GREATER MANCHESTER

DOING THINGS DIFFERENTLY FOR THE ENVIRONMENT

Greater Manchester Climate Change Risk Assessment

October 2024

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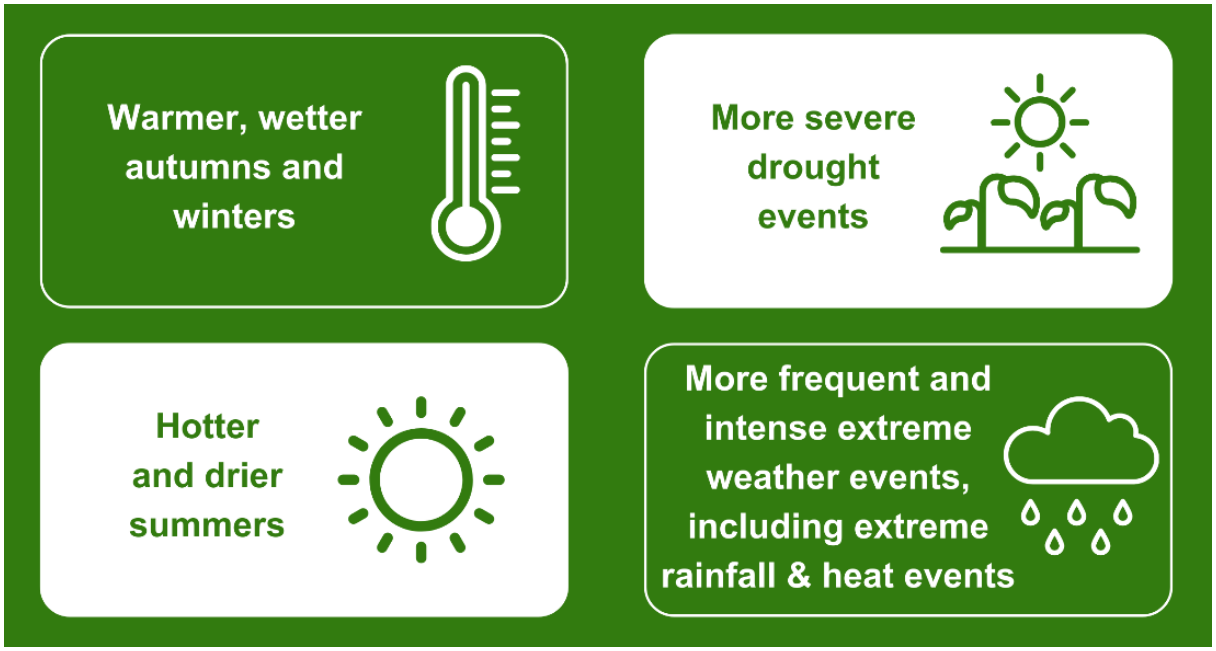
Executive Summary

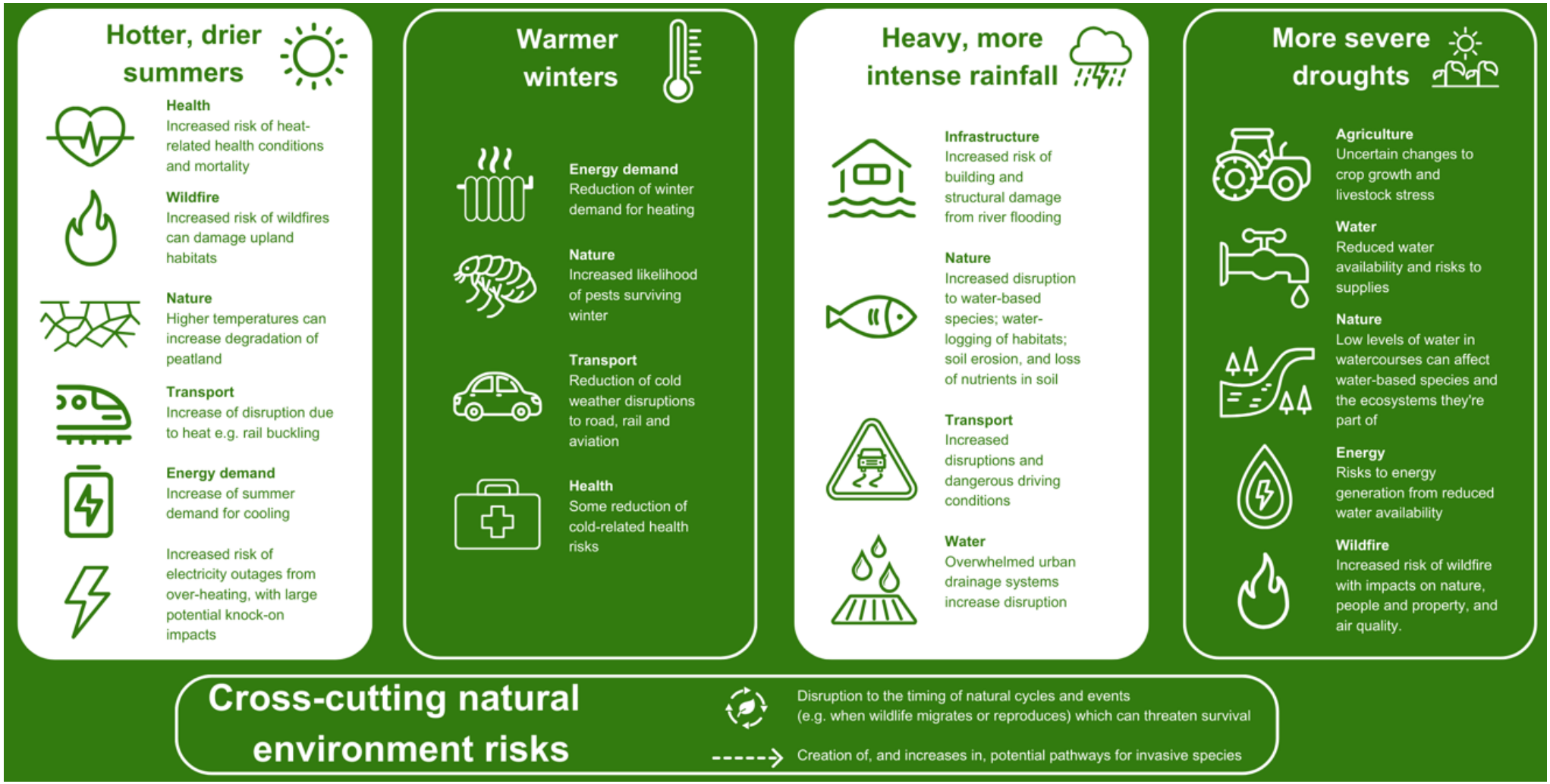
The impacts of climate change and the climate emergency are now being felt across the globe, including in the UK. Several extreme events have been attributed to climate change, including the flooding and extreme heat events experienced in Greater Manchester over recent years, such as the 2015 Boxing Day floods, and the July 2022 extreme heatwave; both of which have been found to be more likely to occur because of climate change.

The climate in Greater Manchester has already changed; 5 of the warmest years on record have occurred since 2006, and the most recent decade (2012 to 2021) has been on average 1.0°C warmer than the 1961 to 1990 average. Seasonal rainfall has also changed significantly, with decreasing summer rainfall and increasing winter rainfall.

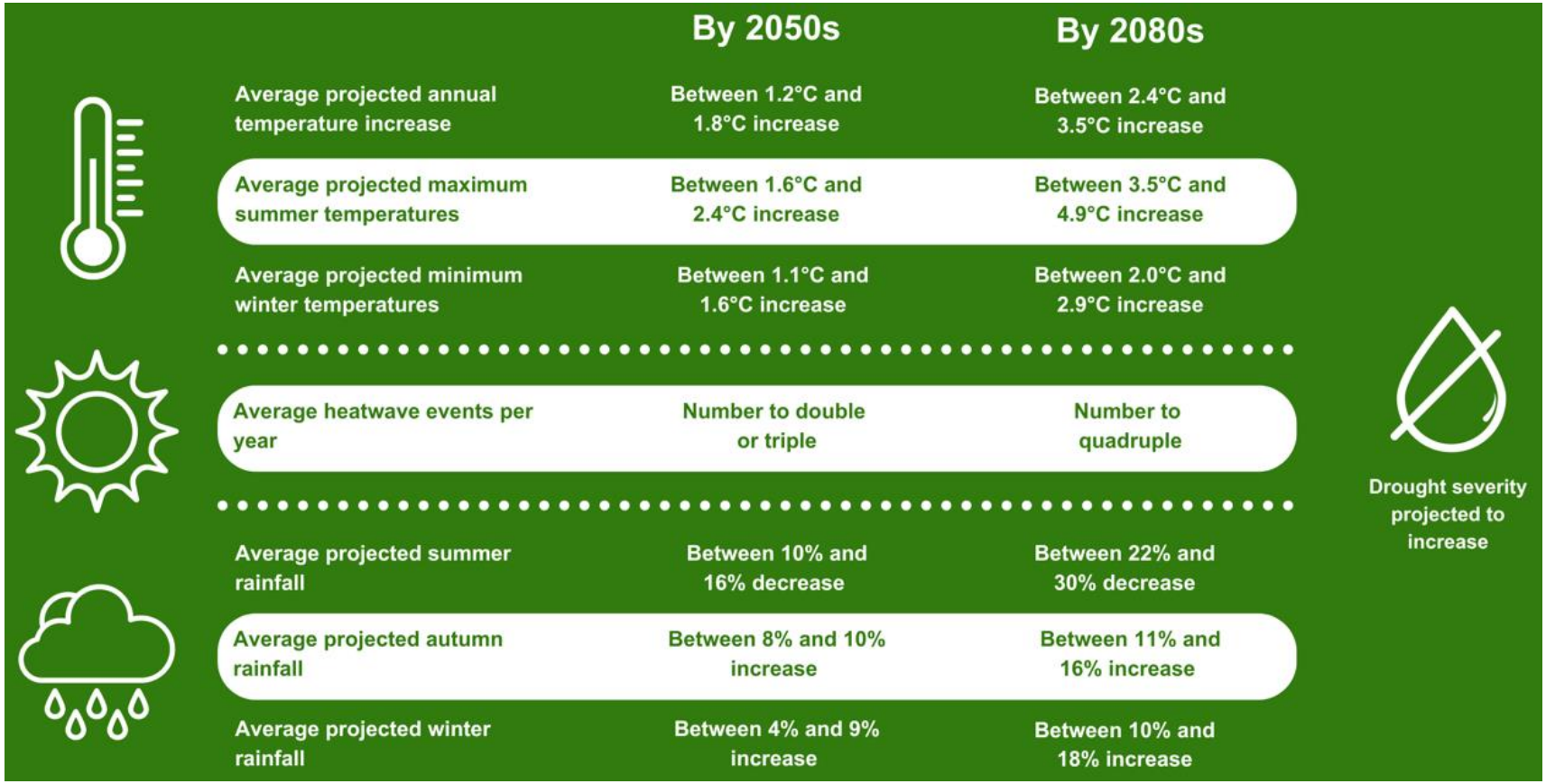
Climate projections show that for Greater Manchester, we can expect to see:



This is projected to bring the following climate-related impacts:



Climate projections make use of different global greenhouse gas emission scenarios to project a range of potential changes in climate. In Greater Manchester, our climate is projected to change in several ways, shown in the infographic below.[1, 2] These changes are relative to the 1981-2010 baseline period.[3]



[1] Range of values taken from Met Office UK Climate Projections using a medium-high carbon emissions scenario and a high carbon emissions scenario (RCP 6.0 and RCP 8.5). More information can be found at: Met Office (2018) UKCP18 Guidance: Representative Concentration Pathways, link.

[2] Drought Severity Index is calculated with 12-month rainfall deficits provided as a percentage of the mean annual climatological total rainfall (1981–2000) for that location. It measures the severity of a drought, not the frequency. Higher values indicate more severe drought. It uses Met Office UK Climate Projections 18 (UKCP18) data. link.

