slow the flow' upstream. In total an additional 2,989,078 litres of water can now be stored during heavy rainfall events reducing the pressure on drainage systems.[26]

For more information on rain gardens see the Case Study on Rain gardens at Cinderford.

***Figure 6.7.** Rain garden at Springbank Community Centre [26]*

6.4 Case studies of climate adaptation and resilience

Stroud Valleys Natural Flood Management

The Stroud Valleys Natural Flood Management (NFM) Project is an innovative partnership to reduce flood risk, improve water quality, and restore nature across the 250 km² catchment of the River Frome and its tributaries (Slad Brook, Painswick Stream, Nailsworth Stream, Ruscombe Brook, and others). It brings together Stroud District Council, the Environment Agency, local landowners, community flood groups, and other partners to implement a catchment-wide approach that uses a suite of NFM measures to slow flows and buffer peak discharges downstream[9]

The project team's key achievements to date include[8]:

- Over **1000 interventions** throughout the wider Frome Catchment
- **50 local land managers** and contractors working together to implement NFM actions
- **Strong partnership working** and networking locally and regionally
- Establishment of a **monitoring network** for NFM in Stroud Valleys
- **Positive feedback and engagement** from the community
- **41 km of watercourses improved**
- **1m reduction in peak river levels**
- Development of '**The Sound of the River' comic** depicting the impact of Nature based solutions
- These features now intercept runoff from around **25% of the catchment**—directly moderating flow rates upstream of vulnerable communities

The Stroud Valleys NFM Project demonstrates how a landscape-scale, nature-based approach can effectively manage flood risk while delivering co-benefits for water quality, biodiversity, and community engagement. Its success has been proven through continuous monitoring that have shown reductions in peak flows. The project has also contributed to an evidence base of nature-based solutions through numerous scientific studies, working with universities and scientific institutions. Work continues to implement NFM measures in the Stroud Valleys with each intervention providing small but beneficial impacts in the catchment.

Figure 6.8. *Leaky Woody Dams at Snows Farm Nature Reserve*[7]

Benefits of Natural Flood Management

- Enhance drought resilience
- Reduce flood risk by 'slowing the flow'
- Improve health and wellbeing
- Increase biodiversity through improved and created habitats

6.4 Case studies of climate adaptation and resilience

Forest of Dean Natural Flood Management Project

Gloucestershire County Council Flood Risk Management (FRM) Team are working in partnership with Forestry England (FE) to deliver an ambitious and groundbreaking project in the Forest of Dean, working with natural processes to increase biodiversity, sequester carbon and reduce the impact of the climate emergency by reducing peak flood flows.

Lydney, in the Cannop catchment, is one of GCC's highest priority and most frequently flooded communities. In seeking to address the impact on homes and businesses, the FRM team carried out a wide-scale hydrological modelling study to identify flood risk mechanisms and test opportunities to mitigate the risk. As a result of the study, the most beneficial option was shown to be creation of upstream attenuation through the application of natural flood management (NFM) techniques.

Due to the hard work and commitment of key individuals within both organisations, GCC and FE have developed a regional, if not national partnership model to deliver NFM measures throughout the catchment and reduce downstream flood risk, building on and augmenting the objectives of FE's Catchment Management Plan. These measures are diverse and numerous, but all seek to mimic and enhance the way nature works with water. They include approaches such as large 'woody debris dams', wetland creation, bankside buffer planting and river restoration.
The project is slowing the flow of water, reconnecting floodplains, increasing habitat connectivity and diversity and helping to build a more climate-resilient catchment.

Key statistics include:

- 8 hectares of wetland created
- 5 hectares of wet-woodland habitat created
- 15 reaches buffer-planted
- Over 5,000 woody-debris dams created
- 40,000 trees (native species) to be planted, with some non-native species removed
- 74.5 Km of river restoration
- Total four years project lifespan, with potential to extend
- £888,000 national funding awarded, augmenting existing GCC capital and revenue commitment.

***Figure 6.9**. Perryhay beaver release © Steven Gregory Photography*

Gloucester City Council Riparian Restoration

Riparian restoration is the ecological process of rehabilitating the interface between land and water along rivers, streams, lakes, floodplains, and other hydrologic systems. It focuses on re-establishing native vegetation, restoring natural hydrological and geomorphological functions, and improving the physical, chemical, and biological linkages between terrestrial and aquatic ecosystems

Gloucester City Council have undertaken multiple riparian restoration projects to reduce flood risk and improve biodiversity. At Sud Brook and Twyver, Gloucester City Council are removing the concrete channel and creating a wildflower meadow and wetland features. As a result of this project, the meadows are continuing to establish, and the river has settled producing riffles and habitats for wildlife. Additionally, families of moorhens have already started to inhabit the area along with large populations of bees, damselflies and dragonflies[12].

Similarly, at Whaddon Brook off of Holmleigh Park, channel improvements have been made to the river and the wildflower meadow areas have been created. At this site nearly 50 new trees have been planted, supplemented with 10 bird and bat boxes[13]. Changes at the site have reduced flood risk, reconnected waterways and reduced pollution impacts. Benches have also been provided for the community to enjoy the aesthetic surroundings.[14]

***Figure 6.10.** Sud Brook and Twyver catchment [12]*

6.4 Case studies of climate adaptation and resilience

Gloucestershire Natural Flood Management Partnership

The Gloucestershire Natural Flood Management (NFM) Partnership brings together 18 local partners involved in sustainable water management including; county agencies, environmental non-governmental organisations, and community groups to implement landscape-scale adaptation measures across the Severn Vale catchment. By combining governance frameworks, funding mechanisms, and on-the-ground interventions, the partnership aims to reduce flood risk, improve water quality, and enhance biodiversity[5].
Early work has focused on establishing 'Principles of Good NFM Delivery' and creating a project pipeline for more than twenty priority sites. Key interventions included installation of large woody debris dams and leaky structures to slow river flows, wetland creation and channel re-naturalisation to store and filter runoff.[6]

Key features of the partnership include[6]:
- Over 400 large woody debris structures installed to buffer peak flows
- Wetland restoration to enhance habitats and buffer water flows
- Enhanced streamside connectivity supporting species such as brown trout and native amphibians
- Engagement of more than 30 landowners in long-term management of NFM features

These results validate the partnership model for scaling adaptation across diverse landscapes.

Figure 6.11. *Gloucestershire Natural Flood Management Partners*

Priors Farm Estate SuDS Retrofitting Project

The Priors Farm Estate in Oakley, Cheltenham, was originally built in the 1960s and featured large gardens and open grassy spaces. Over time, the area became increasingly vulnerable to surface water flooding due to the expansion of hard surfaces within the catchment and capacity limitations in the local surface water sewer network. These issues contributed to downstream flooding and poor ecological conditions in the Wymans Brook, a tributary of the River Swilgate.[27]

To address these challenges, Cheltenham Borough Council implemented Sustainable Drainage Systems (SuDS) on the housing estate. The design incorporated two main components: detention basins in public open spaces and rain gardens installed in private front gardens. The detention basins were created to temporarily store road runoff and release it slowly into the sewer system, while the rain gardens managed roof runoff by disconnecting downpipes and diverting water into landscaped areas with layered construction for filtration and storage.[27]

Community engagement played a vital role in the success of the project. Residents were consulted extensively and given opportunities to influence design choices, The project delivered multiple benefits, including significant reductions in surface water flooding, and enhanced biodiversity through the introduction of wildflower meadows and diverse planting schemes. It also raised awareness of SuDS among the local community.[27]

Figure 6.12. *Rain garden in a private garden* [27]

6.4 Case studies of climate adaptation and resilience

Rain Gardens at Cinderford

Rain gardens are designed to capture rainwater flowing off roofs and can slow the flow of water back to watercourses, reducing the risk to flooding. Rain gardens provide multiple benefits, such as reducing pollution through filtering water and storing rainwater to reduce the likelihood of surface water flooding[4]

The Gloucestershire Wildlife Trust is working in partnership with Severn Trent and the Environment Agency to install 5 rain gardens at community buildings and create two areas where pavement has been removed to restore natural soil and greenery.
At the Forest Community Church building, metal planters have been filled with plants to tackle runoff issues, and attract pollinators and insects[4]

Figure 6.13. *Metal Tanker Rain Garden[4]*

Tewkesbury School Dining Canopy

Tewkesbury School in Gloucestershire, were looking to repurpose outdoor space to give pupils the chance to enjoy fresh air at lunchtimes and breaktimes despite weather conditions.

As a result, they recently had an outdoor canopy installed. The structure provides a sheltered outdoor space that offers some shading in summer and protection from rainfall. It can also be used for outdoor learning and social activities. Ensuring children and staff can enjoy fresh air promotes health and wellbeing, as well as being a mechanism to adapt to climate change.[3]

Figure 6.14. *Canopy Design at Tewkesbury School[3]*

Bromford Housing Association – Embedding Climate Resilient Measures

Bromford Housing Association owns 47,000 homes spread across central and southwest England, providing affordable housing for those who cannot access the market easily. Per annum, Bromford Housing Association has a build programme of ~1750 new homes, of which 700 new homes are constructed in-house.

Bromford Housing Association decided to increase the resilience of its properties to climate change. Recent desktop research undertaken by the housing association identified that ~2500 properties were at risk from overheating in summer. In addition, through customer surveys it was identified that 44% of the sample size surveyed showed probable overheating exposure. The results indicate the risk of rising temperatures and heatwaves to Bromford's properties and occupiers.

Following on from the results, Bromford Housing Association developed a suite of actions to be implemented on existing sites and new build homes. Sustainable green spaces in communities were reviewed to ensure enough shading is available, as well as using solar PV as a mechanism to provide shading. Water harvesting systems are also being implemented to capture rainwater and prevent surface water flooding. To combat overheating, increased ventilation measures are being implemented in existing homes. The actions that Bromford Housing Association
Have implemented ensure their property stock remains resilient in the face of climate change

6.4 Case studies of climate adaptation and resilience

The Forum, Kings Quarter, Gloucester City

The Forum in Kings Quarter, located in the heart of Gloucester City will offer premium offices, residential apartments, retail space and restaurants. The building has been designed with sustainability at its core, as it is planned to be built to a BREEAM rating of Excellent and to be net-zero in operation. The development incorporates a range of climate adaptation measures that respond to the growing challenges of extreme weather. The building will have a 600 square metre vertical garden – the largest in the southwest region- which will contain 5,000 panels and 48,000 individual plants. This living wall will provide multiple benefits including; improved air quality, enhanced biodiversity and provide cooling to occupiers within the building. The green wall will be watered through a hydroponic system that utilises recycled rainwater[15].

The Forum is also net-zero carbon enabled with renewable energy integrated into its design. Solar panels are planned to be installed on the roof contributing to clean energy generation. A separate area consists of a green roof to manage stormwater and provide temperature regulation[15].

In addition to the features outlined above that promote net-zero carbon and adaptation, the development promotes sustainable transport options. It offers 42 electric vehicle charging points and is located next to Gloucester's transport Hub[15].

Figure 6.15. *Forum Development* [25]

South West Infrastructure Partnership

The South West Infrastructure Partnership (SWIP) is a cross-sector infrastructure community convened by the Institution of Civil Engineers (ICE) South West, to create lasting value for the region by breaking down silos, sparking collaborative conversations and bringing people together to create an informed, coordinated regional voice on infrastructure[16].

The aim of the partnership is to build an inclusive, sustainable and resilient community in the South West, meeting the region's infrastructure needs over the next 30 years[16].

SWIP has created a regional voice in the built environment on topics such as decarbonization, adaptation and the development of green skills. The partnership recognizes the need for cross-collaboration across all sectors from highways and rail to power and energy. SWIP has run multiple workshops focused on adaptation pathways. The workshops that SWIP has hosted brought together representatives from a range of sectors to discuss the most urgent adaptation challenges for infrastructure and possible solutions. The workshops and cross-sector collaboration are key for driving forward progress in adaptation through innovating, co-creating solutions and sharing best practice[17,18].

The SWIP have recognised an approach that embeds nature into decision-making to achieve more sustainable growth. This includes harnessing nature-based opportunities to achieve adaptation and resilience, whilst taking a whole-systems approach to design.

SOUTH WEST INFRASTRUCTURE PARTNERSHIP

The organisation promotes this thinking whilst appreciating the co-benefits such as increased biodiversity net gain, enhanced placemaking and improved mental health[18]

6.4 Case studies of climate adaptation and resilience

Severn Trent Water – Building Resilience through Adaptation Measures

Severn Trent serves over 4.6 million households, and covers an area of 21,000km^2 and 6,800km of rivers[19].

In recent years, Severn Trent have experienced the impact of extreme weather events. In July 2022, the extreme hot weather caused most reservoirs in the catchment area to be in drought. Reservoir levels fell from 96% to <30%, whilst the increased temperatures increased water demand. Also in 2022, extreme cold weather posed risks to Severn Trent's water network. Intense cold temperatures followed by rapid thawing led to a 40% increase in burst pipes during this period.[20]

Severn Trent are taking action to implement adaptation activities and plan ahead to reduce climate change risks. During interviews with Severn Trent, it was found that the following actions are being implemented to make their organisation and operations more resilient:

- Engagement with residents to reduce water use during hot weather to in turn reduce demand
- Capital investment to improve the resilience of services through mechanisms such as flexible water management and increasing the capacity to supply water
- Utilisation of weather predictions to increase preparedness across the business through the development of playbooks that outline how to act in specific weather conditions
- Reviewing and updating design standards to futureproof assets to future climate conditions
- Building resilience to power supply through an increased number of backup generators
- Increasing number of flood defence protection to assets
- Enhanced biodiversity on 11,500 hectares of land as of 2024

National Grid – Retrofitting assets to build resilience

National Grid plays a critical role in the energy sector and has made a commitment to ensuring its assets and operations are climate resilient. As a result of its commitment, National Grid has undertaken a climate change risk assessment to identify climate hazards, the potential impacts and adaptation actions required for implementation.

In response to climate change challenges, National Grid are innovating and building asset resilience. National Grid are retrofitting insulated cross arms (RICA's), allowing existing 275kV towers to be uprated to 400kV without the need for new overhead lines. RICA's can help withstand more extreme weather with improved insulation reducing the risk of faults in storms and heatwaves[21].

National Grid are also using a range of data-led approaches to inform decision making and future investment needs. National Grid are investigating coastal and estuarine climate risks on electricity asset management (ICECREAM). This project addresses coastal erosion and chemical reactions on network assets, which can cause failures across their networks. As part of ICECREAM, new cameras and sensors gathering real-time data will give insights into a multi-hazard assessment of risks posed by flooding and erosion to assets. This will enable National Grid to monitor asset health, identify critical risk moments in real-time and enable cost benefit analysis to maintain network resilience. National Grid's Environmental Risk and Assurance (ERA) project is developing an automated weather alert tool to provide an early warning system for flood risk to their infrastructure. This enables engineers to have better visibility of the risks around incoming extreme weather events[22].