[3] The range of values are taken from the Met Office UK Climate Projections 18 (UKCP18) data, using a medium-high carbon emissions scenario and a high carbon emissions scenario.

Climate adaptation is one of two key policy responses to climate change, alongside mitigation (or reduction of greenhouse gas emissions). Both adaptation and mitigation are necessary as adaptation is needed to reduce the associated risks of climate change that are now locked in. The first step in ensuring our city-region is well-adapted to the increasing impacts of climate change is to understand the risks and opportunities that we face from a changing climate.

To do this, 63 climate risks and opportunities for Greater Manchester have been identified in the development of this Greater Manchester Climate Change Risk Assessment, across the following themes: Natural Environment; Business and Industry; Infrastructure; Built Environment, Health and Communities; and International Dimensions (which are international in nature but will have some impacts in Greater Manchester).

The UK's Third Climate Change Risk Assessment (UK CCRA3) was used as the primary resource for identifying climate risks and opportunities. Using climate projections data for Greater Manchester, stakeholder workshops and expert input, these were re-assessed for Greater Manchester, including their risk magnitude scores.

Of these 63 climate risks, 14 have been classed as of High or Very High Magnitude for Greater Manchester in the present day, and 27 have been classed as of High or Very High Magnitude by the 2050s (see **Table 1** and **Table 2** below); (**Chapter 3** has the risk descriptions and summary of evidence underpinning the risk magnitude scores for Greater Manchester). It should be noted that risks in the 'International Dimensions' theme in the UK CCRA3 have not been reassessed for Greater Manchester, as these are national-level risks and are unlikely to be influenced greatly by local/regional context and activity. These International Dimensions risks have therefore been included in the GM CCRA using the UK-level CCRA risk magnitude scores.[4] These are highlighted in grey in the tables below.

This report looks at how our climate in Greater Manchester has already changed, how it is projected to change over the coming decades, and the climate-related risks and opportunities that could be experienced in Greater Manchester as a result of this

[4] Full information on these climate risks is available in Chapter 7 of the UK CCRA3.

climate change, to develop a Greater Manchester Climate Change Risk Assessment. It has been developed alongside key stakeholders and local experts from across Greater Manchester.

This Greater Manchester Climate Change Risk Assessment is a key part of the evidence base to inform the development of a Climate Change Adaptation Strategy and Action Plan for Greater Manchester. This Strategy and Action Plan will provide the strategic direction to realise our vision of a well-adapted, resilient and climate-ready Greater Manchester, outline appraised adaptation actions, and seek to integrate adaptation into relevant projects, policies and plans.

Table 1. Present day High Magnitude risks and opportunities for Greater Manchester.

Theme	**Risk or Opportunity**	**Risk Magnitude Score**
Natural Environment	N1 Risks to terrestrial species and habitats from changing climatic conditions and extreme events, including temperature change, water scarcity, wildfire, flooding, wind, and altered hydrology (including water scarcity, flooding and saline intrusion)	High
	N5 Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions, including temperature change, water scarcity and wildfires	High
	N12 Risks to freshwater species and habitats from pests, pathogens and invasive species	High
Infrastructure	I1 Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures	High
	I2 Risks to infrastructure services from river, surface water and groundwater flooding	High
	I10 Risks to energy from high and low temperatures, high winds, lightning	High
Health, Communities and Built Environment	H1 Risks to health and wellbeing from high temperatures	High
	H3 Risks to people, communities and buildings from flooding and storms	High
	H7 Risks to health and wellbeing from changes in indoor and outdoor air quality	High
	H9 Risks to food safety and food security	High
Business	B1 Risks to business sites from flooding	High
International Dimensions	ID1 Risks to UK food availability, safety, and quality from climate change overseas	High (UK Score)
	ID9 Risk to UK public health from climate change overseas	High (UK Score)

Theme	Risk or Opportunity	Risk Magnitude Score
	ID10 Risk multiplication from the interactions and cascades of named risks across systems and geographies	High (UK Score)

Table 2. 2050s High Magnitude risks and opportunities for Greater Manchester.[5]

Theme	Risk	Risk Magnitude Score
Natural Environment	N1 Risks to terrestrial species and habitats from changing climatic conditions and extreme events, including temperature change, water scarcity, wildfire, flooding, wind, and altered hydrology (including water scarcity, flooding and saline intrusion)	High
	N2 Risks to terrestrial species and habitats from pests, pathogens and invasive species	High
	N4 Risk to soils from changing climatic conditions, including seasonal aridity and wetness.	High
	N5 Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions, including temperature change, water scarcity and wildfires	**Very High**
	N11 Risks to freshwater species and habitats from changing climatic conditions and extreme events, including higher water temperatures, flooding, water scarcity and phenological shifts.	High
	N12 Risks to freshwater species and habitats from pests, pathogens and invasive species	High
	N18 Risks and opportunities from climate change to landscape character	High

[5] Assuming a 2°C end-of-century global warming level, compared to pre-industrial levels.

Theme	Risk	Risk Magnitude Score
Infrastructure	**I1 Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures**	**Very High**
	I2 Risks to infrastructure services from river, surface water and groundwater flooding	**Very High**
	I4 Risks to bridges and pipelines from flooding and erosion	High
	I9 Risks to energy generation from reduced water availability	High
	I10 Risks to energy from high and low temperatures, high winds, lightning	High
	I12Risks to transport from high and low temperatures, high winds, lightning	High
	I13 Risks to digital from high and low temperatures, high winds, lightning	High
Health, Communities and Built Environment	**H1 Risks to health and wellbeing from high temperatures**	**Very High**
	H3 Risks to people, communities and buildings from flooding and storms	**Very High**
	H6 Risks and opportunities from summer and winter household energy demand, (a) **Opportunity** -winter	High
	H9 Risks to food safety and food security	High
	H12 Risks to health and social care delivery from extreme weather	High
	H15 Social inequalities exacerbated as a result of climate change, with disadvantaged and vulnerable groups facing disproportionate climate impacts	High
Business	B1 Risks to business sites from flooding	High
	B6 Risks to business from disruption to supply chains and distribution networks	Unknown magnitude as difficult to quantify, but **High Priority** due

Theme	Risk	Risk Magnitude Score
		to potentially very large impacts
	B7 Opportunities for business from changes in demand for goods and services	High
International Dimensions	ID1 Risks to UK food availability, safety, and quality from climate change overseas	High (UK Score)
	ID6 Opportunities from climate change on international trade routes	High (UK Score)
	ID9 Risk to UK public health from climate change overseas	High (UK Score)
	ID10 Risk multiplication from the interactions and cascades of named risks across systems and geographies	High (UK Score)

1. Introduction

Climate adaptation and mitigation

The impacts of climate change and the climate emergency are already being felt across the world, including through the increased frequency and intensity of flooding, droughts and extreme heat events. In Greater Manchester, the flooding and extreme heat events experienced over recent years, such as the 2015 Boxing Day floods, and the July 2022 extreme heatwave, have been made more likely because of climate change[6,7,8]. These events are projected to become more frequent and intense over the coming decades.

Two policy responses are required to tackle this:

- Mitigation – reducing greenhouse gas emissions to reduce the degree and severity of climate change and its impacts.
- Adaptation – adjusting to actual or expected future climate change, reducing risks and aiming to benefit from any associated opportunities where possible.[9]

Both these responses are crucial, as is the link between them – the greater the progress in mitigation, the fewer adjustments that will be required to be made to a changing climate. However, even if we were to reach net-zero carbon emissions tomorrow, a certain level of climate change is already locked into the global climate system – further global temperature increases, beyond what is already being experienced, are now unavoidable. Adaptation will therefore be needed to reduce the associated risks of climate change. There will be significant costs (both economic and social) from adaptation inaction; that is, where we do not adapt sufficiently to climate change, meaning the negative impacts from climate events will be greater. The annual economic cost of climate change in Greater Manchester has been estimated by the London School of Economics[10] at around 2.5% of our Gross Domestic Product (GDP) by the 2050s, assuming current policies on climate and

[6] Friederike E L Otto et al 2018 Environ. Res. Lett. 13 024006, link
[7] Met Office (2020) Chances of 40°C days in the UK increasing, link.
[8] Met Office (2022) UK and Global extreme events – Heatwaves, link
[9] LSE (2021) What is Climate Change Adaptation? Link
[10] LSE (2022) What will climate Change Cost the UK? Link

carbon continue,[11] or around 1.7% of GDP under a high mitigation scenario.[12] Adaptation is therefore required to help reduce these costs, and the impacts felt by wider society.

In addition, there is a strong body of evidence that there are potentially high economic benefits from further adaptation for many climate risks and opportunities, with many early adaptation investments delivering high value for money.[13] **Figure 1** from the UK Climate Change Risk Assessment shows that the benefit-cost ratios often range from 2:1 to 10:1; meaning every £1 invested in climate adaptation could result in £2 to £10 in net economic benefits. The analysis also found that adaptation also often leads to important co-benefits, and that there are benefits from taking further adaptation action for almost every risk assessed in the CCRA report.

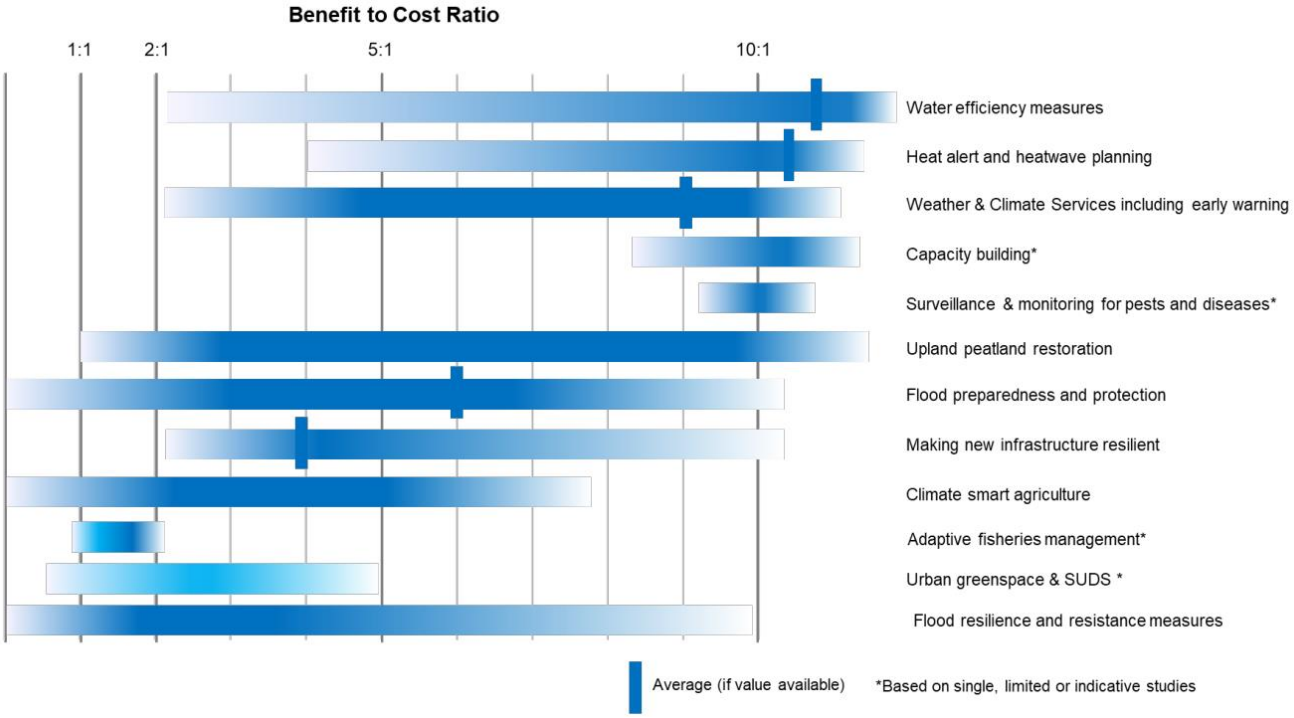


Figure 1. Benefit to Cost ratios for Adaptation for selected measures.[14]

[11] The 'current policies' scenario is characterised by a lack of climate policy ambition and global coordination. CO2 emissions and global temperatures continue to increase.
[12] The 'high mitigation' scenario is characterised by sustainable action through strong investments in green technologies. Global emissions fall throughout the century and become net-negative after 2075 through carbon dioxide removal; global temperatures increase but by a lower level than in the 'current policies' scenario.
[13] Watkiss P, Cimato F and Hunt A (2021) Monetary Valuation of Risks and Opportunities in CCRA3. UK Climate Risk, Report to the Climate Change Committee as part of the UK Climate Change Risk Assessment 3. Link
[14] Notes: Figure shows the indicative benefit: cost ratios and ranges for a number of adaptation measures. It is based on the evidence review undertaken in the CCRA3 Valuation study, which was co-funded by the EU's Horizon 2020 RTD COACCH project (CO-designing the Assessment of Climate Change costs). Vertical bars show where an average Benefit-Cost Ratio (BCR) is available, either from multiple studies or reviews. It is stressed that BCRs of adaptation measures are highly site- and context-specific and there is future uncertainty about the scale of climate change: actual BCRs will depend on these factors.

The purpose of the GM CCRA

The first step in ensuring our city-region is well-adapted to the increasing impacts of climate change is to understand the risks and opportunities that we face from a changing climate. To do this, we need to understand, for Greater Manchester:

- How our climate is already changing.
- How our climate will change in the future.
- What this means for future climate risks and opportunities.

This is the purpose of this Greater Manchester Climate Change Risk Assessment (GM CCRA). It is also important to recognise that the impact of climate risks will be unequal; many climate risks will affect the most vulnerable in our city region the most severely. Climate hazards can interact with and exacerbate risks from other challenges, such as poverty, poor health or poor housing. This has been accounted for in this GM CCRA through desk-based research and stakeholder workshops.

The GM CCRA will form a key part of the evidence base to inform the development of a future Climate Change Adaptation Strategy and Action Plan for Greater Manchester. This Strategy and Action Plan will provide the strategic direction to realise our vision of a well-adapted, resilient and climate-ready Greater Manchester, outline appraised adaptation actions, and seek to integrate adaptation into relevant projects, policies and plans.

Who is this GM CCRA for and how can you use it

This GM CCRA can be used by Local Authorities, public and private sector organisations, infrastructure providers, community groups and residents in Greater Manchester to better understand the relevant climate risks and opportunities across the city-region.

A GM CCRA helps to improve our understanding of how climate risks will be felt locally and allows for a collaborative, coordinated approach to adaptation action to address the climate risks and opportunities identified.

The climate risks and opportunities assessed for Greater Manchester can also be translated into a CCRA specific to an organisation, service area or local area in Greater Manchester, and prioritised based on local/organisational need, context and priorities, to produce a local/organisational CCRA.

How it was developed

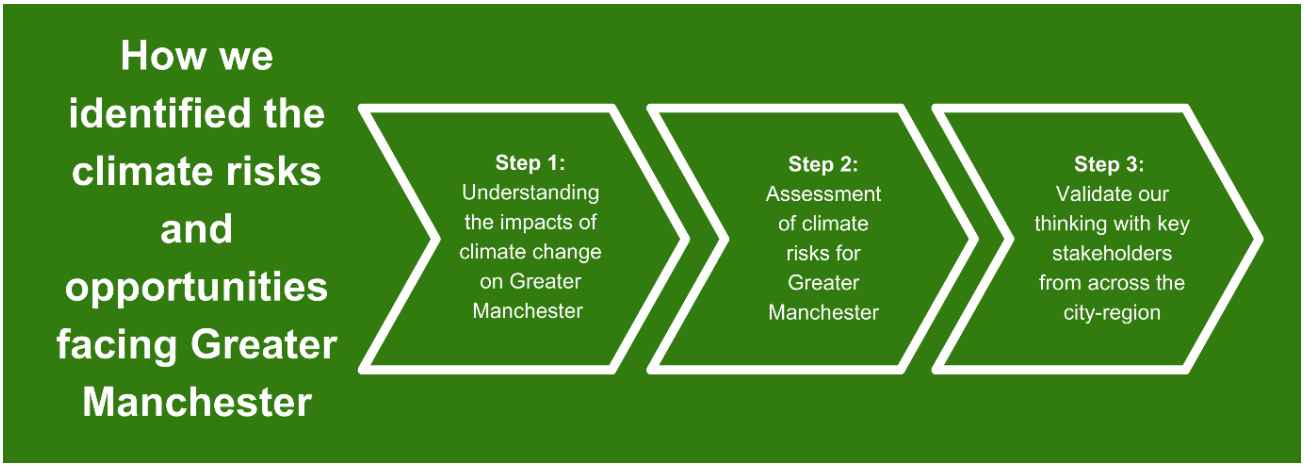
This GM CCRA has primarily followed Adaptation Scotland's Public Sector Climate Adaptation Framework.[15] This framework outlines 5 stages that make up the adaptation process, shown in **Figure 2** below. This GM CCRA forms a key part of Stage 2: 'Understand the impacts of climate change', and will be a key input used to inform Stage 3: 'Identify and prioritise actions'.

Figure 2. Adaptation Framework.

The GM CCRA has drawn upon national resources, stakeholder engagement and regional and local evidence to identify 63 climate-related risks and opportunities of

[15] Adaptation Scotland (2020) Public Sector: The Framework, link

relevance to GM. The assessment has assigned risk magnitude scores ranging from low to very high for both present-day risk and risk by the 2050s, under a 2°C Global Warming Level.[16] A brief methodology is outlined below, with the full methodology in Appendix A: Methodology.



Step 1: Understanding the impacts of climate change

Research was undertaken to understand how past weather events have impacted Greater Manchester, and therefore how similar events may impact us in the future as they become more frequent or intense due to climate change.

The evidence base for how the climate is projected to change in Greater Manchester was developed, primarily using the UK's Third Climate Change Risk Assessment (UK CCRA3), Met Office UKCP18 data, alongside GMCA-commissioned data, Climate Just and others.

Step 2: Assessment of climate risks for Greater Manchester

The UK CCRA3 was used as the primary resource for identifying climate risks and opportunities.[17] Using understanding developed in Step 1, alongside desk-based research, stakeholder workshops and expert input, these UK climate risks were re-assessed for Greater Manchester. [18] This involved assessing relevant evidence to

[16] 2°C increase in Global Warming Level by 2100 compared to pre-industrial levels. This mirrors the approach taken in the UK CCRA3.
[17] The UK CCRA3 is the national climate change risk assessment, developed by the Climate Change Committee. A UK CCRA is developed every 5 years; the Third UK CCRA was published in 2021.
[18] Risks in the 'International Dimensions' theme in the UK CCRA3 have not been reassessed for Greater Manchester, as these are national-level risks and are unlikely to be influenced greatly by local/regional context, activity and/or policy. These International Dimensions risks have therefore been included in the GM CCRA using the UK-level CCRA risk magnitude scores from the UK CCRA3.

understand the impacts of these risks and opportunities, and their appropriate risk magnitude score, specific to Greater Manchester. This resulted in the development of the GM CCRA Evidence Base report (link to report TBC).

Climate risks and opportunities, as well as their risk magnitude scores, were then identified for Greater Manchester.

Step 3: Validate with stakeholders

The climate risks and opportunities identified for Greater Manchester, and their risk magnitude scores, were confirmed with further discussions with key stakeholders.

2. How has our climate changed already?

About Greater Manchester

Greater Manchester is located in the North-West region of England, which includes Cheshire, Merseyside, Greater Manchester, Lancashire and Cumbria.[19] The range of topography and altitude in North-West England provides a varied climate. Southern and Western areas of Greater Manchester are lower-lying, with Northern and Eastern areas of the city-region at higher elevations (**Figure *3***).

Greater Manchester has a mean annual temperature of around 10°C, with slightly cooler temperatures in upland areas. These upland areas also receive high levels of rainfall (around 1100mm/year), with lower lying areas receiving less rainfall, including the large urban area of Manchester, which receives around 800mm of rainfall/year.[20]

North-West England is also a relatively exposed area of the UK and experiences strong winds, with the strongest coming off the Irish Sea, often during the winter period.

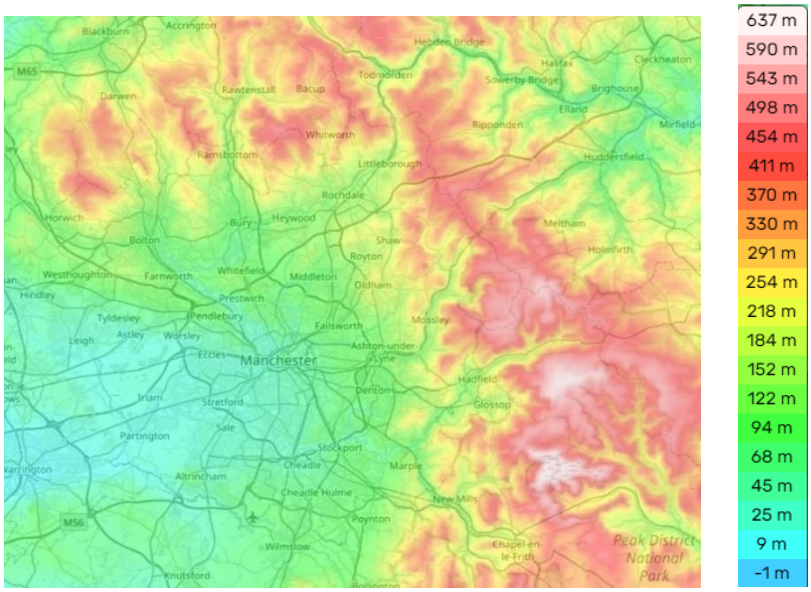


Figure 3. Greater Manchester topographic map.[21]

[19] Met Office (2019) North West England & Isle of Man: climate. Link
[20] Met Office: UK Climate Averages. Link
[21] Topographic Map website: Greater Manchester topographic map, link

Climate baseline summary

Greater Manchester has a generally temperate climate, with cool, wet winters and warm, drier summers. **Figure 4** shows the mean monthly temperature and mean monthly rainfall for two climate stations in Greater Manchester: Stockport and Rochdale (southern and northern Greater Manchester, respectively), for the period 1981-2010.