National Grid need to better understand the effects of extreme temperature events on network assets. As a result, the organisation plan to simulate extreme weather events in a tool to test the 'worst case scenarios' and identify the most resilient technologies. The data informed approach will help to inform future investment strategies and National Grid's climate adaptation strategy[22].

6.4 Case studies of climate adaptation and resilience

Gloucestershire Local Resilience Forum

The Gloucestershire Local Resilience Forum (LRF) is a collaborative partnership involving multiple agencies, including emergency services, local councils, the NHS, the Environment Agency, and others. Together, they coordinate integrated emergency management across Gloucestershire to help individuals, businesses, and communities prepare for potential disruptions and emergencies[23].

As part of its responsibilities, the LRF conducts comprehensive risk assessments to identify local hazards, evaluate their likelihood, and understand the potential health, social, economic, and environmental impacts. These assessments guide the Forum's priorities and ensure that preparedness efforts are targeted and effective[23].

To support public readiness, the LRF offers practical advice through its 'Are You Ready' booklet, covering how to prepare in events such as cold weather, fires, flooding, storms, extreme heat, power outages, and evacuation procedures. Being well-prepared can help reduce the impact of severe weather, lessen reliance on emergency services, and empower individuals to assist vulnerable members of their community[14].

For more information on the Local Resilience Forum's Risk Register see Chapter 6.1

Gloucester City Open Spaces Strategy

The City of Gloucester has over 200 areas of public open space which includes parks, allotments, nature reserves and more. Between 2014 and 2019 alone, the council added an additional 15 hectares of open spaces. However, with the district's growing population, local green spaces are in demand[24].

Gloucester City Council's Open Spaces Strategy 2021–2026 establishes a framework to manage and enhance the city's green infrastructure with explicit goals for climate adaptation. By leveraging open natural spaces through processes such as evapotranspiration, rainwater interception, and soil infiltration, the strategy aims to reduce flood risk, mitigate urban heat, and bolster biodiversity across all neighbourhoods[24].

The Open Spaces Strategy provides residents and visitors with opportunities to reconnect with and visit nature. Open spaces also provide habitats for wildlife and bring an element of the countryside to the city [24].

The Open Spaces strategy aims to use green spaces to mitigate and reverse the effects of climate change and biodiversity loss. The strategy plans to plant trees, implement water management schemes and other measures to support the health and wellbeing agenda, and reduce inequalities when it comes to accessing open and green spaces[14].

Figure 6.16. *Open Space in Gloucester City*

6.5 Longlist of adaptation projects

A longlist of potential adaptation projects is presented, alongside a multi-criteria analysis to prioritise adaptation projects which could be brought forward in Gloucestershire.

This provides an illustrative example of possible projects, assessed based on their performance/benefits, approximate cost and deliverability. A long list of projects is presented for the six key sectors across Gloucestershire, alongside overarching recommendations which centre around education and awareness, cross-sector collaboration and policy and governance.

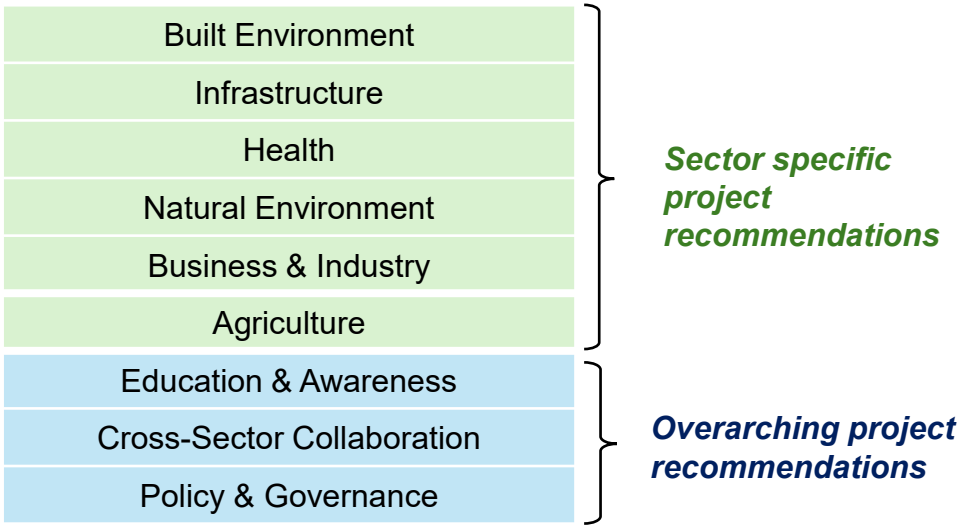


Figure 6.15 *Grouping of adaptation projects for the multi-criteria analysis.*

The longlist of adaptation projects was derived from stakeholder engagement including interviews and an online workshop, literature review from sources such as the Local Climate Adaptation Tool and expert guidance. To prioritise projects, a multi-criteria analysis was completed across three criteria:

1. **Performance/benefits:** How well does the option perform in meeting its objective / providing the intended primary benefits.
2. **Cost:** High level and approximate understanding of the financial cost of the option.
3. **Deliverability:** Deliverability of actions including potential of 'opportunistic adaptation' piggybacking onto other programmes/capital works.

A select number of high scoring adaptation projects are outlined in further detail in Chapter 6.6.

The full longlist of adaptation projects and all criteria assessed as part of the multi-criteria analysis is presented in Appendix D.

Benefits from adaptation projects do not sit siloed within sectors, due to the interdependencies across sectors. Therefore, **although potential adaptation projects are grouped into specific sectors or themes, these projects will have cross-sector relevance and benefits.**

Appendix D, outlines how the adaptation measures are relevant and provide benefits across multiple sectors or themes. For example, adaptation projects which sit within the Built Environment sector, such as built measures to cool buildings, would also apply to the Health sector and NHS buildings such as hospitals and Business and Industry such as offices.

6.5.1 Multi-criteria analysis of the longlist of adaptation options

++	+	-	- -
Very high adaptation benefits, very low cost, highly deliverable	High adaptation benefits, low cost, highly deliverable	Lower adaptation benefits, high cost, lower deliverability	Very low adaptation benefits, very high cost, very low deliverability

Table 6.16 *Multi-criteria analysis of potential adaptation projects*

Sector or topic	Adaptation project	Quick wins	Overall score	Spheres of influence
Built Environment	Education for construction and property management/maintenance workforce on climate-resilient design and maintenance	Y	+	Within remit of local authority
	Consistent planning guidance across Gloucestershire's districts to ensure a common approach to climate adaptation implementation	Y	+	
	Embed adaptation activities into Local Plan policies, Local Growth Plan and the upcoming Strategic and Local Plan (SLP) which covers Gloucester City Council, Cheltenham Borough Council and Tewkesbury Borough Council	Y	+	
	Tree planting and landscaping across the built environment for shade and drainage benefits		+	
	Reducing flood risk to buildings through Sustainable Drainage Systems (SuDS) such as swales, rain gardens and soakaways **- SHORTLISTED**		+	
	Cool spaces in local authority run buildings e.g. libraries **– SHORTLISTED**	Y	+ +	
	Built measures to cool buildings e.g. shutters, awnings, blinds, green roofs, through retrofit and on new builds **- SHORTLISTED**		+	
	Loft and wall insulation in line with a 'fabric first' principle to address cold, damp and overheating		+	
	Property level flood resilience measures such as flood walls and embankments in high risk areas		-	
	Low to no flammability in external cladding materials to prevent the spread of wildfires		-	
	Damp and mould measures such as ventilation and extractor fans		-	
	All housing associations and council property management to conduct building stock assessments of climate risk and recommended adaptation measures		+	Partnership approach
	Complete retrofit pilot projects for traditional buildings in line with Cotswold District's Retrofit Guidance for Traditional and Listed Buildings		+	
	Showcase successful examples of adapted homes such as through the Green Home/Open Home programme	Y	+	
Infrastructure	Embed climate adaptation requirements into tenders for infrastructure projects **– SHORTLISTED**	Y	+	Within remit of local authority
	Water retention systems in place such as rainwater harvesting and greywater reuse across transport, water and energy infrastructure sites	Y	+	
	Contingency measures to power outages such as backup generators		+	Partnership approach required
	Flood defences such as engineered flood alleviation, raising critical infrastructure, including flood walls, levees and culverts		-	
	Permeable pavements to allow for the drainage of stormwater		+	
	Road resurfacing with asphalt resilient to high temperatures >50ºC **– SHORTLISTED**		+	
	Stormwater drain enlargement		-	
	Local drought management plans in place and awareness of processes during a drought period understood and communicated	Y	+	
	Rail measures such as embankment strengthening, drainage improvements and regular maintenance		-	Outside sphere of influence

6.5.1 Multi-criteria analysis of the longlist of adaptation options

Figure 6.17 *Grouping of adaptation projects for the multi-criteria analysis.*

++	+	-	- -
Very high adaptation benefits, very low cost, highly deliverable	High adaptation benefits, low cost, highly deliverable	Lower adaptation benefits, high cost, lower deliverability	Very low adaptation benefits, very high cost, very low deliverability

Sector or topic	Adaptation project	Quick wins	Overall score	Spheres of influence
Health	Work with all relevant partners to ensure that climate risks are addressed and considered in the commissioning and provision of all healthcare services and assets, for example local authority social care delivery	Y	+	Partnership approach required
	Behavioural guidance for staff and patients during extreme weather created, including extreme heat, drought, storms and high winds and flooding **– SHORTLISTED**	Y	+	
	Survey all hospitals and other health centres that support vulnerable people to identify which are most at risk of overheating and identify suitable measures to reduce the risk		+	
	Training on climate adaptation for health professionals, aligning with existing national NHS guidance on building capabilities in understanding climate risk and adaptation **– SHORTLISTED**	Y	+	
	Hospital adaptation to heat including such as upgraded heating, ventilation and air conditioning systems and delaying the discharge of patients during extreme heat and heatwave periods		-	
	Joint adaptation planning between NHS and local infrastructure planners	Y	+	
	Ensure climate risks to health, buildings and infrastructure that affect hospitals, care homes, GPs and other health settings are embedded into corporate risk and business continuity plans	Y	+	
	Prioritise measures such as improved drainage (SuDS), green infrastructure integration and cooling stations (water fountains/shaded benches) across the NHS estate.		+	
Natural Enviro-nment	Landscape enhancement for cooling and water management		+	Partnership approach required
	Natural flood management (NFM) **- SHORTLISTED**		+	
	Wildlife-friendly urban spaces and rewilding		+	
	Move debris and mature vegetation away from strategically and economically important areas such as roads, businesses and homes		+	
	Landscaping with wind-resistant vegetation and regular tree maintenance		-	
	Trees as windbreaks and for shading which are resilient to future conditions of drought and flooding. For example, tree species such as Aspen, Corsican Pine and Field Maple are commended by the Forestry Commission as 'species of the future'.		-	
	Establishing floodplain habitats including floodplain meadows, wetland, saltmarsh and wet woodlands in the Severn Estuary to protect against sea level rise and flooding **- SHORTLISTED**		+	
	River buffer zones and riparian trees to reduce river water temperatures through shading and evapotranspiration		+	
	Management of species rich grasslands to reduce fire risk, aligning with traditional management, such as regular cutting or mowing and seasonal maintenance before summer when greater likelihood of dry vegetation which is more likely to ignite		+	
	Promote good biosecurity to slow the spread of invasive non-native species and associated diseases, whilst also providing pollution control		+	
	Prevent over abstraction of water supply in rivers to ensure aquatic habitats are not disrupted and prevent low flows downstream		+	
Business & Industry	Awareness campaigns for businesses on climate risk and resilience	Y	+	Partnership approach required
	Supply chain education on climate resilience and playbook sharing of climate risk and adaptation **- SHORTLISTED**		+	
	Support for small businesses in evaluating supply chain criticality		+	
	Retrofit incentives for commercial buildings (e.g., greywater reuse)		+	
	Engagement on climate risk and adaptation through the business networks such as the Growth Hub, GFirst LEP and other industry lead organisations **- SHORTLISTED**	Y	+	

6.5.1 Multi-criteria analysis of the longlist of adaptation options

Figure 6.17 *Grouping of adaptation projects for the multi-criteria analysis.*

++	+	-	- -
Very high adaptation benefits, very low cost, highly deliverable	High adaptation benefits, low cost, highly deliverable	Lower adaptation benefits, high cost, lower deliverability	Very low adaptation benefits, very high cost, very low deliverability

Sector or topic	Adaptation project	Quick wins	Overall score	Spheres of influence
Agriculture	Partner with Royal Agricultural University, University of Gloucestershire Countryside and Community Research Institute, Hartpury University, Hartpury College, FarmED, Farming and Wildlife Advisory Group South West for farmer education and innovation on climate resilience	**Y**	+	Partnership approach
	Water storage on farmland such as run off ponds and compensation mechanisms for implementing natural flood management methods		+	
	Drought and flood resilient farming techniques and crops **– SHORTLISTED**		+	Outside sphere of influence
	Farming techniques to manage and maintain soil health to withstand flooding and drought such as regenerative farming		+	
Education & Awareness	Launch county-wide climate adaptation education campaign (residents, businesses, schools)	**Y**	+	Within influence/ organisational remit of local authority
	Develop training modules for planners, heritage officers, construction professionals and sharing of best practice examples in climate adaptation and understanding of climate risk	**Y**	+ +	
	Create climate risk and adaptation toolkits and playbooks for heatwave, flood, drought, wildfire, storms/high winds with relevant information across all sectors in Gloucestershire.	**Y**	+	
	Early warning systems and integration of Met Office warnings in corporate risk management including organisations' risk registers	**Y**	+ +	Partnership approach required
Cross-Sector Collaboration	Cross-sector collaboration across existing networks and organisations (e.g. SWIP, National Grid, Severn Trent)	**Y**	+ +	
	Facilitate workshops and forums to align adaptation strategies		+	
	Establish cross-sector networks to understand and map out climate risk interdependencies	**Y**	+ +	
	Promote the sharing of climate risk assessments and mutual support planning for adaptation	**Y**	+	
	Liaise with local catchment management, including groups upstream of Gloucestershire.	**Y**	+	
	Collaboration and engagement of organisations with the Gloucestershire Local Resilience Forum including participation in plans, training exercises and debriefings from extreme weather events such as flooding and extreme heat.	**Y**	+	
Policy & Governance	Advocate for long-term climate adaptation legislation beyond political cycles		+	Within influence/ organisational remit of local authority
	Align adaptation goals with funding programmes	**Y**	+	
	Organisation-level climate risk assessments and adaptation plans in place in line with Gloucestershire Local Resilience Forum, UK Climate Change Risk Assessment and Cabinet Office National Risk Register.		+	
	Invest to expand successful adaptation projects across the county		+	
	Advocate for a strategic funding mechanism for adaptation as part of a national adaptation programme alongside a countywide strategic fund for adaptation		+	Partnership approach required
	Identify an independent guiding body (e.g., NISTA) to oversee climate adaptation efforts		+	