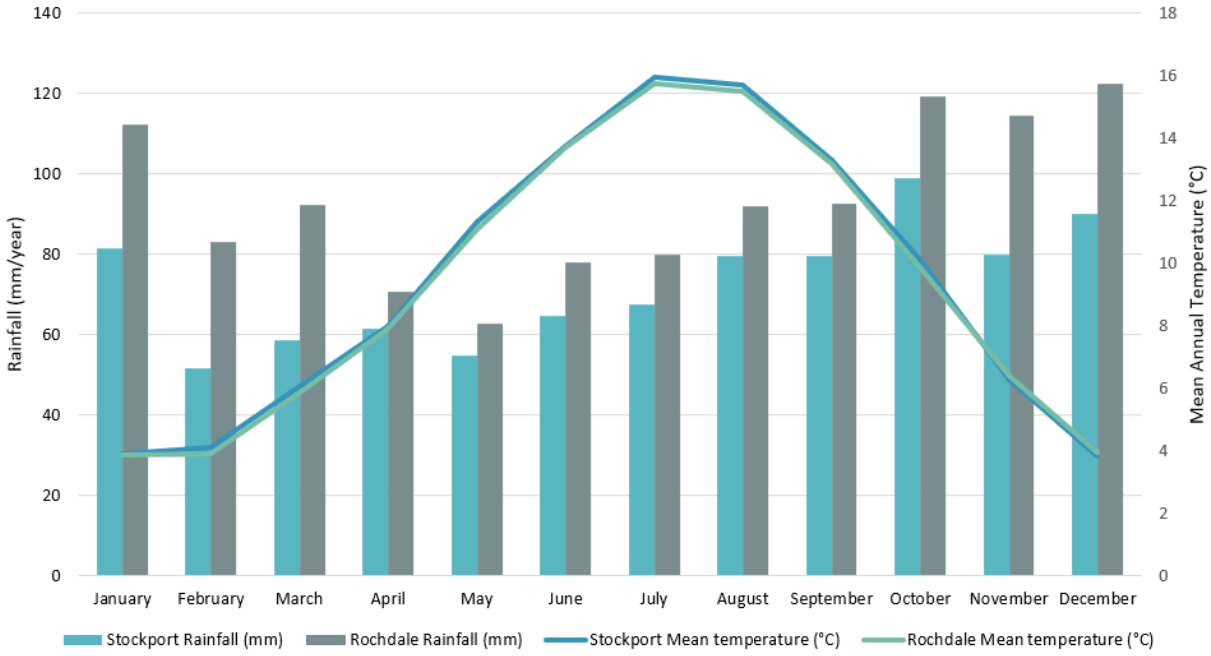


Figure 4. Climate averages for Stockport and Rochdale climate stations, Greater Manchester, for the period 1981-2010.[22]

Observed Climate Trends

The five warmest years on record in Manchester have all occurred since 2006 (shown in **Figure *5***). For the UK, the most recent decade (2012 to 2021) has been on average 1.0°C warmer than the 1961 to 1990 average.[23]

[22] Met Office – UK Climate averages, Woodford climate station. Accessed here.
[23] UK Government Department for Energy Security and Net Zero (2023) Climate Change Explained, link

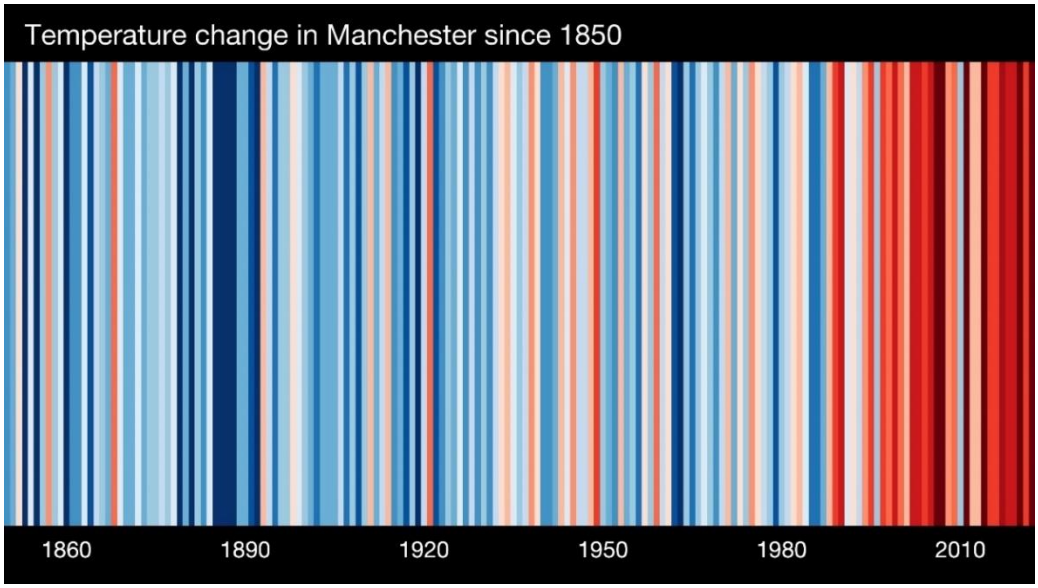


Figure 5. Temperature change in Manchester for period 1850 to 2022; relative to average of 1971-2000.[24]

Historical climate data shown below is from the Ringway climate data station in south Manchester. This station closed in 2004, and therefore data is only presented up to 2004. No other historic climate data stations exist in Greater Manchester.

This data shows that observed mean annual temperatures increased substantially (by nearly 1.5°C) over the period 1961-2004 (**Figure 6**), with average annual rainfall also seeing some increase over the same period (**Figure 7**).[25]

[24] Climate Stripes, National Centre for Atmospheric Science, University of Reading, Accessed here
[25] Met Office Historic Station Data: Ringway, Location: 53.356, -2.279; Opened: 1946, Closed: 2004. Accessed here.

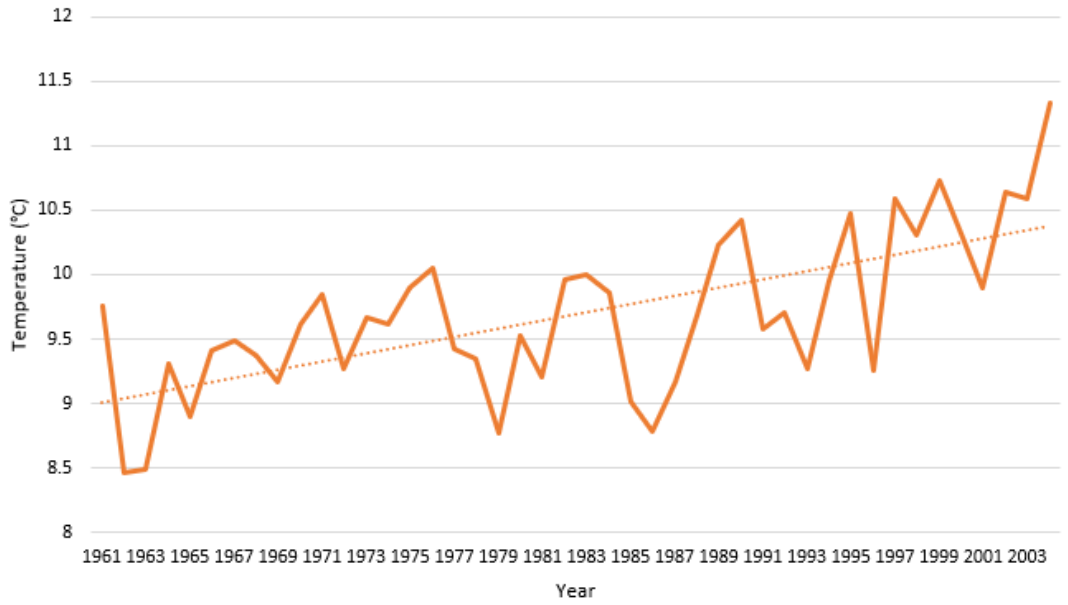


Figure 6. Historical Average Annual Temperature in Manchester (1961-2004).

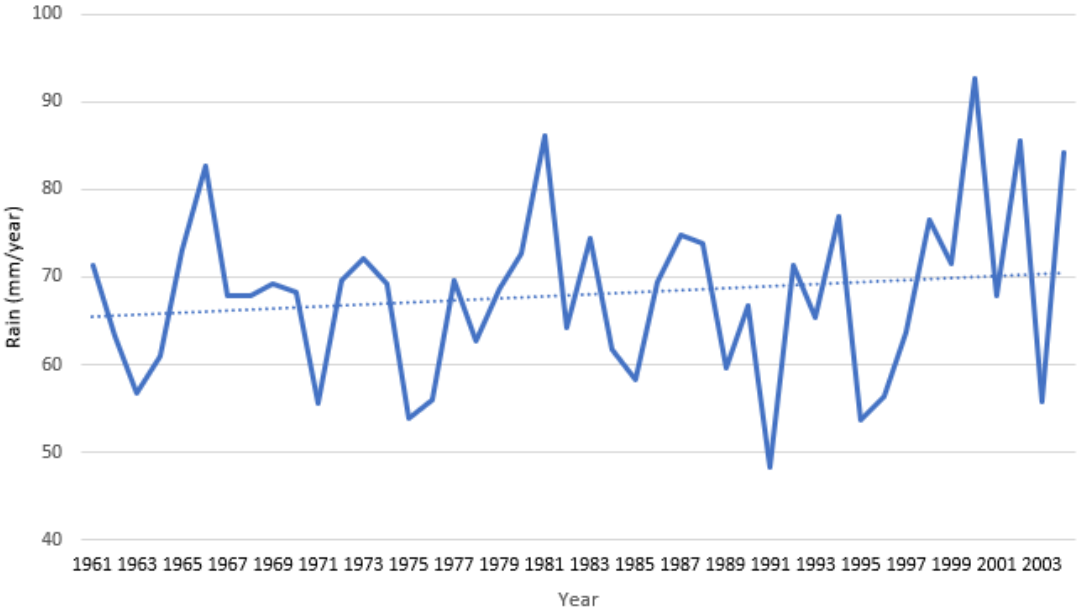


Figure 7. Historical Average Annual Rainfall in Manchester (1961-2004).

Whilst historical average annual rainfall shows a modest increase over the same period, by around 5mm or ~7%, annual rainfall can mask the significant changes observed in *seasonal* rainfall. Met Office climate observations (**Figure *8***) show that winter precipitation has increased by between 10 and 50% across Greater Manchester, for the period 1961-2006; over the same period, summer precipitation

has decreased by between 10 and 25% across much of Greater Manchester and North-West England.[26]

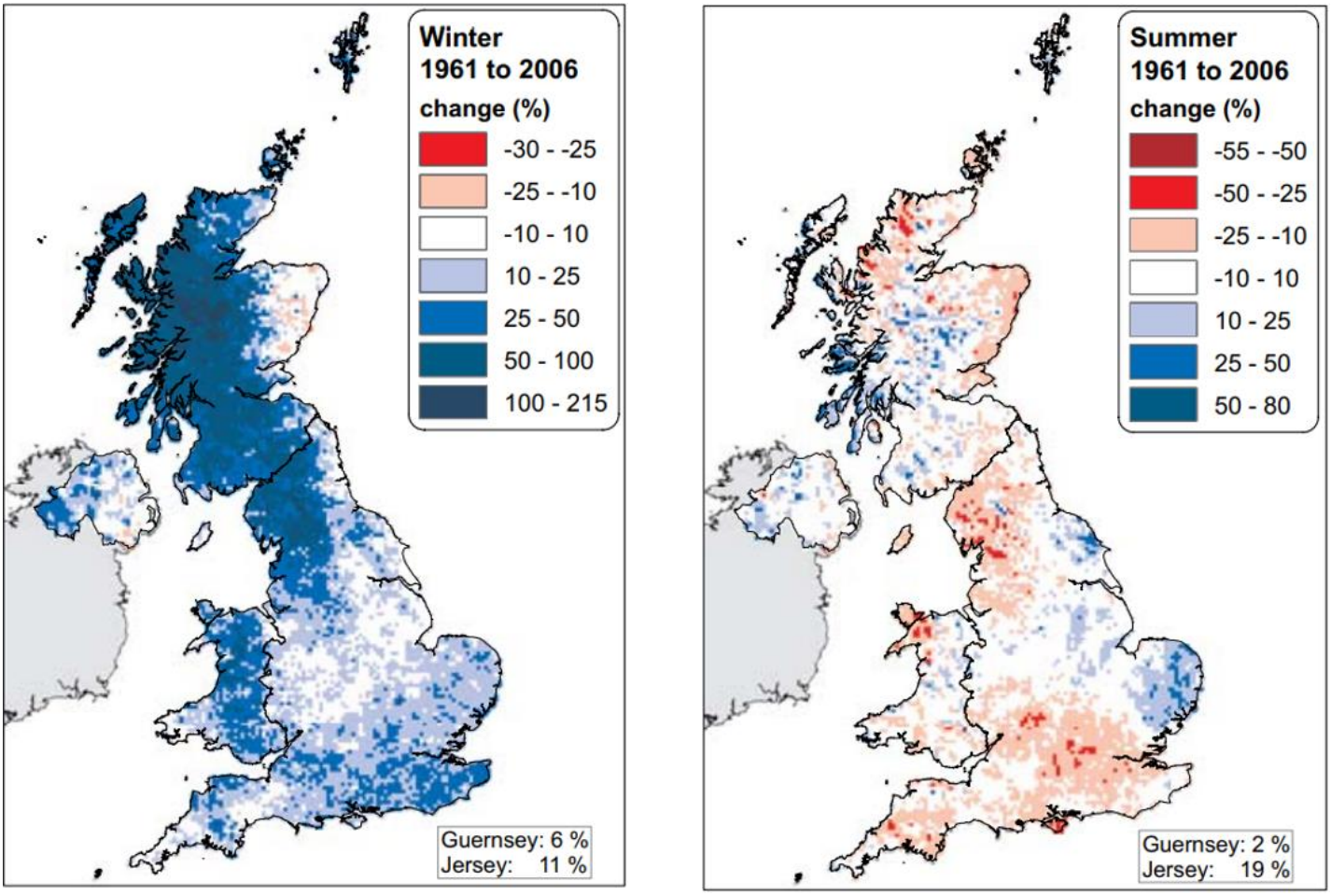


Figure 8. Percentage change in total precipitation amount from 1961-2006 based on a linear trend, for the winter season (left) and summer season (right).