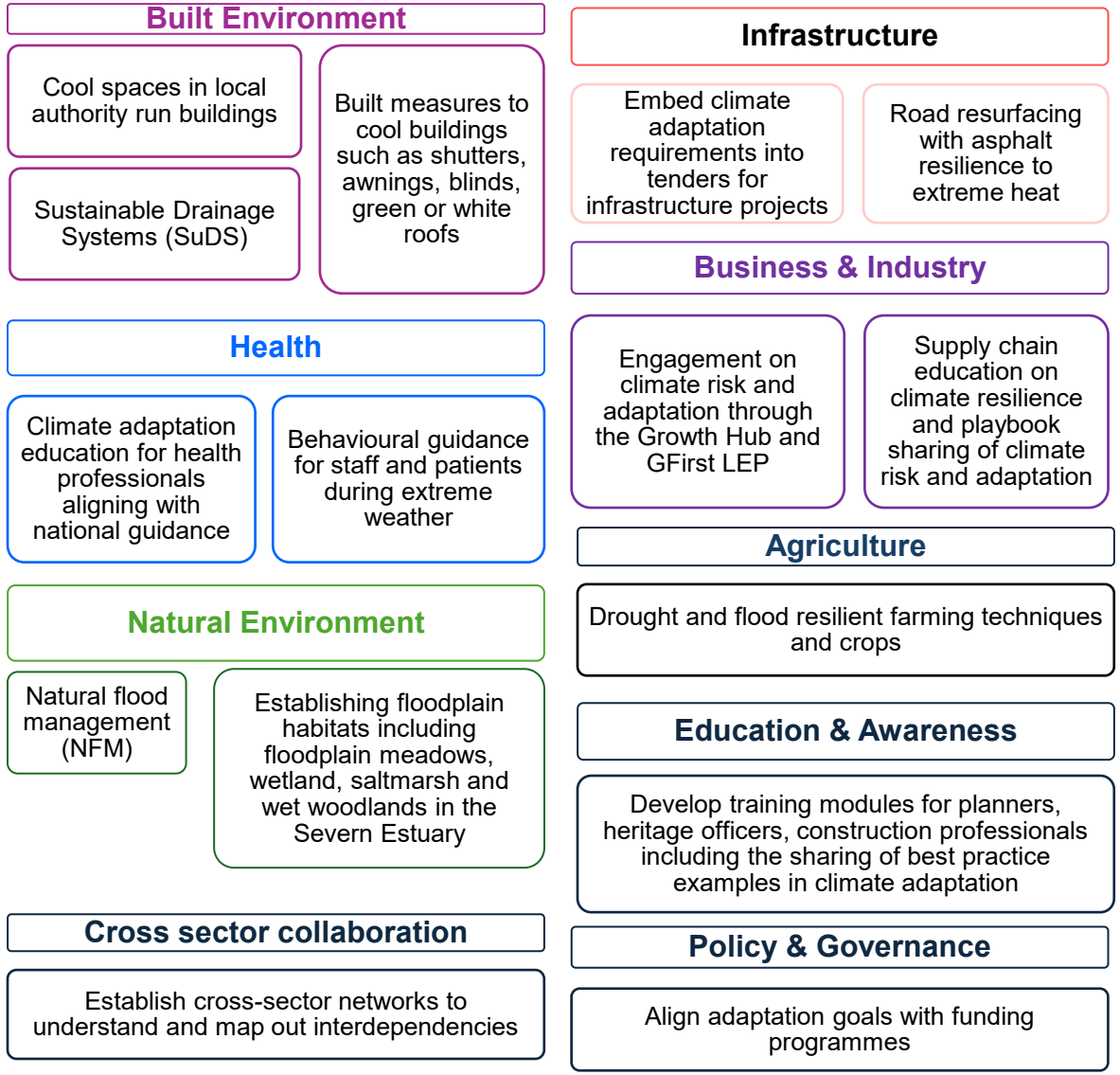
6.6 Short list of priority projects

Adaptation projects will be essential to ensure Gloucestershire's resilience to the impacts of climate change moving forward. Example priority projects are presented based on the multi-criteria analysis, stakeholder engagement, existing adaptation activities and literature review of adaptation integration into existing plans and policies.

This short list of projects should not act as a finalised list of projects but should be a first step in the adaptation journey, providing a sense of the variety of adaptation projects needed across Gloucestershire. Adaptation should not be limited to this list of projects and future projects should be developed collaboratively with partners across Gloucestershire.

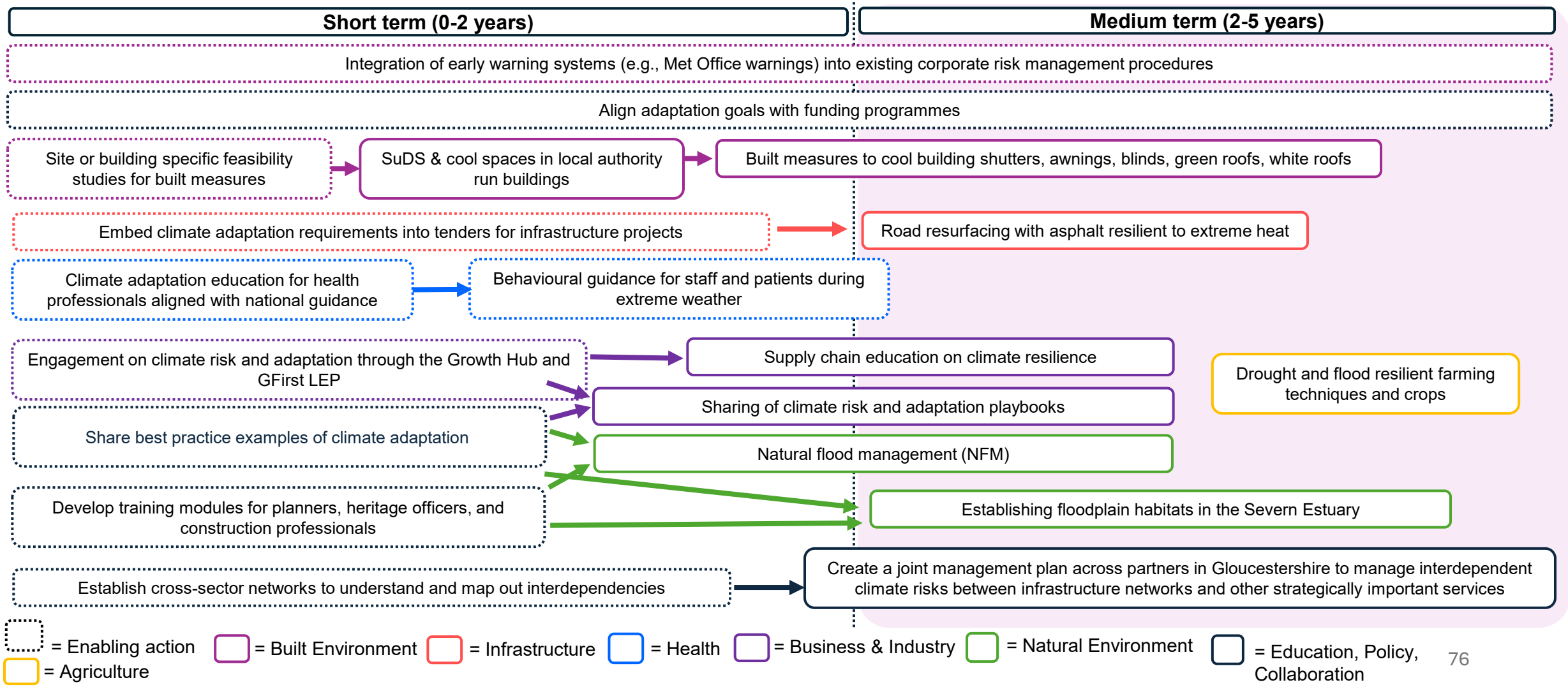
Projects are shortlisted for each of the six sectors **Built Environment, Health, Infrastructure, Business & Industry, Agriculture and Natural Environment** and the longlist of adaptation projected presented in Chapter 6.5. Additionally, three adaptation projects are shortlisted from each of the **Education & Awareness, Cross-Sector Collaboration and Policy & Governance.**

The following section provides further detail on each of the shortlisted projects including a review of the effectiveness, high level costs and time frame and spatial scale of implementation.



6.6 Short list of priority projects

To implement recommended priority climate adaptation projects, a process and enabling framework is required to ensure the successful planning and implementation of projects. A potential timeline of projects is presented aligned to high level time scales to illustrate a process of planning and implementation, alongside enabling factors to help support the implementation of short-listed adaptation projects. This framework could be applied to the wider longlist of adaptation projects presented, ensuring the mapping of enabling actions to support adaptation action..



6.6 Short list of priority projects

Built Environment

Built measures to cool buildings

Built measures such as shutters, awnings, blinds and green or white roofs and walls provide a cooling effect on buildings during extreme heat and increasing temperatures. Bromford Housing Association is implementing such measures across their estate in Gloucestershire.

- **Effectiveness:** External window shutters can reduce heat gain by 50%.[1] Awnings should be positioned, where possible on south facing windows to be most effective. Green walls can achieve up to a 15.5ºC decrease in surface temperatures on external walls.[2]
- **Cost:** For white roofs solar reflective paint costs[3] £7-£8 per m^2. Shutters can range from £300-£635.[4] Green roofs can range from £75-£348 for initial capital expenditure with operational costs and £0.59-£1.17 per square foot annual maintenance.[5] These are high level indicative costs and do not take into account labour required for installation and other pricing considerations such as inflation.
- **Time frame:** Short-term 0-2 years (white roofs and walls, blinds) and medium-term 2-5 years (shutters, green roofs, awnings).
- **Where:** County wide but particularly in urban areas such as Gloucester City, Cheltenham and Tewkesbury.

Cool spaces in local authority run buildings

Cool spaces can offer respite from extreme heat conditions in public locations such as libraries or religious establishments, a cool spaces was ran in Christchurch in Cheltenham in 2022.

- **Effectiveness:** Barriers may remain in terms of access to cool spaces for vulnerable groups such as elderly or disabled individuals.[6] The effectiveness of the cooling space will depend on features such as the material buildings are made of and the aperture and orientation of windows.
- **Cost:** Additional cost of opening public facilities for longer hours in summer months during extreme heat and associated running and staffing costs. Costs of maintenance and adaptations to buildings to ensure that public buildings remain cool should also be considered.
- **Time frame: Quick Win**, Short-term 0-2 years
- **Where:** Urban heat hot spots in Gloucester City, Cheltenham and Tewkesbury.

Figure 6.18 *Christchurch in Cheltenham cool space in 2022. (Source: BBC News)*

Sustainable Drainage Systems (SuDS)

SuDS or Sustainable Drainage Systems aims to manage stormwater and reduce surface water flooding. SuDS is often used in urban areas and to support highways drainage. There are many different types of SuDS options which can either attenuate (slow runoff) or infiltrate (allow water to soak into ground). Further information is provided by Susdrain on delivering SuDS. Forest of Dean Community Hospital is a key example implementing SuDS across its estate.

Source control
Green roofs, rainwater harvesting, permeable paving

Retention & detention
Detention basins, retention ponds

Infiltration
Rain gardens, soakaways, infiltration basin and trench

Wetlands

Swales, channels and rills

- **Effectiveness:** SuDS works with natural drainage and encourages infiltration, attenuation and passive treatment.[21]. The unique local hydrology, depth of water table, soil permeability and size of catchment area should be considered when implementing and choosing SuDS features
- **Cost:** Soakaway crates are £255-£870 per m^3 and Rainwater harvesting system 1500 litre tank is £3275[3]. Additional costs outlines in Natural Environment short listed projects.
- **Time frame:** Short-term 0-2 and medium-term 2-5 years
- **Where:** County wide but particularly in urban areas such as Gloucester City, Cheltenham and Tewkesbury.

6.6 Short list of priority projects

Infrastructure

Embed climate adaptation measures into tenders for infrastructure projects

Embedding climate adaptation at the outset of the procurement stage ensures that suppliers which provide a service are held to account for climate risk and adaptation. South West Infrastructure Partnership promotes thinking on climate adaptation through workshops, which could be used to understand how to embed measures at the early stages of project planning.

- **Effectiveness:** Recent changes to the Procurement Act 2023, ensures that contracting authorities should ensure public contracts deliver measurable environmental benefits.[7] This can ensure that climate risk and adaptation are included as specific commitments in procurement and supplier selection. Effectiveness can be high, given suppliers commit to set targets for climate risk and adaptation and can agree to frequent monitoring of these targets throughout a project life cycle.
- **Cost:** Costs would include the upfront time and staffing costs to create specific questions for the procurement process.
- **Time frame:** **Quick Win**, Short-term 0-2 years.
- **Where:** Across Gloucestershire in all procurement activities.

Road resurfacing with asphalt resilient to extreme heat

Road surfaces will need to be able to withstand extreme heat as temperatures increase in future to avoid road surfaces expanding, rutting and melting. Asphalt can soften when surfaces reach above 50ºC, at air temperatures above 30ºC. [8]

- **Effectiveness:** Long-life road surfaces which can withstand extreme temperatures and flood damage can reduce road user costs by 25%. [9]
- **Cost:** Surface dressing of road surfaces can cost £20 per square metre and provide a 10–15-year lifetime of the road surface. A full reconstruction of the road would cost £40 per square metre with a 15+ years lifetime.[10] Where rutting of the road surface has occurred, micro asphalt may be required which is a higher cost. These are high level indicative costs and do not take into account labour required for installation and other pricing considerations such as inflation. Further detail on costs of maintenance are provided by the Local Government Association.[11]
- **Time frame:** Medium-term 2-5 years
- **Where:** Urban heat hot spots in Gloucester City, Cheltenham and Tewkesbury. Roads with existing surface damage and key routes of strategic importance with high traffic flows.

Agriculture

Drought and flood resilient farming techniques and crops

Drought tolerant crops and management techniques to improve resilience of farm assets to flooding allow for increased resilience to climate change. This may include deep rooting crops, flood tolerant crops, natural flood management and crop diversification.[26] Drought resilient farming techniques and nature management are key priorities set out in Gloucestershire's Local Nature Recovery Strategy.

- **Effectiveness:** Improving the resilience of crops can result in higher yields following extreme weather events and can have other benefits such as improving soil structure.[27]
- **Cost:** The cost of drought resilient species can vary significantly. Lucerne, a forage crop which is drought resistant, cost £250 per hectare in a recent trial in Wales.[28] A full cost-benefit analysis would be required on a case by case basis to understand the overall balance of failure of crops due to climate change versus planting costs. Natural flood management techniques are noted within the Natural Environment Sector short listed projects, which could be applied on agricultural land.
- **Time frame:** **Quick Win**, Short-term 0-2 years
- **Where:** Agricultural land across Gloucestershire.

6.6 Short list of priority projects

Health

Behavioural guidance for staff and patients during extreme weather

Guidance is available for healthcare professionals from the UK Health Security Agency for working in hot weather and individual NHS trusts have produced guidance. [12] Specific guidance could be produced for Gloucestershire or ensuring increased awareness of existing national guidance.

- **Effectiveness:** Guidance is specific to extreme heat and provides actionable points to complete in line with actions to take at each Heat-Health Alert Level (yellow, amber, red). This guidance will be effective if understood ahead of extreme heat events and incorporated into existing operational processes[13] and acute services across NHS sites.
- **Cost:** Additional costs such as maintenance and staffing required to keep buildings and resources cool. These actions vary from quick, low cost actions such as closing blinds to planting trees and landscaping.
- **Time frame: Quick Win**, Short-term 0-2 years
- **Where:** All NHS organisation sites in Gloucestershire and community staff.

Climate adaptation education for health professionals

NHS organisations in Gloucestershire can be supported to understand the risks posed by climate change on their services through the existing climate adaptation framework for NHS organisations in England.[14] This would align Gloucestershire Health and Care NHS Trust, Gloucestershire Integrated Care Board and Gloucestershire Hospitals NHS Foundation Trust with national guidance.

- **Effectiveness:** A useful framework for non-experts and uses the WeAdapt website to provide guidance on strengthening adaptive capacity and knowledge of climate change risk and adaptation. Increasing adaptive capacity is shown to be a "necessary condition for the design and implementation of effective adaptation strategies so as to reduce the likelihood and the magnitude of harmful outcomes resulting from climate change".[15]
- **Cost:** Free to use framework and tool. Time cost of staff to review, understand and implement the framework across activities.
- **Time frame: Quick Win**, Short-term 0-2 years
- **Where:** All NHS organisation sites in Gloucestershire and community staff.

NHS England

A climate adaptation framework for NHS organisations in England

Education & Awareness

Sharing of best practice examples in climate adaptation

Training modules and the sharing of best practice examples of climate adaptation across sectors would ensure the valuable dissemination of information. Existing training modules have been produced by other local authorities such as West Midlands Combined Authority.

- **Effectiveness:** Shared learnings on climate adaptations can help to build awareness of success stories. Adaptation can be more effective if lessons learnt during the planning and implementation of adaptation are shared. This will be an effective exercise if completed regularly and is driven by a lead organisation who chairs meetings and captures actions and learnings.
- **Cost:** If sharing of best practice is completed within existing partnerships and networks, the costs will remain minimal. Minor costs associated with time and staffing efforts to produce written content for best practice examples.
- **Time frame: Quick Win**, Short-term 0-2 years.
- **Where:** County wide across Gloucestershire.

6.6 Short list of priority projects

Business & Industry

Engagement on climate risk and adaptation through the Growth Hub the Growth Hub, GFirst LEP and other industry lead organisations

Utilising existing groups such as the Gloucestershire Growth Hub and GFirst LEP to help support businesses across Gloucestershire with their approach and understanding of climate risk and adaptation.

- **Effectiveness:** The Growth Hub has existing guidance for Net Zero, therefore, setting up similar resourcing and guidance on climate risk and adaptation could be highly effective, building on the Growth Hub's reputation for sector knowledge. Whilst GFirst LEP has worked with the Growth Hub previously on a Net Zero Conference. To be effective, advice and resources should be tailored to the specific contexts e.g. specialist material provided for small-medium enterprises versus larger organisations based in Gloucestershire.
- **Cost:** Additional resourcing or expertise in order to train up key personnel and create relevant training materials and resources.
- **Time frame:** **Quick Win**, Short-term 0-2 years
- **Where:** Across Gloucestershire.

Supply chain education on climate resilience and playbook sharing of climate risk and adaptation

Supply chains were identified during stakeholder engagement as needing a joint approach to managing and understanding climate risk and adaptation. To ensure awareness of climate risk and adaptation across supply chains, educational playbooks on climate risk and adaptation should be created and shared across supply chains. A playbook would act as a strategic guide for the wider supply chain of organisations within business and industry supply chains.

- **Effectiveness:** Creating playbooks would help support other adaptation activities identified above, including the use of the Growth Hub to disseminate educational material and the use of the Procurement Act 2023 to ingrain climate adaptation from the procurement stage. Playbooks to support these actions would need to be tailored to specific sectors, building on existing materials such as the NHS's existing climate adaptation framework for NHS organisations in England. Key organisations across Gloucestershire should lead the write up of educational materials. For example, for businesses in the infrastructure sector, the South West Infrastructure Partnerships in collaboration with the National Infrastructure and Service Transformation Authority (NISTA) could play a leading role.
- **Cost:** Additional resourcing or expertise in order to train up key personnel and pull together relevant training materials and resources.
- **Time frame:** Short-term 0-2 years to medium-term (2-5 years).
- **Where:** Across Gloucestershire.

6.6 Short list of priority projects

Natural Environment

Natural flood management (NFM)

Gloucestershire regularly uses NFM to store and slow water flows and reduce the risk of flooding. NFM tends to be soft engineered measures such as tree planting, swales, rain gardens and restoring natural river courses. NFM is already being implemented across Gloucestershire, including through the Gloucestershire Natural Flood Management Partnership.

- **Effectiveness:** Swales, a shallow drainage channel with gentle side slopes in the ground, can help in reducing the magnitude of peak flows during a storm and swales can also help in pollutant removal from storm runoff. Rain gardens that soak stormwater into the ground through a soil-based medium, remove pathogens, reduces nutrients, organic substances and various heavy metals present in stormwater runoff.[16]
- **Cost:** Swales can range from £10-£15 per m^2 of swale area, infiltration basins range from £10-£15 per m^3 stored volume and a constructed wetland can range from £25-£30 per m^3 treated volume. [16] Planting of a semi mature tree can range from £1,000 (40-45cm girth) to £7,014 (80-90cm girth).[17] These are high level indicative costs and do not take into account labour required for installation and other pricing considerations such as inflation.
- **Time frame:** Medium-term 2-5 years
- **Where:** County wide across Gloucestershire, in particular in rural areas.

Establishing floodplain habitats including floodplain meadows, wetland, saltmarsh and wet woodlands

Gloucestershire's floodplains are at risk of sea level rise and flooding. Establishing floodplain habitats is a specific natural flood management technique which can be implemented to protect communities, infrastructure and the natural environment sited in floodplains. Restoring and creating wetland in floodplains is a key priority set out in Gloucestershire's Local Nature Recovery Strategy.

- **Effectiveness:** The planting of flood plain habitats increases surface roughness, slowing the flow of water during heavy rainfall events.[23] New wetlands can also provide opportunity for water storage during high rainfall events. These habitats in estuarine environments can reduce wave energy, attenuate storm surges and stabilise sediment impacted by sea level rise and coastal flooding.[24]
- **Cost:** Habitat creation can cost £15,174 per hectare for wet grassland, £14,424 per hectare for bogs, marshes and fens, £9,674 per hectare for wet woodlands and £23,174 per hectare for inland water bodies and lagoons.[25]
- **Time frame:** Medium-term 2-5 years to long-term 5+ years
- **Where:** Severn Estuary and riverine environments in high and medium risk catchments

Policy & Governance

Align adaptation goals with funding programmes

Funding streams tend to occur in cycles or at particular milestone dates. Aligning planned adaptation implementation with funding availability ensures a joined-up approach and quicker implementation of adaptation measures.

- **Effectiveness:** will be an effective approach if suitable expertise and understanding of funding streams is in place to align planning of adaptation measures. Prioritisation of resourcing to prepare for the release of funding should be in place to avoid a reactive approach when funding becomes available.
- **Cost:** Additional resourcing or expertise in order to understand funding streams and how best to respond to applications for funding.
- **Time frame:** **Quick Win**, Short-term 0-2 years
- **Where:** County wide across Gloucestershire.

6.6 Short list of priority projects

Cross Sector Collaboration

Establish cross-sector networks to understand and map out interdependencies

Cross-sector networks including transport, energy, water, built environment and health organisations can help to map out key climate risk interdependencies across Gloucestershire, building on interdependencies identified in this Climate Risk Assessment.

- **Effectiveness:** Identifying interdependencies allows for a whole network view of how climate can impact across different infrastructure and services. Mapping climate risk interdependencies show where interacting assets or systems are at risk of cascading climate risks. A number of meetings with key personnel would ensure this information is collected. A visual understanding of risk can aid communication of climate risk.
- **Cost:** Additional resourcing or expertise in order to train up key personnel in identifying key interdependencies across networks.
- **Time frame:** **Quick Win**, Short-term 0-2 years
- **Where:** County wide across Gloucestershire.

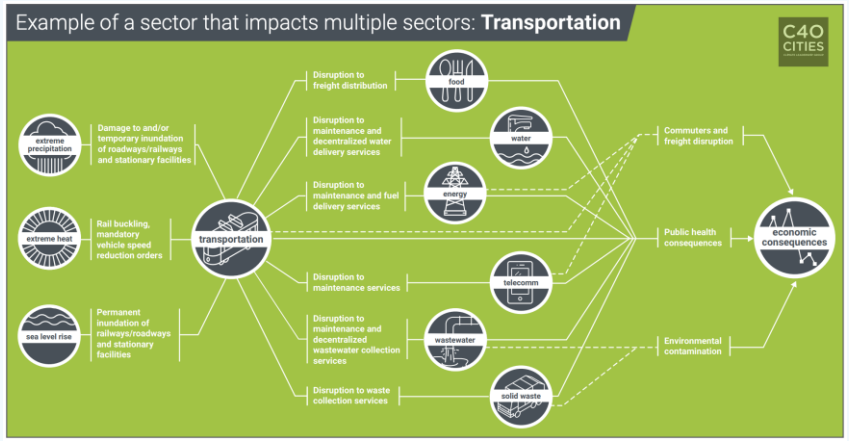


***Figure 6.19** Example of interdependencies mapping*[22]

Local authority adaptation resources

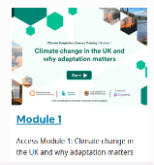
A number of existing adaptation resources may help audiences to further develop their understanding of climate adaptation and potential training resources.

Local Partnerships Climate Adaptation Toolkit and Risk and UK Opportunities Matrix provides a five step process for risk assessment and adaptation planning. Templates for risk registers are provided and guidance for integrating adaptation into council services.

The Met Office's Local Authority Climate Service (LACS) provides open access climate data tailored to local authorities and creates local climate reports as a first step for climate risk assessment and adaptation planning. Adaptation resources are provided including key policies and links to the Local Partnerships tool above.

LCAT LOCAL CLIMATE ADAPTATION TOOL

The Local Climate Adaptation Tool (LCAT) provides climate profile for local authorities including tailored data and impact information. A glossary of adaptation measures is provided for different climate hazards, with links to literature with further detail on adaptation measures.



West Midlands Combined Authority Climate Adaptation Literacy Training created in collaboration with the University of Birmingham provides free, online training for local councillors and local authority officers to understand climate risks and adaptations. Modules cover UK context on climate risk and adaptation and more specific context to the West Midlands.

ClimateKIC

Climate KIC Academy provides more advanced training modules offering professional development and training programmes for adaptation suitable for local authority and government officials. A mixture of free and paid online courses are available.

weADAPT

weADAPT is a collaborative platform for climate change adaptation, providing global case studies and articles on climate risk and adaptation.

6.7 Funding mechanisms for climate change adaptation

Finding the resources required for local climate adaptation remains a significant challenge, in particular given pressures on local government budgets, and the lack of a central government for adaptation. Effective adaptation across Gloucestershire requires partnerships, with different organisations working together to lead implementation and identify resources to support adaptation action. This section focuses on practical options for funding adaptation, with a focus on integration into existing schemes and budgets.

- **Community Infrastructure Levy (CIL)** – the CIL is a well-established mechanism for councils to raise funds from developers, that can be used to invest in supporting infrastructure. Investments in flood defences and green space may already be funded under the CIL, but there is an opportunity to more explicitly use CIL funds for strategic investments to increase local resilience.
- **Strategic Social Value** – The social value process provides a way to harness public procurement for social, economic or environmental good. A strategic approach to the social value requirements included in procurement processes could provide a consistent stream of in-kind revenue or expertise that could support priority adaptation actions, for example helping to develop local climate resilience plans.
- **Integrating Adaptation into existing funding** – A number of nature and climate-related funds already exist within the county, including the Gloucestershire Climate and Nature Fund, the Greener Gloucestershire Community Fund, and energy retrofit programmes. Including a specific focus on climate adaptation within these existing funds would both support local communities to adapt, and increase the synergies between decarbonisation, nature recovery and climate adaptation actions.
- **Community investment funds** – there are several examples of community investment funds that have been set up in partnership between financial institutions and local authorities, aimed at raising funds for investment in nature and climate. By harnessing the desire of local residents to invest in schemes that deliver local benefits, these funds can raise significant capital to invest in adaptation projects.
- **Grant funding** – while competitive, there are a number of local authorities that have been successful in accessing significant money through applications to grant funding both at the national and European level. Funding can range from small grants to multi-million pound programmes, but does require significant investment in bid-writing resources

Examples of funds

Bristol Climate Action Investment Fund:
Launched by Bristol City Council in 2025 and administered by Abundance Investment, the Climate Action Investment Fund is designed to raise money from citizen investments, which will then be used to fund climate-related projects across the city. The fund lets individuals invest money for a fixed period, over which they receive market competitive interest on their investment. The initial phase raised £1.5m, with a second phase expected to launch in Q4 2025.

Gloucestershire Climate and Nature Fund
Broker of Biodiversity Net Gain (BNG) credits, matching Gloucestershire businesses required to show BNG for a development, with sites with good potential for habitat restoration. This allows a more strategic approach to BNG, and could be adapted to emphasise adaptation co-benefits such as flood reduction or urban cooling.

National Lottery Climate Action Fund
Competitive bid process with regular application cycles. Focus of grants varies, with partnership approaches encouraged. Bristol Climate and Nature Partnership has been successful with funding to develop the Community Climate Action Programme, providing support to community groups to develop their own climate action plans, and covering both neighbourhood-based plans, as well as the Climate and Disability programme.