Similarly, average annual temperatures show a direction of travel, but it is also important to understand how maximum and minimum temperatures have changed, as these often have a greater impact on human health, society and the natural environment. **Figure 9** and **Figure 10** show the observed average summer maximum temperatures and average minimum winter temperatures from the Met Office Historic Climate Station in Manchester – both of which have increased

[26] Jenkins, G.J., Perry, M.C., and Prior, M.J. (2008). The climate of the United Kingdom and recent trends. Met Office Hadley Centre, Exeter, UK. Accessed here.

significantly over the period 1961-2004. Average summer maximum temperatures are now almost 1.5°C hotter over this period, and average winter minimum temperatures have increased by over 1°C.

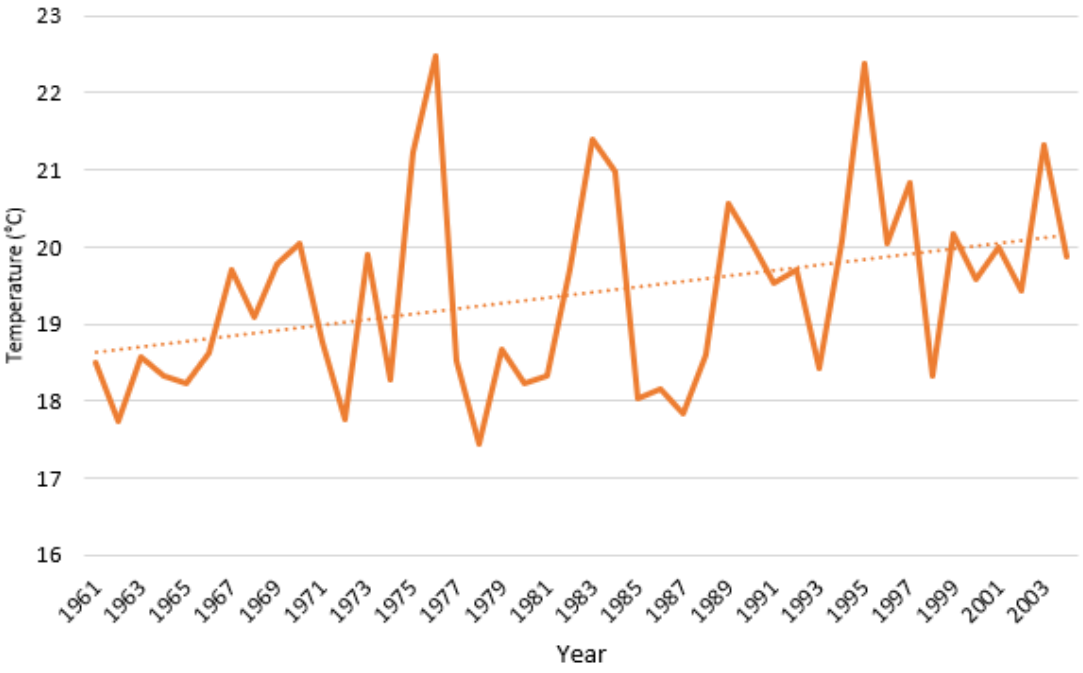


Figure 9. Historical Average Maximum Summer Temperatures in Manchester (1961-2004).

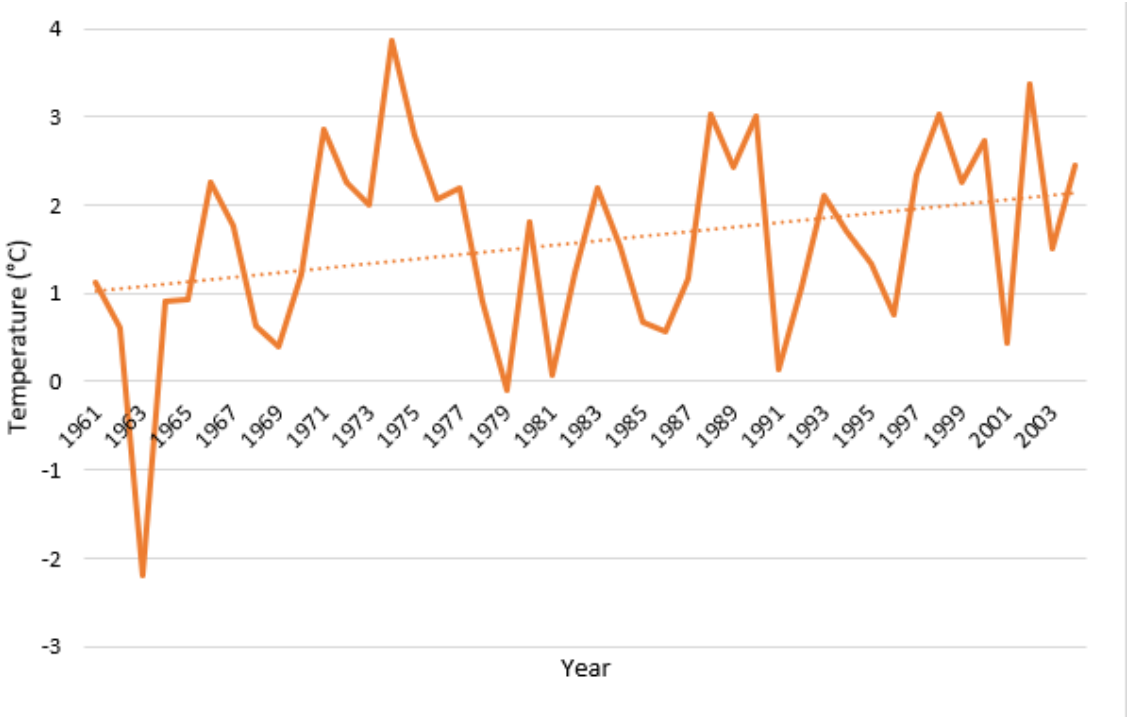


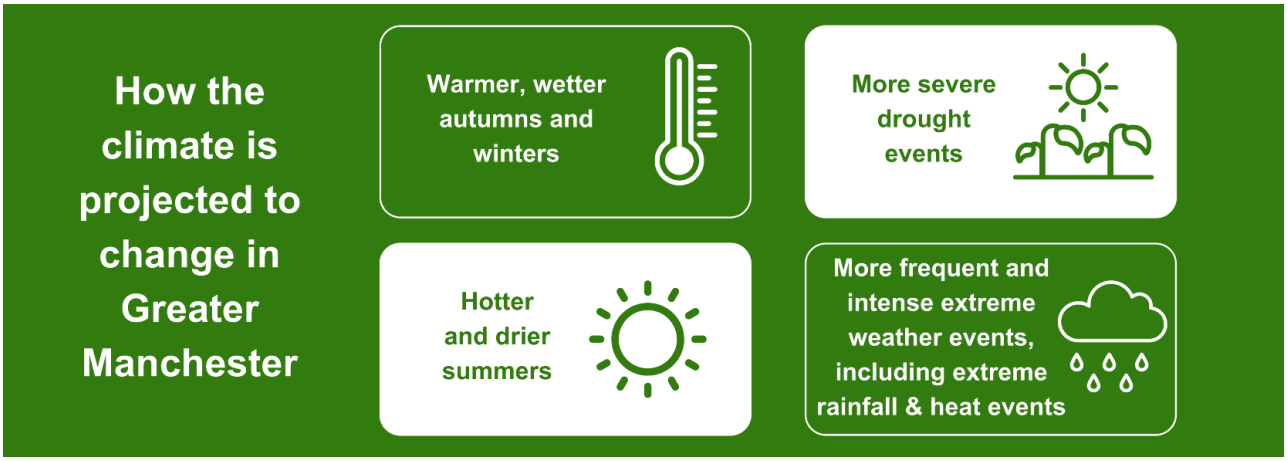
Figure 10. Historical Average Minimum Winter Temperatures in Manchester (1961-2004).

A summary of recent, significant weather-related historical events in Greater Manchester can be found in Appendix B: Summary of past weather-related events in Greater Manchester.

3. How will our climate change in the future?

This section presents the summary of climate projections for Greater Manchester.

Our future climate will be determined by current and future global greenhouse gas emissions. According to Met Office UK Climate Projections (UKCP18), as a result of climate change Greater Manchester can expect to see:



This UKCP18 climate projections data is available for different future time horizons, and for different global greenhouse gas emissions scenarios (i.e. how much global greenhouse gas is emitted over the coming decades).

Future global greenhouse gas emissions, or 'Emissions Scenarios', can also be expressed as 'Representative Concentration Pathways' (RCPs).[27] Different RCPs assume different emissions of greenhouse gases to the end of the 21st century. They include a wide range of assumptions regarding population growth, economic development, technological innovation and attitudes to social and environmental sustainability.

[27] Met Office (2018) UKCP18 Guidance: Representative Concentration Pathways link

For the purpose of this CCRA, we have assessed climate projections (UKCP18)[28] for the following time horizons and global emissions scenarios:

- The 2040s, 2050s and 2080s time horizons
- A 'medium-high' greenhouse gas emissions scenario (RCP 6.0) and a 'High' emissions scenario (RCP 8.5).

Any changes are relative to the 1981-2010 baseline period.

More detail on the global emissions scenarios, the rationale behind the selected emissions scenarios, and the rationale for the chosen time periods, is in Appendix D: Information on climate projections. In summary, it is good practice to select a range of emissions scenarios because future greenhouse gas emissions are unpredictable. This assessment has used the medium-high (RCP 6.0) emissions scenario as this scenario most closely aligns to the estimated end-of-century global temperature increases that will be experienced if current national climate policies around the world are assumed.[29] This assessment has also used the high (RCP 8.5) emissions scenarios, as this provides an upper range within which climate change is projected to take place.

It is also good practice to select mid-century time horizons to align with medium (2040s) and longer-term (2050s) regional plans, alongside an end of century time horizon (2080s) which helps show the full available extent of projected climate change associated with each emissions scenario.