7. Next steps

This Climate Risk and Vulnerability Assessment set out to complete the following:

- Alignment with the **Climate Change Committee's 10 principles for good adaptation**,
- **Co-create the Climate Risk and Vulnerability Assessment** with a diverse groups of stakeholders across the county.
- **Provide an understanding of climate risk** across Gloucestershire and **prioritise these risks.**
- Set out a **vision for climate adaptation** across the county and a case for adaptation investment.

Next steps for Climate Leadership Gloucestershire are to use the Climate Risk and Vulnerability Assessment as a key evidence base for planning and implementing climate adaptation measures. Key suggested next steps are outlined. These will need to be agreed and confirmed by Climate Leadership Gloucestershire.

Suggested next steps

Prioritise adaptation actions which address key climate risks identified in the Climate Risk Assessment, including risks to health and infrastructure from extreme heat and risks to people, communities and buildings from flooding.

Continually monitor climate risks and update the Climate Risk and Vulnerability Assessment on a regular basis.

Explore funding mechanisms for climate adaptation, including instruments such as green bonds, and start to proactively plan for funding cycles and applications.

Explore the implementation of suggested priority projects, identifying locations for implementation, owners and funding.

Draw on the longlist of adaptation projects for future planning, notably, lower cost quick wins that could be implemented.

Continue engagement on climate risk and climate adaptation planning and implementation with diverse stakeholders across Gloucestershire.

Glossary and definitions

Adaptive capacity: an organisations' ability to adjust to potential damage, to take advantage of opportunities, or to respond to consequences of climate change.

Amber-heat health alerts: Adverse weather impacts are to be felt across the whole health service

Cascading risks: disruptions caused by an extreme weather event cause a chain of impacts across multiple sectors.

Climate Adaptation: The process of communities making changes and undertaking actions to become more able to cope with climate change.

Climate Change: Changes to weather patterns and the world's climate caused by the burning of fossil fuels. Climate change is causing temperatures to increase, rainfall to become more extreme during storms, droughts to worsen, and increasing landslides, floods, and wildfires.

Climate Hazard: Climate hazards include heatwaves, storms, flooding, drought, landslides, wildfires, and other weather and climate events.

Climate Mitigation: The process of communities and cities making changes and undertaking actions to reduce greenhouse gas (GHG) emissions to limit the extent of climate change.

Climate Risk: The potential for negative impacts caused by climate change.
The level of risk depends on: 1. likelihood of the hazard occurring and 2. the impact the hazard poses to assets, infrastructure, people and services.

Equality Act: The Equality Act 2010 legally protects people from discrimination in the workplace and in wider society.

HadUK: HadUK is a collection of gridded climate variables produced by the UK's Met Office informed by land surface observations. The dataset spans the period from 1836 to the present day.

Heatwave: Defined by the Met Office in Gloucestershire as three consecutive days with daily maximum temperatures meeting or exceeding the heatwave threshold of 27ºC

High Emissions Scenario: A high emissions scenario assumes emissions continue to rise throughout the century resulting in higher levels of warming.

Index of Multiple Deprivation: A measure of relative deprivation. Takes into account income, employment, education, health, crime, barriers to housing and services and the living environment.

Interdependent risks: Interdependencies can be categorised as: Physical, where one sector's operation depends on the commodities or services offered by another sector. Geographic, where multiple system failures occur in close proximity due to a hazard event. Cyber, where infrastructure depends on information technology systems, which is an increasing risk as cities automate

Impact: Effects on natural and human systems of extreme weather and climate events and of climate change.

Likelihood: The chance of a specific outcome occurring, where this might be estimated probabilistically.

Medium Emissions Scenario: A medium emissions scenario, assumes that greenhouse gas emissions peak around 2040 and then decline, leading to a moderate level of warming

Met Office Fire Severity Index (MOFSI): combines temperature, humidity, wind and rainfall to estimate days in a given period when fire conditions reach the "Very High" level

Natural Flood Management (NFM): NFM stores and slows water flows and reduces the risk of flooding. NFM tends to be soft engineered measures such as tree planting, swales, rain gardens and restoring natural river courses.

Productivity: Ratio between output and input of businesses. Higher productivity means that a business produces more output for each worker it employs.

Rainfall intensity: Rate of precipitation, defined here as hourly rainfall levels.

Representative Concentration Pathways (RCP): These scenarios are based on how much greenhouse gas is emitted in the coming decades.

Soil moisture deficit: Balance between rainfall input and losses through evaporation and transpiration

Sustainable Drainage Systems (SuDS): Sustainable Drainage Systems aims to manage stormwater and reduce surface water flooding. SuDS works with natural drainage and encourages infiltration, attenuation and passive treatment.

UKCP18: UK Climate Projections provides a comprehensive set of climate model projections for the UK, showing how the climate is likely to change in the future.

Vulnerability: Characteristics which make people more prone to negative impacts from climate risks. For example, older people are likely to be more vulnerable to climate hazards.

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Appendix A: Climate Risk Scoring

			Likelihood					Impact	Risk				
	Hazard	Risk	Baseline	2050s Medium emissions scenario	2050s High emissions scenario	2080s Medium emissions scenario	2080s High emissions scenario		Baseline	2050s Medium emissions scenario	2050s High emissions scenario	2080s Medium emissions scenario	2080s High emissions scenario
Health	High temperatures	Risks to health and social care delivery from high temperatures	M	H	H	VH	VH	M	M	H	H	H	H
	High temperatures	Risks to public health and wellbeing from high temperatures	M	H	H	VH	VH	M	M	H	H	H	H
	Flooding	Risks to health and social care delivery from flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
Built Environment	Storm, high winds	Risks to building fabric from moisture, wind, and driving rain	M	Unavailable data	Unavailable data	H	H	L	M	M	M	M	M
	Drought	Risk of household water supply interruptions	L	M	M	M	M	L	L	M	M	M	M
	Surface water flooding	Risks to people, communities & buildings from flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	River flooding	Risks to people, communities & buildings from flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
Business & Industry	Surface water flooding	Risks to business sites from surface water flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	River flooding	Risks to business sites from river and tidal flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	High temperatures	Employee productivity impacts in heatwaves and from severe weather infrastructure disruption	M	H	H	VH	VH	L	M	M	M	H	H
Natural Environment	Drought	Risks to habitats and wildlife from water scarcity	M	M	M	M	H	M	M	M	M	M	H
	Surface water flooding	Risks to habitats and wildlife from surface water flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	River flooding	Risks to habitats and wildlife from river and tidal flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	High temperatures	Risks to soils from increased seasonal aridity	M	M	H	M	H	L	M	M	M	M	M
	High temperatures & wildfire	Extreme weather/wildfire risks to habitats, forestry & wildlife	H	VH	VH	VH	VH	L	M	H	H	H	H
Agriculture	Drought	Risks to agriculture from water scarcity	M	M	H	H	H	M	M	M	H	H	H
	Surface water flooding	Risks to agriculture from surface water flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	River flooding	Risks to agriculture from river and tidal flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	High temperatures	Risks to soils from increased seasonal aridity	M	M	H	M	H	L	M	M	M	M	M
	High temperatures & wildfire	Extreme weather/wildfire risks to farming	H	VH	VH	VH	VH	M	M	H	H	H	H
Infrastructure	Drought	Risks to public water supplies from drought and low river flows	L	M	M	M	H	L	L	M	M	M	M
	Flooding	Risks to infrastructure from river, surface/groundwater flooding	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	Surface water flooding	Risks of sewer flooding due to heavy rainfall	M	Unavailable data	H	Unavailable data	Unavailable data	M	M	M-H*	H	Unavailable data	Unavailable data
	Storm, high winds	Risks to energy, transport & ICT from high winds & lightning	M	M	M	M	M	L	M	M	M	M	M
	High temperatures	Extreme heat risks to rail, road, ICT and energy infrastructure	M	H	H	VH	VH	M	M	H	H	H	H

*Qualitative scorings based on expert judgement

Appendix B: Dairy Cattle Heat Stress

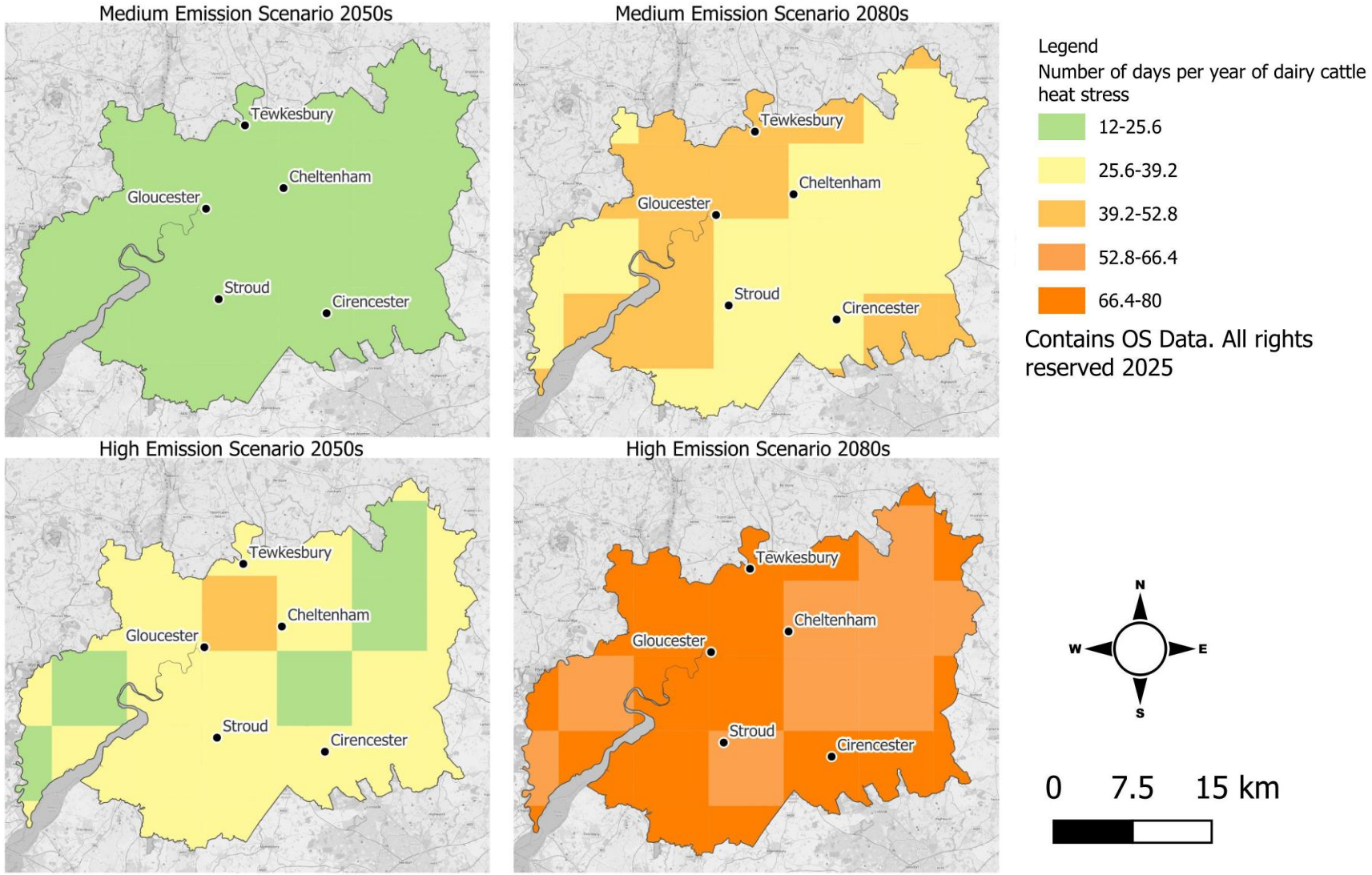

Figure B.1 *Dairy Cattle Heat Stress in a medium emissions scenario (RCP 4.5) and high emissions scenario (RCP 8.5) in the 2050s and 2080s in Gloucestershire*[4]

Appendix B: Risk from Flooding from Rivers and Seas- Climate Change

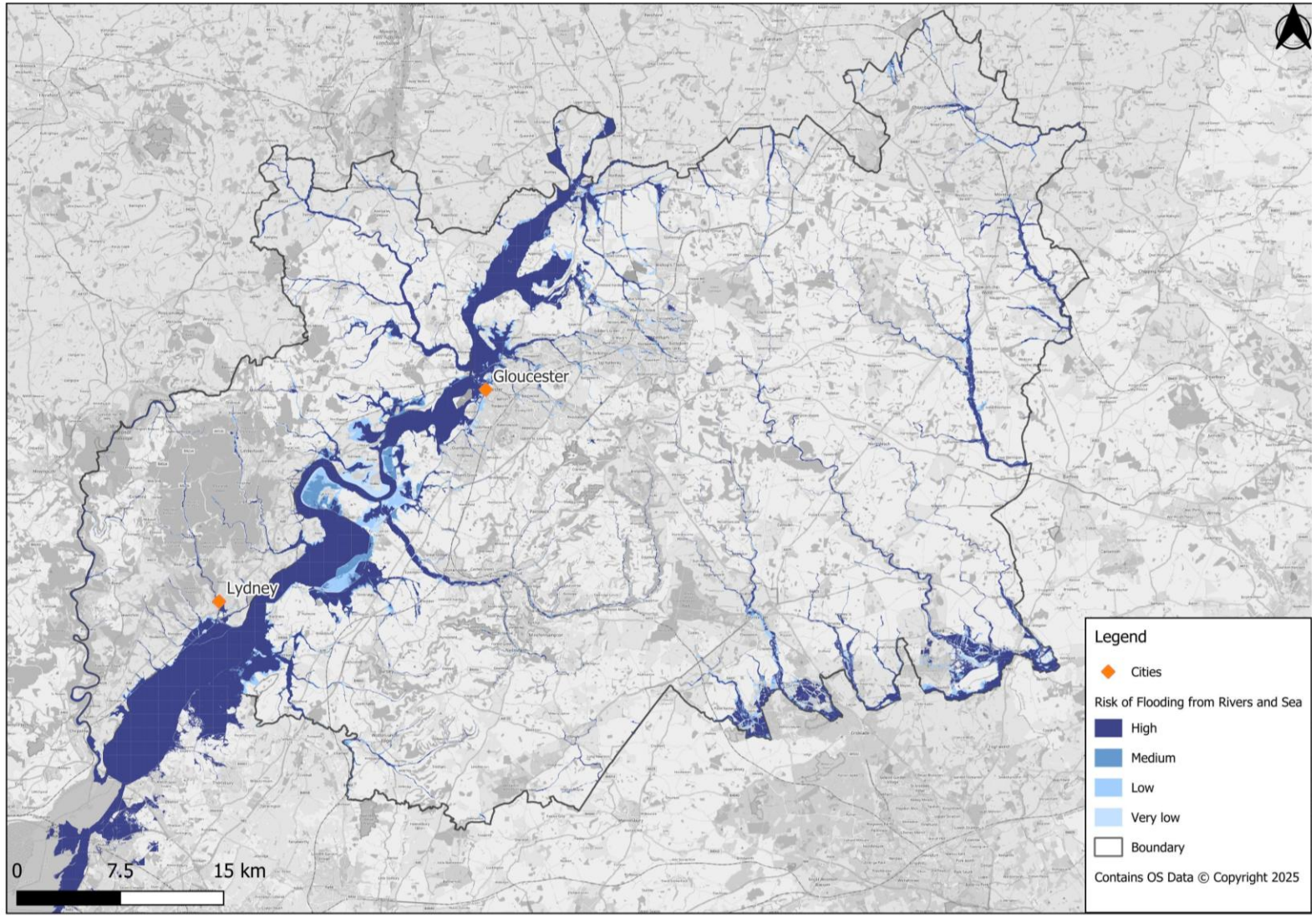

Figure B.2 *Risk from flooding from rivers and seas in Gloucestershire under a high emissions scenario by 2050s*[8]

Appendix B: Risk from Surface Water Flooding- Climate Change

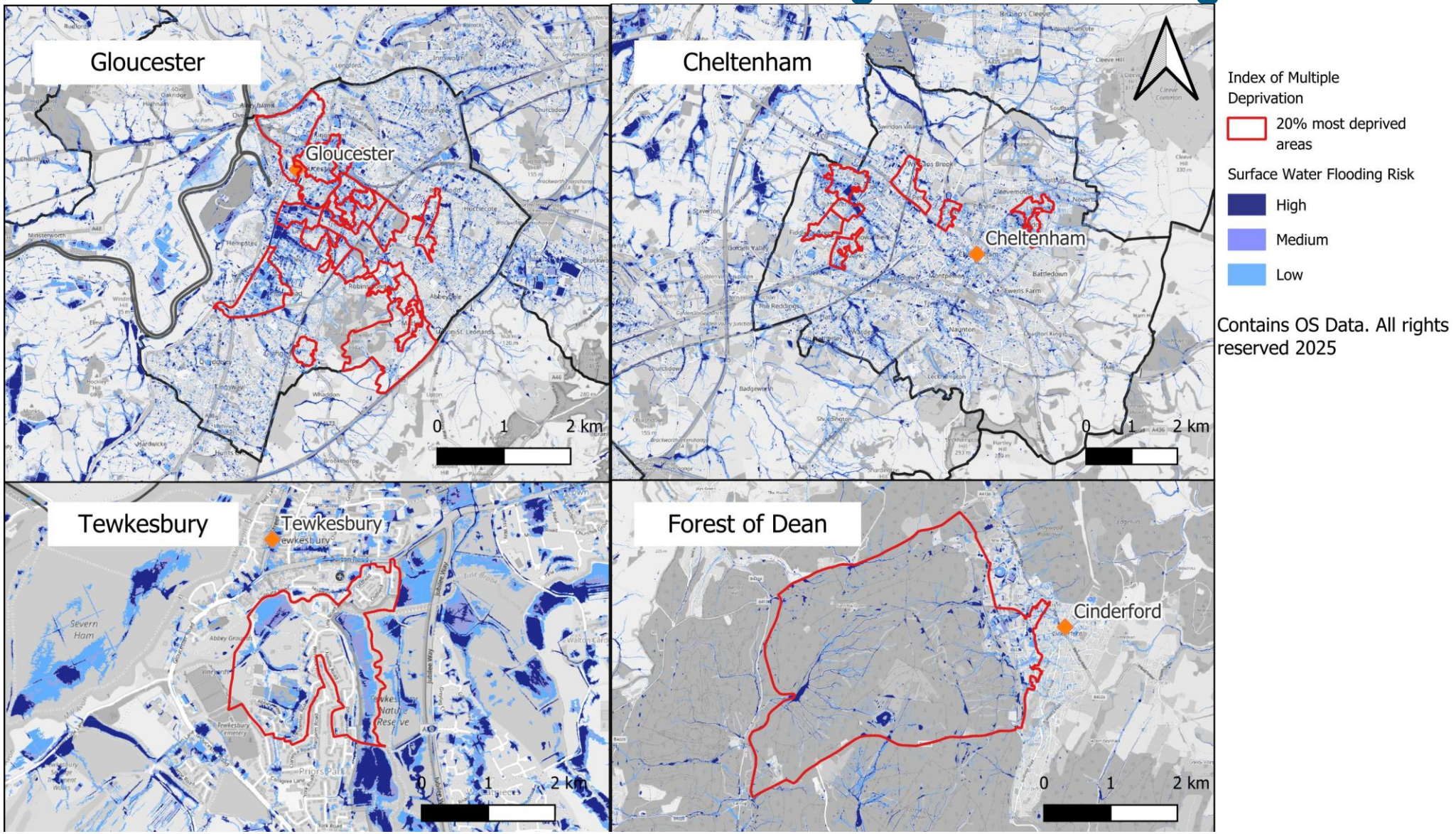

Figure B.3 *20% most deprived areas in the UK in Gloucestershire and risk from flooding from rivers and seas in the 2050s under a high emissions scenario*[8]

Appendix B: Soil Moisture Deficit and Agricultural Land

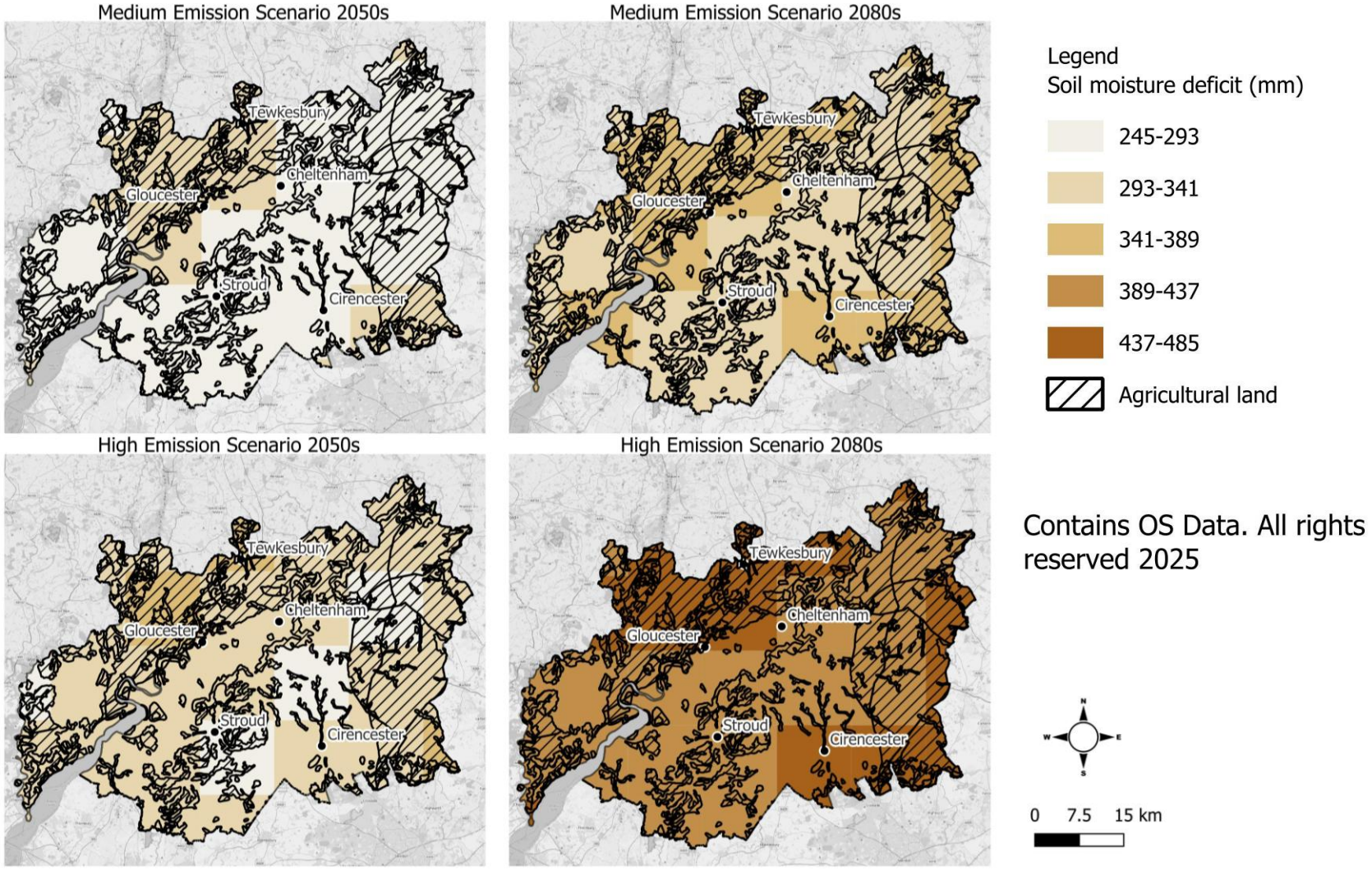

Figure B.4 *Soil moisture deficit overlaid with agricultural land in a medium emissions scenario (RCP 4.5) and high emissions scenario (RCP 8.5) in the 2050s and 2080s in Gloucestershire*[4]

Appendix B: Future Risk from Surface Water Flooding

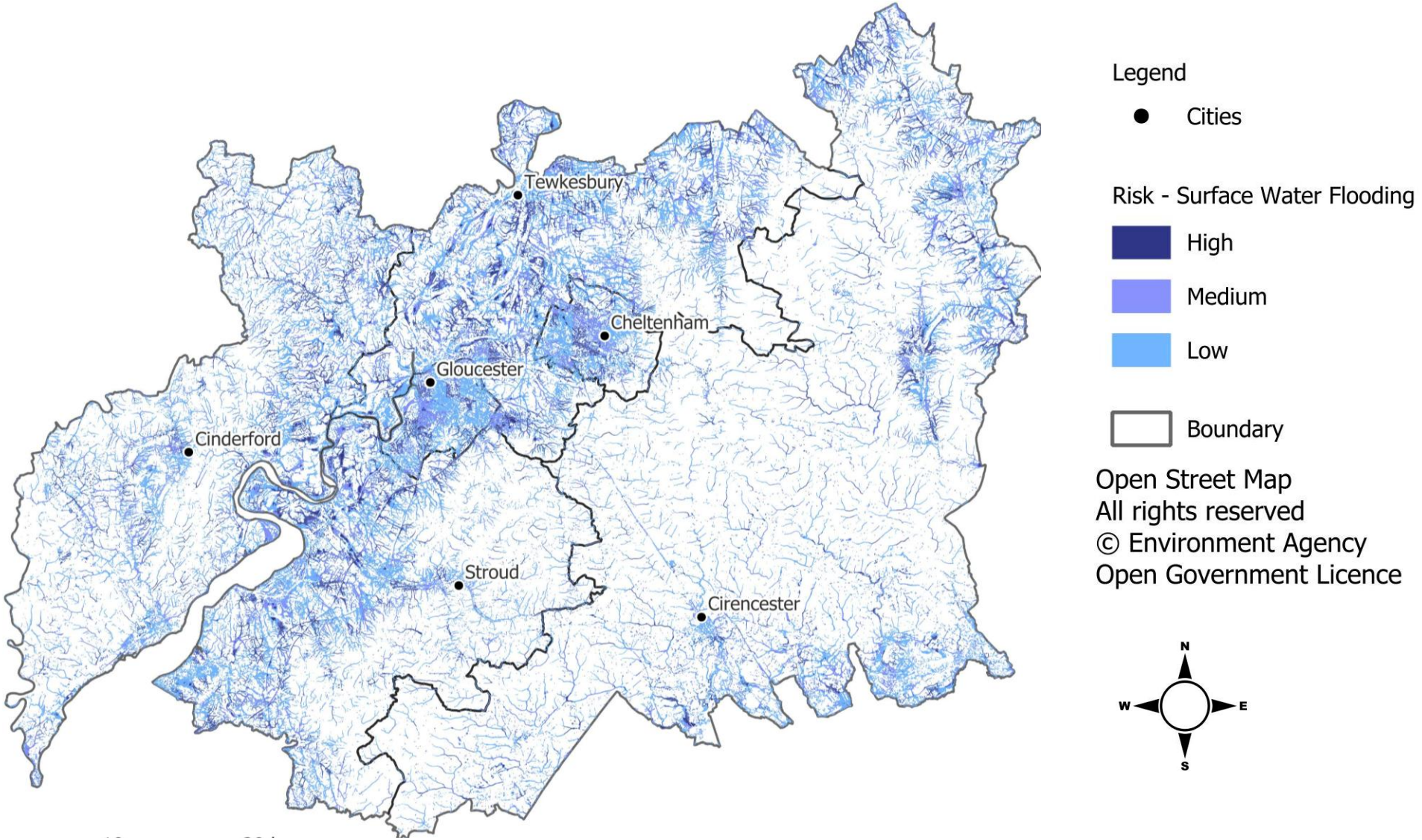

Figure B.5 *Future risk of Flooding from Surface Water in a high emissions scenario by 2050 in Gloucestershire*[8]