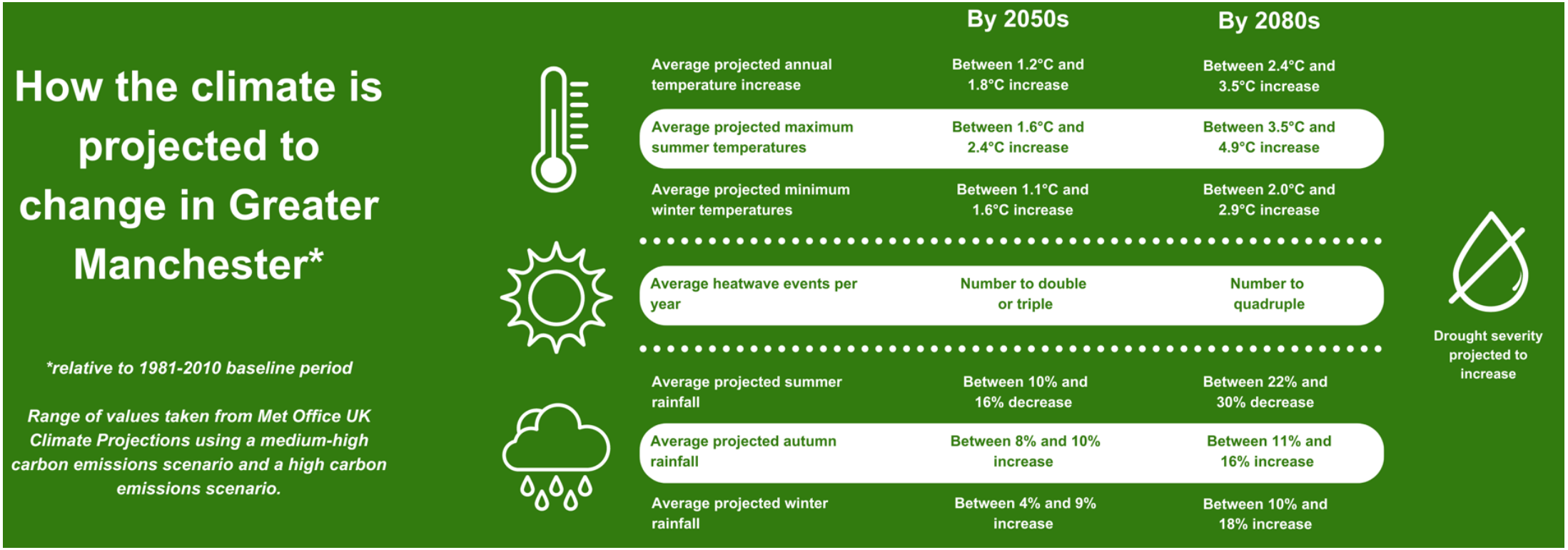
The infographic in the section below, and Table 8 in Appendix C: Greater Manchester Climate Projections, shows the climate projections summary for Greater Manchester, for the baseline period 1981-2010, and then for the 2040s, 2050s and 2080s time horizons, under both the medium-high (RCP 6.0) and high (RCP 8.5) emissions scenarios.

More detail on how the climate is projected to change in Greater Manchester, including spatial maps of this data, is available here (GM dashboard link TBC).

[28] Data taken from UKCP18 Probabilistic Projections, Median Values (50th percentile)
[29] Estimates based on the assumption of current national climate policies suggest a median warming level in the region of 2.7°C by 2100, compared to pre-industrial levels (see Figure 1B), Link.

Projections for a range of Climate Indicators

Climate projections data for key climate indicators are shown below for Greater Manchester. **Table 8** in **Appendix C: Greater Manchester Climate** Projections gives Greater Manchester's climate projections for a wider range of climate indicators.



Projections on other climate hazards, including drought severity, river flooding risk and surface water flooding risk, are available in a different format to that used in the infographic above, and in Table 8. For example, drought severity projections are available under different global warming levels (GWL) (i.e. the global temperature increases that may be observed by the end of the century, compared to pre-industrial levels), rather than global greenhouse gas emissions scenarios, and river and surface water flooding projections are available from GMCA-commissioned projects, rather than directly from UKCP18 data. For this reason, these climate hazards are presented separately below.

Projections for Drought Severity

The Drought Severity Index (DSI) measures the severity of a drought, not the frequency. [30,31] **Higher values indicate more severe drought**. DSI projections in **Table 3** are shown for an end-of-century global warming level (GWL) of 2°C and 4°C.

Projections are also shown for the Lake District as Greater Manchester gets a majority of its drinking water from this area, with much of the remainder from local sources.

For context, the highest DSI value for the 2°C global warming level is 20% in south-west England, and for the 4°C global warming level is 17% in south-west England.

Table 3. Drought Severity Index projections for Greater Manchester and wider North-West England.

Location	**Baseline (1981-2000)**	**DSI (GWL 2°C)**	**DSI (GWL 4°C)**
North-East Greater Manchester	5%	14%	13%
North-West Greater Manchester	6%	7.5%	8%
South-West Greater Manchester	6%	6%	8%

[30] Met Office Climate Data Portal (2024) Drought Severity Index, 12-Month Accumulations - Projections, link
[31] DSI is not threshold based, but rather, it is calculated with 12-month rainfall deficits provided as a percentage of the mean annual climatological total rainfall (1981–2000) for that location.

South-East Greater Manchester	6%	6%	8%
Lake District (major reservoir locations for Greater Manchester)	6-7%	8-9%	8-11%

Projections using the Drought Severity Index are also shown spatially in

Figure *11* below, assuming a 2°C global warming level.

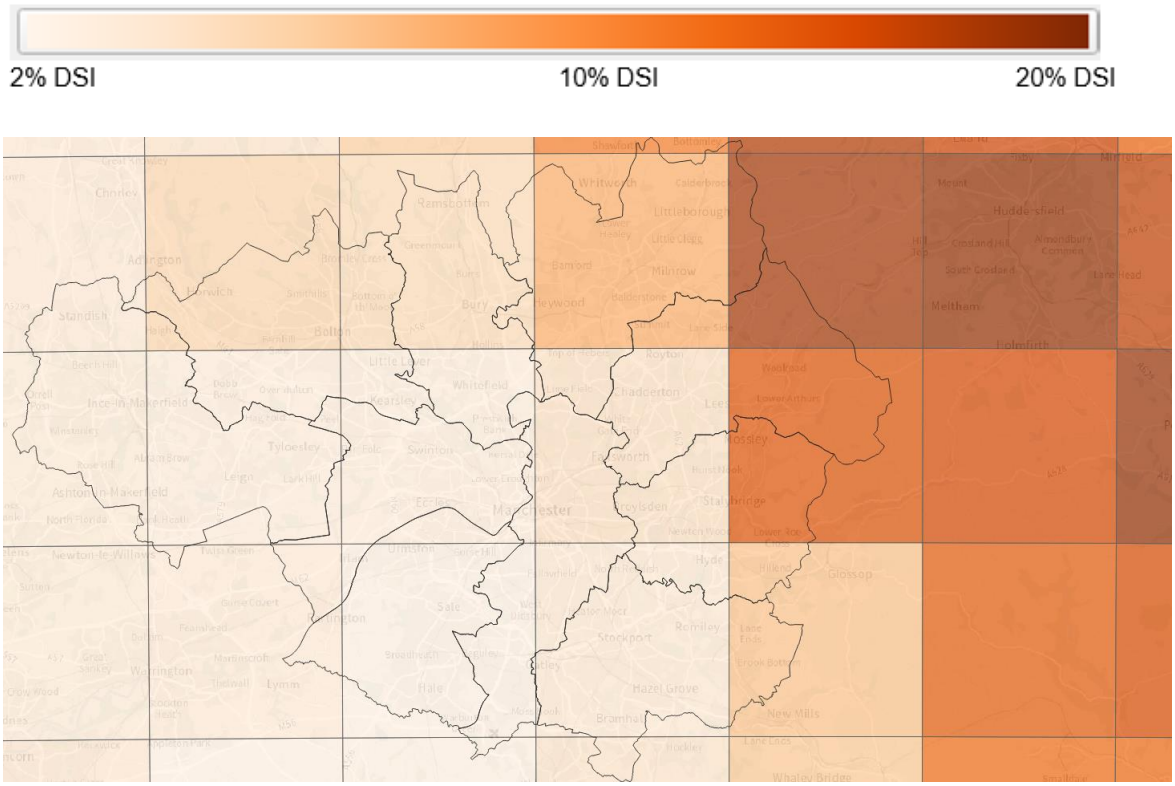


Figure 11. Projected 2050s Drought Severity Index under a 2°C Global Warming Level for Greater Manchester and surrounding areas.

Projections for River Flooding risk

Projected river flooding risk under different climate change scenarios has been modelled through a GMCA-commissioned project.

River flooding risk with both a 35% increase in peak river flow due to climate change by the 2070s, and a 70% increase in peak river flow by the 2070s, have been modelled (based on Environment Agency climate change allowances using medium and high emissions scenarios, respectively).[32,33]

This shows projected future river flooding extents over and above present day/baseline river flooding risk zones, for the time horizon 2070s.

Figure 12 shows these projected river flooding extents and has modelled *including* the flood defences ("Defended") and modelled *excluding* these flood defences ("Undefended") for a worst-case scenario.

This shows significant potential additional river flooding impacts in central Wigan, the Salford-Trafford border, south and central Manchester, and the east of Oldham.

[32] Map available from mappingGM.org.uk

[33] This work considered the 35% and 70% allowances as that was the previous guidance. EA peak river flow allowances guidance for Management Catchment Areas were updated in 2022. Current guidance recommends looking at the Central and Higher allowances for a strategic understanding of risk. At site level this is then based on type of land use. All of the Higher allowances in the current guidance fall within the previous allowance values of 70%.

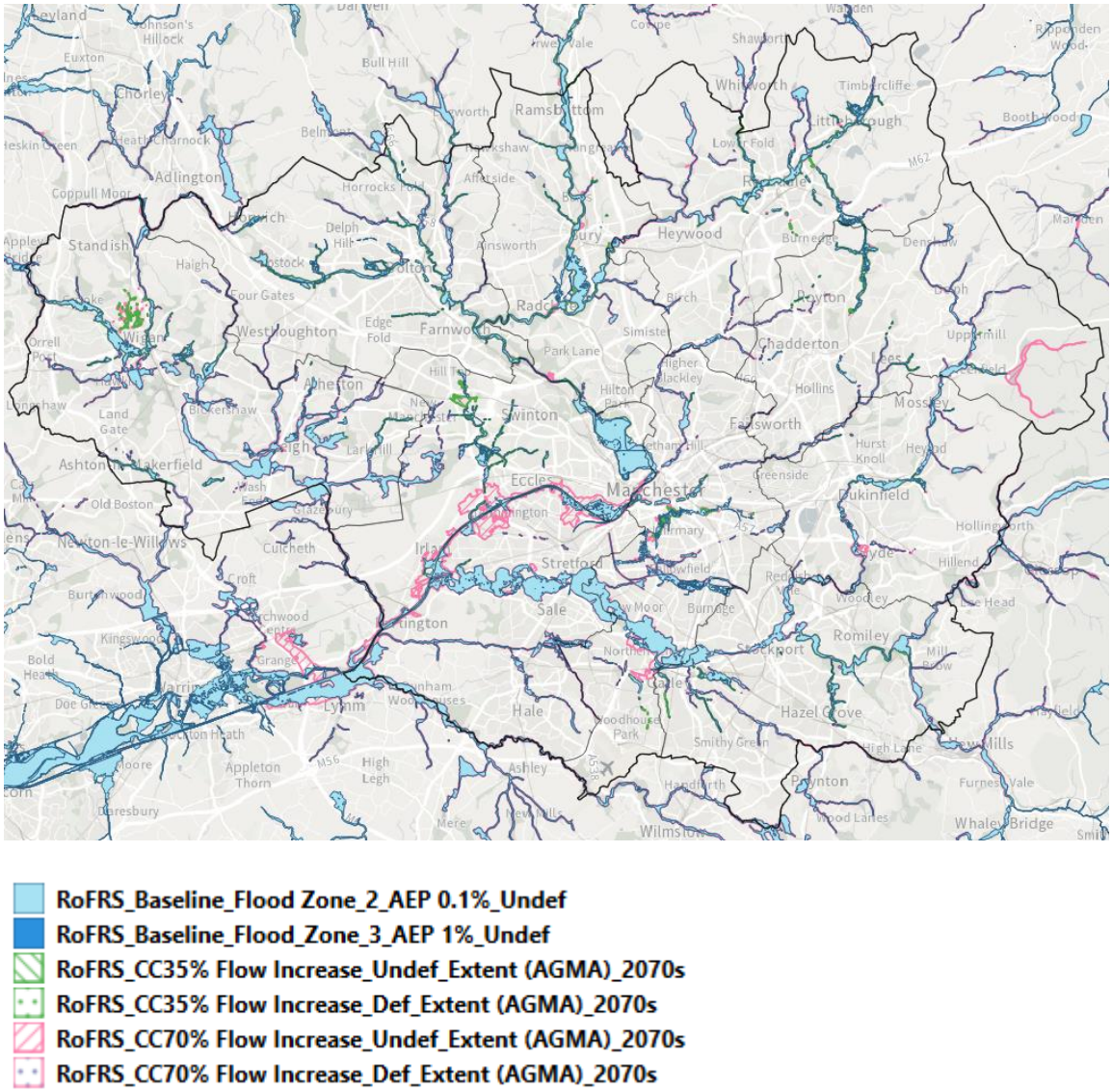


Figure 12. Projected river flooding extent in Greater Manchester under medium and high emissions scenarios (2070s).