Appendix B: Present Risk from River and Tidal Flooding- Infrastructure

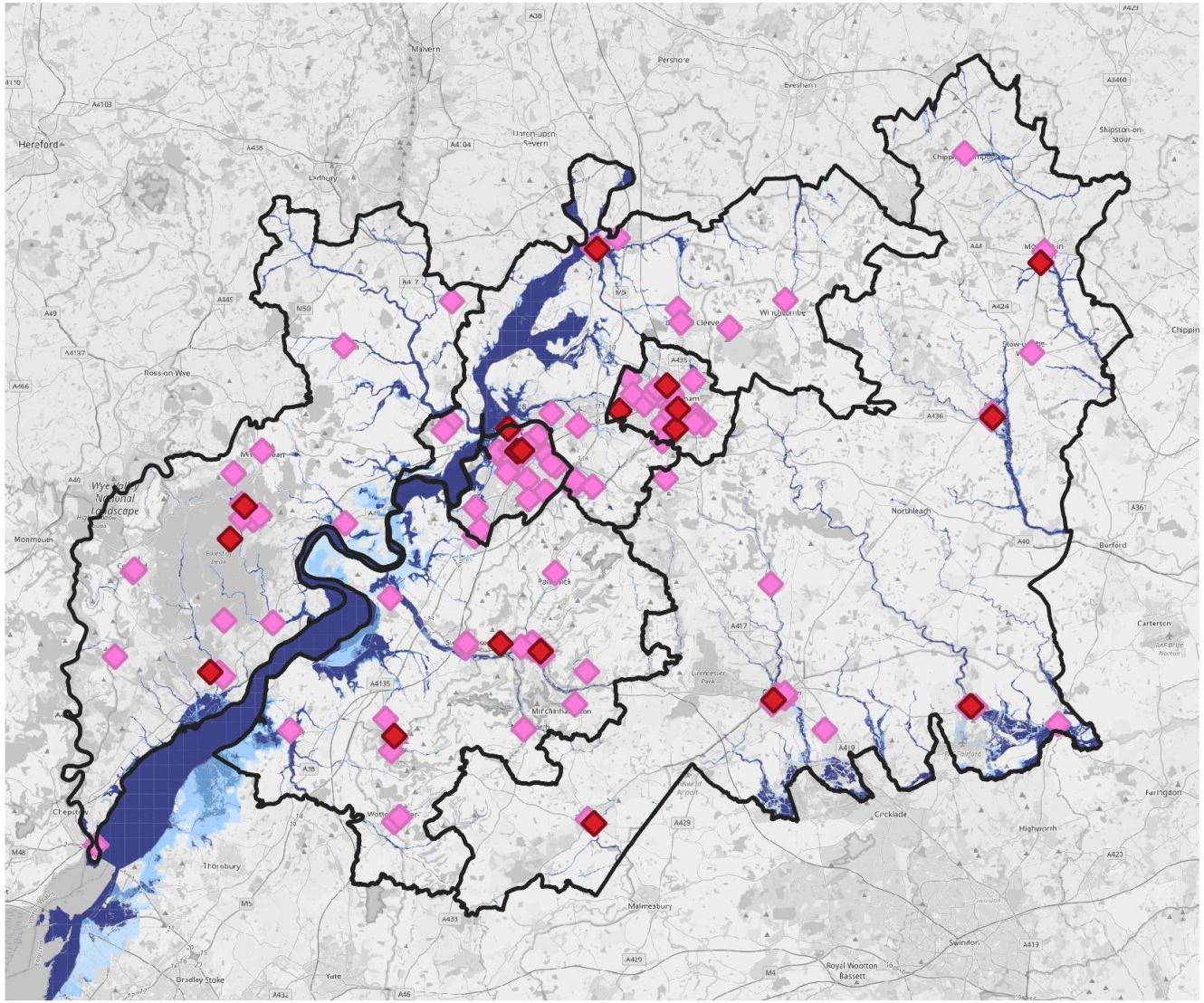

Figure B.6 Present day *risk from flooding from rivers and seas to hospitals and GP practices in Gloucestershire*[8]

Appendix B: Present Risk from River and Tidal Flooding- Infrastructure

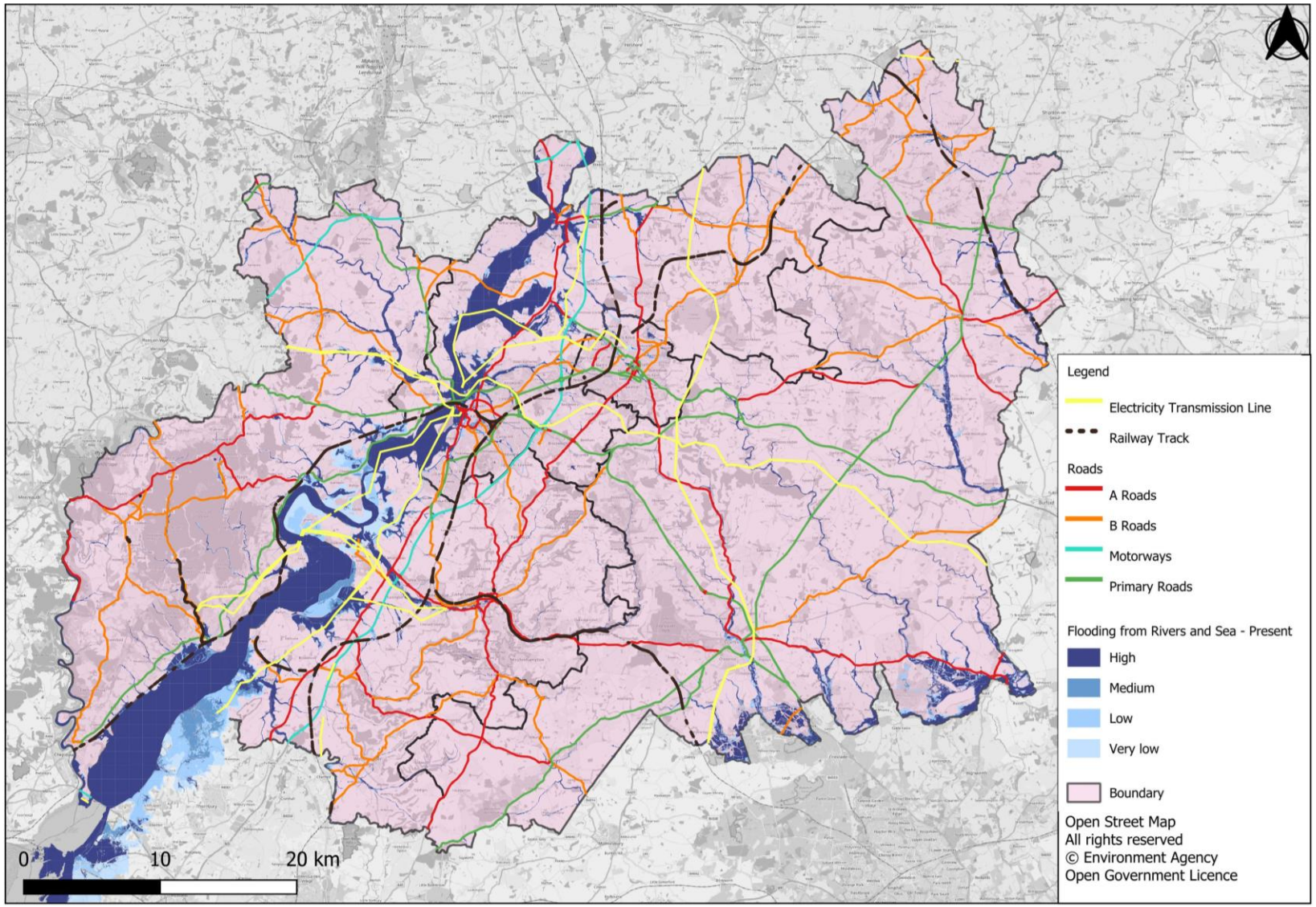

Figure B.7 Present day *risk from flooding from rivers and seas to transport routes and electricity transmission line in Gloucestershire*[8]

Appendix B: Future Risk from River and Tidal Flooding- Health

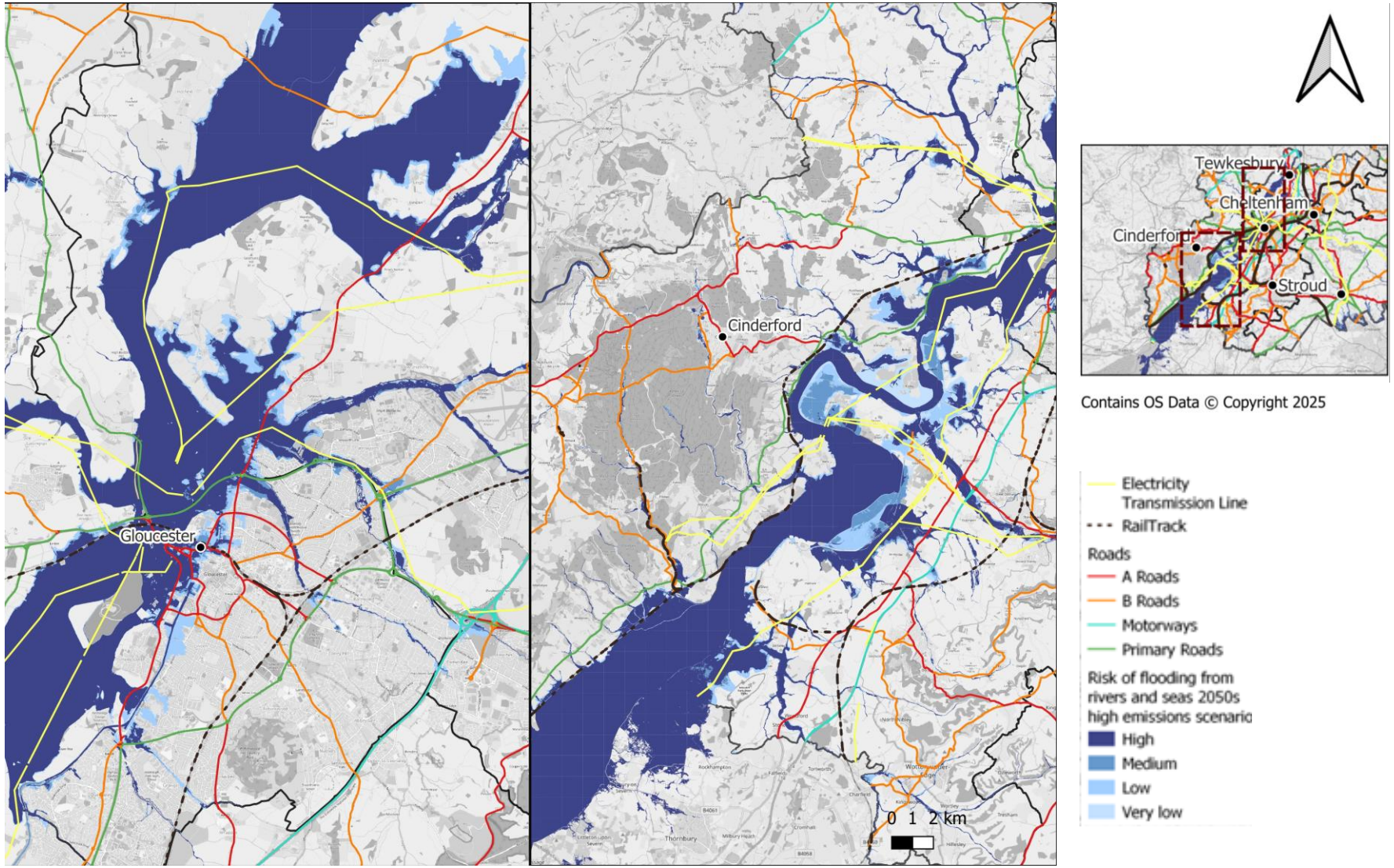

Figure B.8 Present day *risk from flooding from rivers and seas to critical transport routes and electricity transmission line in Gloucestershire*[8]

Appendix C. Methodology

The Climate Risk and Vulnerability Assessment is centred around the Climate Change Committee's 10 principles for good adaptation and is broadly divided into two key sections; (**1) Climate Risk and Vulnerability Assessment**, followed by an overview of adaptation through **(2) Opportunities to Minimise Risk.**

Climate Risk and Vulnerability Assessment

1. Climate baseline and recent extreme weather events

Climate hazards are impacting Gloucestershire, including **flooding, extreme heat, storms and high winds and cold spells**. To understand how Gloucestershire's climate has changed in recent history we have reviewed **observations of temperature and precipitation** from the Met Office's HadUK database[1] and modelled current surface water and river flooding risk data produced by the Environment Agency[2]. Where quantified data was not available, literature review provides an overview of current weather trends and associated impacts.

To understand the impacts of past events, a **timeline of past weather events** has been produced based on a review of relevant literature, outlining impacts from recent extreme events from 2000-2025.

2. Climate projections and spatial representation

To understand how hazards that impact Gloucestershire are going to change in the future under climate change, a review was undertaken of UKCP18 climate model projections[3] and future surface water and river flooding risk data produced by the Environment Agency[2] . In addition to these key datasets, a range of indicators including **maximum temperatures, summer rainfall, winter rainfall, soil moisture deficit and Met Office fire severity index**, were modelled spatially from UK Climate Risk Indicators Portal[4].

To gain a better understanding of the assets at risk within Gloucestershire, spatial mapping was undertaken, predominantly using data from Ordnance Survey Open Data[5]. **Key infrastructure, transport routes, natural environment assets, listed buildings, education and healthcare sites** were mapped within Gloucestershire. These layers were overlaid with the climate projections data to assess the exposure of assets to climate change.

3. Climate Risk Assessment

CCRA3 themes and definitions

The UK's Climate Change Risk Assessment 2022 (CCRA3) was used as a guiding framework to define a list of climate risks of greatest relevance to Gloucestershire[6]. Five key themes are defined across Gloucestershire's Climate Risk and Vulnerability Assessment with risks tailored to each theme as outlined below.

Climate Risk and Vulnerability Assessment themes

Health	Climate change impacts on health & health and social care delivery
Built Environment	Buildings including residences, education centres and community facilities
Business & Industry	Supply chain resilience, distribution networks and business sites and locations
Natural Environment	Terrestrial and freshwater habitats and species, soil health and agriculture and forestry productivity
Agriculture	Agricultural land, soil health and food resilience
Infrastructure	Water, energy, transport, ICT networks

Appendix C. Methodology

The following risks adapted from the UK CCRA3[6] for Gloucestershire are presented below. These risks are a shortlist aligned to each of the five key themes covering significant climate hazards such as **drought, high temperatures, flooding and storms and high winds.**

Table C.1 *Shortlist of climate risks assessed for Gloucestershire*

Theme	Hazard	Risk
Health	Flooding	Risks to health and social care delivery from river, surface water and tidal flooding
	High temperatures	Risks to health and social care delivery from extreme weather
	High temperatures	Risks to public health and wellbeing from high temperatures
Built Environment	Drought	Risk of household water supply interruptions
	Flooding	Risks to people, communities & buildings from river, surface water and tidal flooding
	Storm, high winds	Risks to building fabric from moisture, wind, and driving rain
Business & industry	Flooding	Risks to business sites from river, surface water and tidal flooding
	High temperatures	Employee productivity impacts in heatwaves and from severe weather infrastructure disruption
Natural Environment	Drought	Risks to habitats & wildlife from water scarcity
	Flooding	Risks to habitats & wildlife from river, surface water and tidal flooding
	High temperatures	Risks to soils from increased seasonal aridity
	High temperatures & wildfire	Extreme weather/wildfire risks to habitats, forestry & wildlife
Agriculture	Drought	Risks to agriculture from water scarcity
	Flooding	Risks to agriculture from river, surface water and tidal flooding
	High temperatures	Risks to soils from increased seasonal aridity
	High temperatures & wildfire	Extreme weather/wildfire risks to farming
Infrastructure	Drought	Risks to public water supplies from drought and low river flows
	Flooding	Risks to infrastructure from river, surface/groundwater flooding
	Flooding	Risks of sewer flooding due to heavy rainfall
	Storm, high winds	Risks to energy, transport & ICT from high winds & lightning
	High temperatures	Extreme heat risks to rail, road, ICT and energy infrastructure

Assessing climate risk

Each of the risks in Table C.1 was scored through an impact and likelihood matrix. **Likelihood scoring** provides an understanding of how frequently climate hazards are occurring. **Impact scoring** provides an assessment of the magnitude of the effect on assets, services and infrastructure due to a climate hazard. Scoring is based on quantitative data and where there are gaps in data, qualitative data and literature is used to define an overall risk score.