Projections for Surface Water Flooding risk

Using a GMCA-commissioned model estimating present-day surface water flood risk at a granular level, a spatial indication of present-day surface water flood risk has been developed (see **Figure 13**).[34] More details can be found in Appendix D: Information on climate projections.

[34] JBA Consulting for GMCA: Flood Risk Heat Mapping

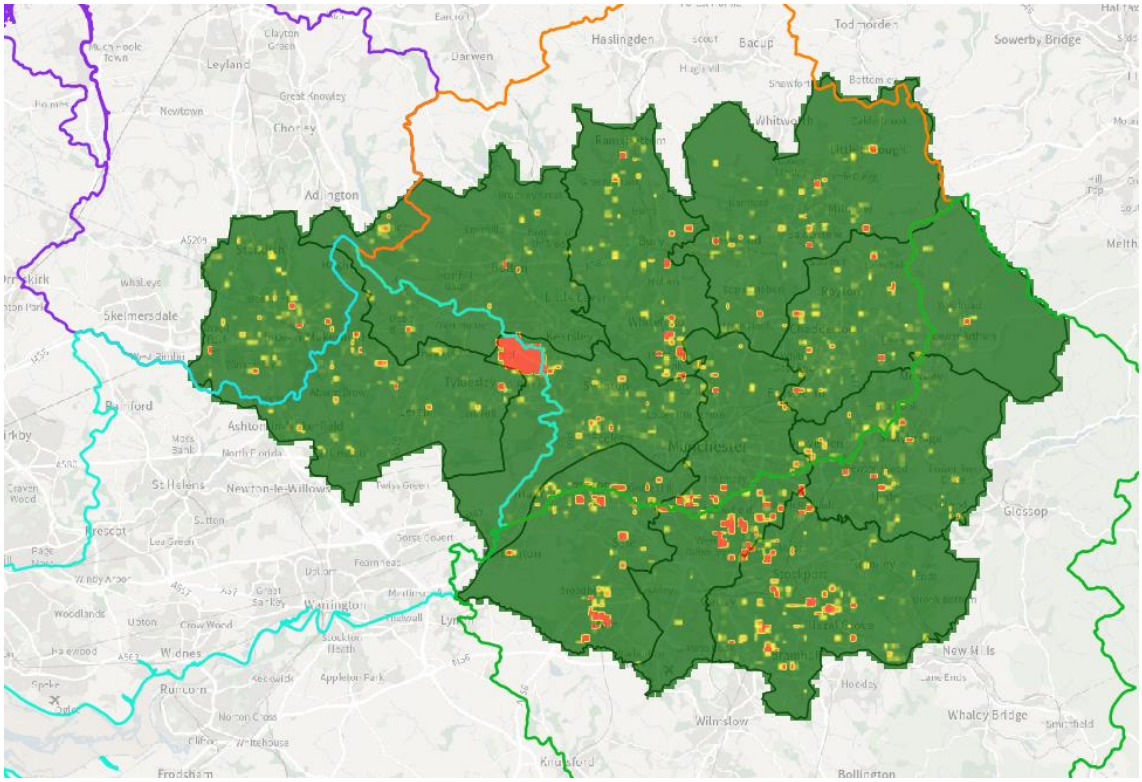


Figure 13. Surface water flooding hotspot areas (present day) with Management Catchment Areas shown.

Surface water flooding risk depends on a range of factors, including: ground conditions (how waterlogged the ground is prior to a rainfall event); extent of impermeable surfaces; drainage capacity or blocked drains, and topography of the land.

Projecting future surface water flooding risk is difficult as it depends on a combination of these factors. **Intense rainfall** is a key driver of surface water flooding. Therefore, to get an understanding of future surface water flooding risk in Greater Manchester, we also need to understand how rainfall intensity is projected to change over the 21st century.

Environment Agency climate change allowances[35] (CCA) are predictions of anticipated change for peak river flow and **peak rainfall intensity** in the future, under different climate change scenarios.[36, 37] **Table 4** shows the projected percentage increases in peak rainfall intensity for the four Management Catchment

[35] Environment Agency (2022) Climate Change Allowances: peak rainfall intensity, link
[36] Climate Change Allowances (peak river flow allowances) data available from link
[37] The central allowance is based on the 50th percentile; upper end allowance is based on the 95th percentile

Areas (MCA) in and around Greater Manchester, for the Central and Upper end climate change allowance and for the 2050s time period.

Table 4. Peak Rainfall Allowances for relevant Management Catchment Areas by the 2050s.

Scenario	Irwell MCA	Upper Mersey MCA	Lower Mersey MCA	Douglas MCA
Central, 3.3% Annual Exceedance Rainfall Event	+25%	+20%	+20%	+25%
Upper End, 3.3% Annual Exceedance Rainfall Event	+35%	+35%	+35%	+35%
Central, 1% Annual Exceedance Rainfall Event	+25%	+25%	+25%	+25%
Upper End, 1% Annual Exceedance Rainfall Event	+40%	+40%	+40%	+40%

This increase in peak rainfall intensity across these Management Catchment Areas will bring significant associated surface water flooding risks for Greater Manchester, in particular in existing surface water hotspot areas.

4. What are the risks and opportunities from climate change for Greater Manchester?

In light of the projected future changes to Greater Manchester's climate and to make an assessment of the risks and opportunities this will bring, we have drawn upon national resources (primarily the UK CCRA3),[38] stakeholder engagement and regional and local evidence to identify 63 climate-related risks and opportunities of relevance to Greater Manchester (of which, 10 relate to International Dimensions, which are international in nature but will have some impacts in Greater Manchester). The assessment has assigned risk magnitude scores ranging from low to very high for both present-day risk and risk by the 2050s, under a 2°C Global Warming Level.[39] Of those 63, the spread of climate risks and opportunities by risk magnitude score and theme, for the time horizon 2050s, are shown in **Figure 14** below.

The assessment has incorporated evidence from desk-based research and stakeholder workshops to better understand how climate hazards may impact different communities and demographics in Greater Manchester, our regional natural environment, infrastructure, economy, and wider society, and therefore assign risk magnitude scores appropriate for Greater Manchester to each risk or opportunity. A summary of this evidence for each climate risk and opportunity is available in the Greater Manchester Climate Risks Evidence Report (link to report TBC).

The 63 risks and opportunities have been categorised using the same themes as the UK CCRA3, namely:

- Natural Environment and Assets
- Infrastructure
- Health, Communities and the Built Environment, and
- Business and Industry

[38] Climate Change Committee (2021) Third UK Climate Change Risk Assessment (UK CCRA3), link
[39] 2°C increase in Global Warming Level by 2100 compared to pre-industrial levels; this was used in the UK CCRA3 assessment.

- International Dimensions

It should be noted that risks in the 'International Dimensions' theme in the UK CCRA3 have not been reassessed for Greater Manchester, as these are national-level risks and are unlikely to be influenced greatly by local/regional context, activity and/or policy. These International Dimensions risks have therefore been included in the GM CCRA using the UK-level CCRA risk magnitude scores.[40]

Those risks or opportunities with a 'High' or 'Very High' risk magnitude score are classed as High Magnitude risks and opportunities. High Magnitude risks and opportunities for Greater Manchester in the present day are shown in **Table 5**, and for the 2050s (assuming an end-of century Global Warming Level of 2°C) in **Table 6.**

More detail can be found in the Methodology section in Appendix A: Methodology.

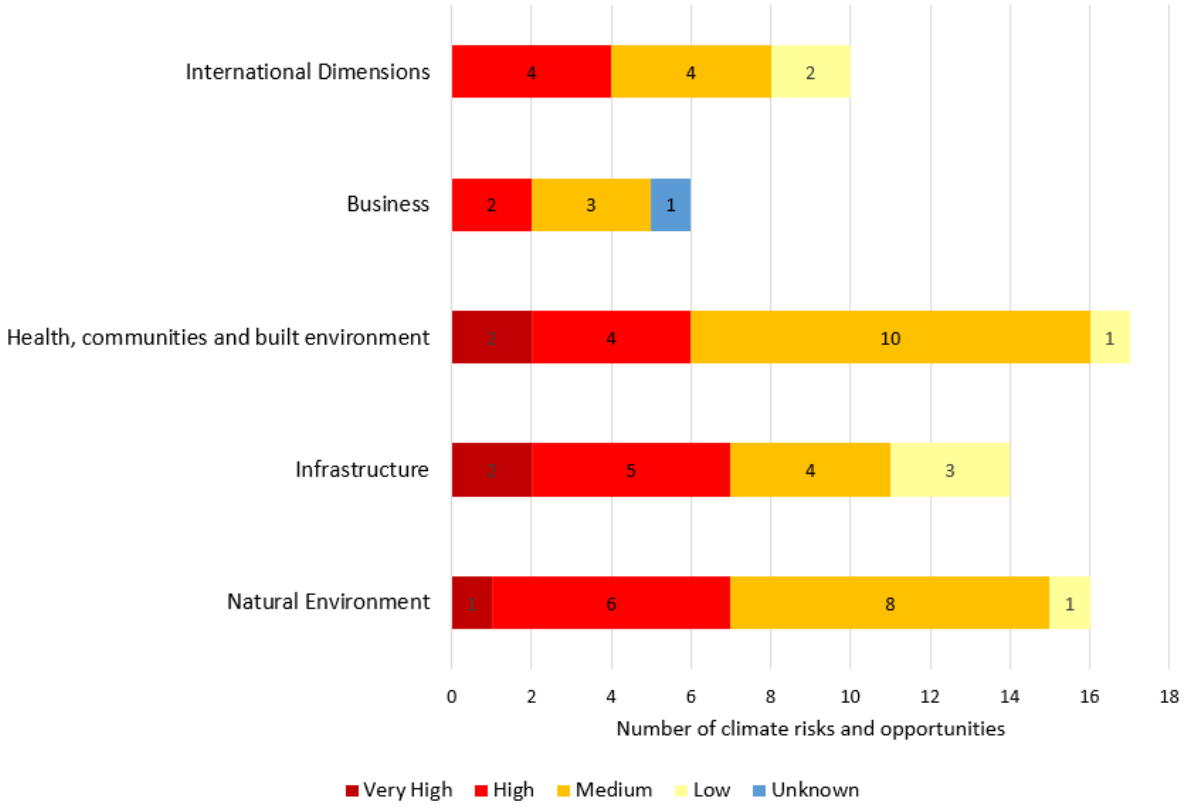


Figure 14. Spread of Greater Manchester climate change risks and opportunities by risk score and theme (2050s).

[40] Full information on these climate risks is available in Chapter 7 of the UK CCRA3.