The likelihood and impact scoring are combined to provide an overall risk score (Table C.3).

Table C.2 *Likelihood and impact scoring categories*

Likelihood

Class	Category	Annual Probability
5	Almost certain	>10%
4	Probably	3.3%-10%
3	Possible	1%-3.3%
2	Unlikely	0.1-1%
1	Remote	<0.1%

Impact

Class	Category	Definition
5	Catastrophic	Widespread service failure with services unable to cope with wide-scale impacts
4	Major	Services seen to be in danger of failing completely with severe/widespread decline in service provision
3	Moderate	Service provision under severe pressure. Appreciable decline in service provision at community level
2	Minor	Isolated but noticeable examples of service decline
1	Insignificant	Appearance of threat but no actual impact on service provision

Table C.3. *Risk matrix: likelihood and impact matrix to define overall risk scoring*

Impact – Likelihood Matrix		Impact				
		1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
Likelihood	5. Almost certain	M / 5	H / 10	H / 15	VH / 20	VH / 25
	4. Probably	L / 4	M / 8	H / 12	VH / 16	VH / 20
	3. Possible	L / 3	M / 6	M / 9	H / 12	H / 15
	2. Unlikely	VL / 2	L / 4	M / 6	M / 8	H / 10
	1. Remote	VL / 1	VL / 2	L / 3	L / 4	M / 5

Appendix C. Methodology

Quantified information to define likelihood scoring is set out in Table C.4. Impact scoring was based primarily on literature review, impact data derived from stakeholder engagement and supported by quantitative data where possible.

Table C.4 *Likelihood scoring data and sources.*

Hazard	Climate variable	Source	Time periods available	Climate scenarios available
Extreme heat and increasing temperatures	Heatwave events (events/year)	UK Climate Risk Indicators[4]	Baseline, 2050s, 2080s	• High emissions scenario (RCP8.5) • Medium emissions scenario (RCP4.5)
	Amber heat health alert (events/ year)		Baseline, 2050s, 2080s	
Cold spells	Cold weather alert (events/ year)		Baseline, 2050s, 2080s	
Wind driven rain	Sum of all wind-driven rain spells in each year	Met Office Climate Data Portal[7]	2100	• 2100 under a +2°C and +4°C warming from pre-industrial period (1850-1900)
Drought	SPI (proportion of time within severe drought)	UK Climate Risk Indicators[4]	Baseline, 2050s, 2080s	• High emissions scenario (RCP8.5) • Medium emissions scenario (RCP4.5)
	Soil moisture deficit (mm)		Baseline, 2050s, 2080s	
Wildfires	Met Office Fire Danger		Baseline, 2050s, 2080s	
Flooding	Surface water flooding	National Flood Risk Assessment (NaFRA2)[8]	Present day, 2050s	• High emissions scenario (RCP8.5)
	River flooding			
Storms/high winds	Qualitative – literature review			

Opportunities to minimise climate risk

To understand what prioritised climate adaptation projects should be put in place across Gloucestershire, a two-step approach was taken.

1. Multi-criteria analysis

A longlist of adaptation projects was derived from stakeholder engagement including interviews and an online workshop, literature review and expert guidance. To prioritise projects, a multi-criteria analysis was completed. Three key criteria were reviewed and rated based on expert judgement from AtkinsRéalis specialists. These three criteria are:

- **Performance/benefits:** How well does the option perform in meeting its objective / providing the intended primary benefits.
- **Cost:** High level and approximate understanding of the financial cost of the option.
- **Deliverability:** Deliverability of actions including potential of 'opportunistic adaptation' piggybacking onto other programmes/capital works.

From the three criteria, an overall score was derived, equally weighting each 'RAG' (red, amber, green scoring). An example of this scoring is presented below to illustrate the RAG scoring to prioritise adaptation options.

Performance/Benefits	*Cost*	*Deliverability*	Overall score
+	-	+	+
+	- -	+	+
+	+ +	+ +	+ +

Figure C.5 *Example RAG scoring for multi-criteria analysis*

2. Shortlisting of priority adaptation projects

The longlist of adaptation projects were then prioritised based on the overall score of each project. Projects were defined for each of the following 5 themes: (1) Built Environment, (2) Health, (3) Infrastructure, (4) Business & Industry and (5) Natural Environment and (6) Agriculture. One project is defined for each of the following themes: (6) Education & Awareness, (7) Cross-Sector Collaboration and (8) Policy & Governance. These 14 priority projects are outlined in more detail, providing an example of cost implications, effectiveness and high level timescales for implementation.

Appendix D: Longlist of projects and multi-criteria analysis

Table D.1 *Longlist of adaptation projects and multi-criteria analysis*

Sector or topic	Adaptation project	Quick wins	Score			Overall score	Spheres of influence
			Performance/ Benefits	Cost	Deliverability		
Built Environment	Education for construction and property management/maintenance workforce on climate-resilient design and maintenance	Y	+	-	+ +	+	Within remit of local authority
	Consistent planning guidance across Gloucestershire's districts to ensure a common approach to climate adaptation implementation	Y	+	+	+ +	+	
	Embed adaptation activities into Local Plan policies, Local Growth Plan and the upcoming Strategic and Local Plan (SLP) which covers Gloucester City Council, Cheltenham Borough Council and Tewkesbury Borough Council	Y	+	+	+ +	+	
	Tree planting and landscaping across the built environment for shade and drainage benefits		+ +	-	+	+	
	Reducing flood risk to buildings through Sustainable Drainage Systems (SuDS) such as swales, rain gardens and soakaways		+ +	-	+	+	
	Cool spaces in local authority run buildings e.g. libraries	Y	+ +	+	+ +	+ +	
	Built measures to cool buildings e.g. shutters, awnings, blinds, green roofs, through retrofit and on new builds		+ +	-	+	+	
	Loft and wall insulation in line with a 'fabric first' principle to address cold, damp and overheating		+ +	-	-	+	
	Property level flood resilience measures such as flood walls and embankments in high risk areas		+ +	- -	-	-	
	Low to no flammability in external cladding materials to prevent the spread of wildfires		+	-	-	-	
	Damp and mould measures such as ventilation and extractor fans		+	-	-	-	
	All housing associations and council property management to conduct building stock assessments of climate risk and recommended adaptation measures		+	-	+	+	Partnership approach required
	Complete retrofit pilot projects for traditional buildings in line with Cotswold District's Retrofit Guidance for Traditional and Listed Buildings		+	- -	+	+	
	Showcase successful examples of adapted homes such as through the Green Home/Open Home programme	Y	+	+ +	+	+	
Infrastructure	Embed climate adaptation requirements into tenders for infrastructure projects	Y	+	+	+ +	+	Within remit of local authority
	Water retention systems in place such as rainwater harvesting and greywater reuse across transport, water and energy infrastructure sites	Y	+ +	-	+	+	
	Contingency measures to power outages such as backup generators		+ +	-	-	+	Partnership approach required
	Flood defences such as engineered flood alleviation, raising critical infrastructure, including flood wall, levees and culverts		+ +	- -	-	-	
	Permeable pavements to allow for the drainage of stormwater		+ +	-	+	+	
	Road resurfacing with asphalt resilient to high temperatures >50ºC		+ +	- -	+	+	
	Stormwater drain enlargement		+	- -	- -	-	
	Local drought management plans in place and awareness of processes during a drought period understood and communicated	Y	+	+	+	+	
	Rail measures such as embankment strengthening, drainage improvements and regular maintenance		+	-	-	-	Outside sphere of influence

Appendix D: Longlist of projects and multi-criteria analysis

Table D.1 *Longlist of adaptation projects and multi-criteria analysis*

Sector or topic	Adaptation project	Quick wins	Score			Overall score	Spheres of influence
			Performance/ Benefits	Cost	Deliverability		
Health	Work with all relevant partners to ensure that climate risks are addressed and considered in the commissioning and provision of all healthcare services and assets, for example local authority social care delivery	Y	+	-	+	+	Partnership approach required
	Behavioural guidance for staff and patients during extreme weather created, including extreme heat, drought, storms and high winds and flooding	Y	+	+	+ +	+	
	Survey all hospitals and other health centres that support vulnerable people to identify which are most at risk of overheating and identify suitable measures to reduce the risk		+	+	-	+	
	Mandatory training on climate adaptation, aligning with existing national NHS guidance on building capabilities in understanding climate risk and adaptation	Y	+	+	+ +	+	
	Hospital adaptation to heat including such as upgraded heating, ventilation and air conditioning systems and delaying the discharge of patients during extreme heat and heatwave periods		+ +	- -	-	-	
	Joint adaptation planning between NHS and local infrastructure planners	Y	+	+	+	+	
	Ensure climate risks to health, buildings and infrastructure that affect hospitals, care homes, GPs and other health settings are embedded in to corporate risk and business continuity plans	Y	+	+	+ +	+	
	Prioritise measures such as improved drainage (SuDS), green infrastructure integration and cooling stations (water fountains/shaded benches) across the NHS estate.		+ +	-	+	+	
Natural Enviro-nment	Landscape enhancement for cooling and water management		+	-	+	+	Partnership approach required
	Natural flood management (NFM)		+ +	-	+	+	
	Wildlife-friendly urban spaces and rewilding		+	-	+	+	
	Landscaping with wind-resistant vegetation/tree maintenance		+	-	-	-	
	Trees as windbreaks and for shading which are resilient to future conditions of drought and flooding. For example, tree species such as Aspen, Corsican Pine and Field Maple are commended by the Forestry Commission as 'species of the future'.		+	-	-	-	
	Move debris and mature vegetation away from strategically and economically important areas such as roads, businesses and homes		+	-	+	+	
	Establishing floodplain habitats including floodplain meadows, wetland, saltmarsh and wet woodlands in the Severn Estuary to protect against sea level rise and flooding		+ +	-	+	+	
	River buffer zones and riparian trees to reduce river water temperatures through shading and evapotranspiration		+	-	+	+	Outside sphere of influence
	Management of species rich grasslands to reduce fire risk, aligning with traditional management, such as regular cutting or mowing and seasonal maintenance before summer when greater likelihood of dry vegetation which is more likely to ignite		+	-	+	+	
	Promote good biosecurity to slow the spread of invasive non-native species and associated diseases, whilst also providing pollution control		+	-	+	+	
	Prevent over abstraction of water supply in rivers to ensure aquatic habitats are not disrupted and prevent low flows downstream		+	-	+	+	
Business & Industry	Awareness campaigns for businesses on climate risk and resilience	Y	+	+	+	+	Partnership approach required
	Supply chain education on climate resilience and playbook sharing of climate risk and adaptation		+	+	+	+	
	Support for small businesses in evaluating supply chain criticality		+	+	+	+	
	Retrofit incentives for commercial buildings (e.g., greywater reuse)		+ +	-	+	+	
	Engagement on climate risk and adaptation through the Growth Hub and GFirst LEP	Y	+	+	+ +	+	

Appendix D: Longlist of projects and multi-criteria analysis

Table D.1 *Longlist of adaptation projects and multi-criteria analysis*

Sector or topic	Adaptation project	Quick wins	Score			Overall score	Spheres of influence
			Performance / Benefits	Cost	Deliverability		
Agriculture	Partner with Royal Agricultural University, University of Gloucestershire Countryside and Community Research Institute, Hartpury University, Hartpury College, FarmED, Farming and Wildlife Advisory Group South West for farmer education and innovation on climate resilience	Y	+	+	+ +	+	Partnership approach
	Water storage on farmland such as run off ponds and compensation mechanisms for implementing natural flood management methods		+ +	-	+	+	
	Drought and flood resilient farming techniques and crops		+	-	+	+	Outside sphere of influence
	Farming techniques to manage and maintaining soil health to withstand flooding and drought such as regenerative farming		+ +	-	+	+	
Education & Awareness	Launch county-wide climate adaptation education campaign (residents, businesses, schools)	Y	+	+	+	+	Within influence/ organisational remit of local authority
	Develop training modules for planners, heritage officers, construction professionals and sharing of best practice examples in climate adaptation and understanding of climate risk	Y	+ +	+	+ +	+ +	
	Create climate risk and adaptation toolkits and playbooks for heatwave, flood, drought, wildfire, storms/high winds with relevant information across all sectors in Gloucestershire.	Y	+	+	+ +	+	
	Early warning systems and integration of Met Office warnings in corporate risk management including organisations' risk registers	Y	+ +	+	+ +	+ +	Partnership approach required
Cross-Sector Collaboration	Cross-sector collaboration across existing networks and organisations (e.g. SWIP, National Grid, Severn Trent)	Y	+ +	+	+ +	+ +	
	Facilitate workshops and forums to align adaptation strategies		+	+	+ +	+	
	Establish cross-sector networks to understand and map out climate risk interdependencies	Y	+ +	+	+ +	+ +	
	Promote the sharing of climate risk assessments and mutual support planning for adaptation	Y	+	+	+ +	+	
	Liaise with local catchment management, including groups upstream of Gloucestershire.	Y	+	+	+ +	+	
	Collaboration and engagement of organisations with the Gloucestershire Local Resilience Forum including participation in plans, training exercises and debriefings from extreme weather events such as flooding and extreme heat.	Y	+	+	+ +	+	
Policy & Governance	Advocate for long-term climate adaptation legislation beyond political cycles		+	+	+	+	Within influence/ organisational remit of local authority
	Align adaptation goals with funding programmes	Y	+	+	+ +	+	
	Organisation-level climate risk assessments and adaptation plans in place in line with Gloucestershire Local Resilience Forum, UK Climate Change Risk Assessment and Cabinet Office National Risk Register.		+	-	+ +	+	
	Invest to expand successful adaptation projects across the county		+	-	+	+	
	Advocate for a strategic funding mechanism for adaptation as part of a national adaptation programme alongside a countywide strategic fund for adaptation		+	+	+	+	Partnership approach required
	Identify an independent guiding body (e.g., NISTA) to oversee climate adaptation efforts		+	+	+	+	