High Magnitude Climate Risks and Opportunities for Greater Manchester

Climate risks and opportunities with a ‘High’ or ‘Very High’ risk magnitude score are shown in **Table 5** (present day) and **Table 6** (2050s) below. There are 14 identified High Magnitude climate risks for Greater Manchester in the present day, rising to 27 High Magnitude climate risks by the 2050s.

The full list of all 63 climate risks and opportunities in **Table 7** includes a description of each risk and a brief summary of the rationale for each risk magnitude score for Greater Manchester. The full evidence base that underpins this rationale for the risk scoring for Greater Manchester can be found in the Greater Manchester Climate Risks Evidence Report (link to report TBC).

Table 5. Present day High Magnitude risks and opportunities for Greater Manchester.

Theme	Risk or Opportunity	Risk Magnitude Score
Natural Environment	N1 Risks to terrestrial species and habitats from changing climatic conditions and extreme events, including temperature change, water scarcity, wildfire, flooding, wind, and altered hydrology (including water scarcity, flooding and saline intrusion)	High
	N5 Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions, including temperature change, water scarcity and wildfires	High
	N12 Risks to freshwater species and habitats from pests, pathogens and invasive species	High
Infrastructure	I1 Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures	High
	I2 Risks to infrastructure services from river, surface water and groundwater flooding	High
	I10 Risks to energy from high and low temperatures, high winds, lightning	High
Health, Communities and Built Environment	H1 Risks to health and wellbeing from high temperatures	High
	H3 Risks to people, communities and buildings from flooding and storms	High
	H7 Risks to health and wellbeing from changes in indoor and outdoor air quality	High
	H9 Risks to food safety and food security	High
Business	B1 Risks to business sites from flooding	High
International Dimensions	ID1 Risks to UK food availability, safety, and quality from climate change overseas	High (UK Score)
	ID9 Risk to UK public health from climate change overseas	High (UK Score)

Theme	Risk or Opportunity	Risk Magnitude Score
	ID10 Risk multiplication from the interactions and cascades of named risks across systems and geographies	High (UK Score)

Table 6. 2050s High Magnitude risks and opportunities for Greater Manchester

Theme	Risk	Risk Magnitude Score
Natural Environment	N1 Risks to terrestrial species and habitats from changing climatic conditions and extreme events, including temperature change, water scarcity, wildfire, flooding, wind, and altered hydrology (including water scarcity, flooding and saline intrusion)	High
	N2 Risks to terrestrial species and habitats from pests, pathogens and invasive species	High
	N4 Risk to soils from changing climatic conditions, including seasonal aridity and wetness.	High
	N5 Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions, including temperature change, water scarcity and wildfires	**Very High**
	N11 Risks to freshwater species and habitats from changing climatic conditions and extreme events, including higher water temperatures, flooding, water scarcity and phenological shifts.	High
	N12 Risks to freshwater species and habitats from pests, pathogens and invasive species	High
	N18 Risks and opportunities from climate change to landscape character	High

Theme	Risk	Risk Magnitude Score
Infrastructure	**I1 Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures**	**Very High**
	I2 Risks to infrastructure services from river, surface water and groundwater flooding	**Very High**
	I4 Risks to bridges and pipelines from flooding and erosion	High
	I9 Risks to energy generation from reduced water availability	High
	I10 Risks to energy from high and low temperatures, high winds, lightning	High
	I12Risks to transport from high and low temperatures, high winds, lightning	High
	I13 Risks to digital from high and low temperatures, high winds, lightning	High
Health, Communities and Built Environment	**H1 Risks to health and wellbeing from high temperatures**	**Very High**
	H3 Risks to people, communities and buildings from flooding and storms	**Very High**
	H6 Risks and opportunities from summer and winter household energy demand, (a) **Opportunity** - winter	High
	H9 Risks to food safety and food security	High
	H12 Risks to health and social care delivery from extreme weather	High
	H15 Social inequalities exacerbated as a result of climate change, with disadvantaged and vulnerable groups facing disproportionate climate impacts	High
Business	B1 Risks to business sites from flooding	High
	B6 Risks to business from disruption to supply chains and distribution networks	Unknown magnitude as difficult to quantify, but **High Priority** due

Theme	Risk	Risk Magnitude Score
		to potentially very large impacts
	B7 Opportunities for business from changes in demand for goods and services	High
International Dimensions	ID1 Risks to UK food availability, safety, and quality from climate change overseas	High (UK Score)
	ID6 Opportunities from climate change on international trade routes	High (UK Score)
	ID9 Risk to UK public health from climate change overseas	High (UK Score)
	ID10 Risk multiplication from the interactions and cascades of named risks across systems and geographies	High (UK Score)

All Climate Risks and Opportunities for Greater Manchester

The full list of 53 climate risks and opportunities re-assessed for Greater Manchester is shown in **Table 7** below (with the additional 10 International Dimensions risks, which have not been re-assessed for Greater Manchester, as previously explained, are listed underneath). Each risk or opportunity has been assessed for both the present day, and for the 2050s under a 2°C end-of-century global warming level (GWL).[41] They have been categorised using the same themes as the UK CCRA3, namely:

- Natural Environment and Assets
- Infrastructure
- Health, Communities and the Built Environment, and
- Business and Industry

A brief description of each risk, alongside a summary of the rationale for each Greater Manchester risk magnitude score, is provided in the table below.[42] The full evidence base that underpins this rationale for the risk scoring for Greater Manchester can be found in the Greater Manchester Climate Risks Evidence Report (link to report TBC).

[41] 2°C increase in global temperatures by the end of the 21st century, compared to pre-industrial levels.
[42] Summaries primarily based on the UK CCRA3 risk descriptions

Table 7. All present day and 2050s climate risks and opportunities for Greater Manchester.

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
N1 Risks to terrestrial species and habitats from changing climatic conditions and extreme events, including temperature change, water scarcity, wildfire, flooding, wind, and altered hydrology (including water scarcity, flooding and saline intrusion)	High	High	High	High	There is substantial evidence on the current and potential future effects of climate change and associated drivers on terrestrial biodiversity in the UK. This includes impacts on individual species and their distribution, as well as the composition and abundance of populations. Expected climate changes, including increasing temperatures, changes in rainfall and wildfire, can lead to losses or gains of species in a community or geographic area. Due to a lack of regional evidence, and to ensure the broad range of species and habitats are properly accounted for, the GM risk magnitude scores remain consistent with the England CCRA scores.
N2 Risks to terrestrial species and habitats from pests, pathogens and invasive species	Medium	Medium	High	High	New and emerging pests, diseases and Invasive Non-native Species (INNS) have been identified as important risks due to their negative effects on biodiversity. Due to a lack of regional evidence the GM risk magnitude scores remain consistent with the England CCRA scores.
N3 Opportunities from new species colonisations in terrestrial habitats	Medium	Medium	Medium	Medium	As species respond to climate change by moving and/or expanding their ranges northwards, they could colonise new areas including the UK and GM. Due to a lack of regional evidence the GM risk magnitude scores remain consistent with the England CCRA scores.
N4 Risk to soils from changing climatic conditions, including seasonal aridity and wetness.	Medium	Medium	High	High	Soil health is crucial for the terrestrial natural environment. There is increasing evidence of the negative impacts of climate change on soil resources, often in combination with other factors (notably land use). Due to a lack of regional evidence relating to soil condition and projected changes in soil condition as a result of climate change, the GM risk magnitude scores remains consistent with the England CCRA risk score.
N5 Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions,	Medium	High	High	Very High	*This risk for GM relates primarily to risks for natural carbon stores and associated GHG emissions.* The natural environment – particularly soils and vegetation – store large amounts of carbon. As the climate changes, these carbon stores will come under increasing pressure from extreme weather which may threaten their ability

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
including temperature change, water scarcity and wildfires					to store existing carbon and lock away more, and wildfires which can damage huge swathes of peatland. GM has important natural carbon stores in its peat but much is degraded / in poor condition; this combined with the projected increase in conditions conducive to peatland degradation due to climate change, and increased wildfire risk in GM mean the risk magnitude scores for GM are deemed to be higher than the England CCRA score, at 'Very high'.
N6a Risks to agricultural productivity from extreme events and changing climatic conditions (including temperature change, water scarcity, wildfire, flooding, coastal erosion, wind and saline intrusion).	Medium	Medium	High	Medium	Weather and climate variations will affect agricultural productivity from changing patterns of heat and cold, wetness and drought, presenting both opportunities and risks. Due to the small size of this sector in GM (in terms of both employment count and Gross Value Added (GVA)), the risk magnitude score for GM is deemed to be lower than the England CCRA, at 'Medium'.
N6b Opportunities for agricultural productivity from extreme events and changing climatic conditions (including temperature change, water scarcity, wildfire, flooding, coastal erosion, wind and saline intrusion).	Medium	Medium	High	Medium	Weather and climate variations will affect agricultural productivity from changing patterns of heat and cold, wetness and drought, presenting both opportunities and risks. Due to the small size of this sector in GM (in terms of both employment count and GVA), the 2050s risk magnitude score for GM is deemed to be lower than the England CCRA, at 'Medium'.
N6c Risks to forestry productivity from extreme events and changing climatic conditions (including temperature change, water scarcity, wildfire, flooding, coastal erosion, wind and saline intrusion).	Medium	Medium	High	Medium	Weather and climate variations will affect forestry productivity from changing patterns of heat and cold, wetness and drought, presenting both opportunities and risks. Due to the small size of this sector in GM (in terms of both employment count and GVA), the risk magnitude score for GM is deemed to be lower than the England CCRA, at 'Medium'.
N6d Opportunities for forestry productivity from extreme events and changing climatic conditions (including temperature change, water scarcity, wildfire, flooding, coastal erosion, wind and saline intrusion).	Medium	Medium	High	Medium	Weather and climate variations will affect forestry productivity from changing patterns of heat and cold, wetness and drought, presenting both opportunities and risks. Due to the small size of this sector in GM (in terms of both employment count and GVA), the risk magnitude score for GM is deemed to be lower than the England CCRA, at 'Medium'.
N7 Risks to agriculture from pests, pathogens and invasive species	Medium	Medium	High	Medium	Pests, pathogens and invasive non-native species present significant risks to agricultural productivity, with impacts on livelihoods and businesses. Large-scale

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					outbreaks or invasions may also have consequences for food security. Due to the small size of this sector in GM relative to the England average (detailed in risk N6a), the risk magnitude score for GM is deemed to be lower than England CCRA, at 'Medium'.
N8 Risks to forestry from pests, pathogens and invasive species	Medium	Medium	High	Medium	Pests, pathogens and invasive non-native species present serious risks to forest productivity, with consequences for livelihoods and businesses, and for the multiple ecosystem services that forests provide. Due to the small size of this sector in GM relative to the England average (detailed in risk N6b), the risk magnitude score for GM is deemed to be lower than England CCRA, at 'Medium'.
N9 Opportunities for agricultural and forestry productivity from new/alternative species becoming suitable.	Medium	Medium	High	Medium	Future climate change, especially warming, will increase climate suitability for new crops. Due to the small size of these sectors in GM relative to the England average (detailed in risk N6a and b), the risk magnitude score for GM is deemed to be lower than England CCRA, at 'Medium'.
N11 Risks to freshwater species and habitats from changing climatic conditions and extreme events, including higher water temperatures, flooding, water scarcity and phenological shifts.	Medium	Medium	Medium	High	Freshwater habitats and species are particularly vulnerable to reduced water availability and higher water temperatures due to climate change, as well as impacts relating to flood events. GM has significant interacting water management risk factors, including the capacity of its sewer and water treatment infrastructure, which negatively impacts upon water quality, freshwater species and habitats. GM also has poor quality waterways currently. The GM 2050s risk is therefore deemed to be 'High', above the England CCRA risk score of 'Medium'.
N12 Risks to freshwater species and habitats from pests, pathogens and invasive species	High	High	High	High	New and emerging pests, pathogens and invasive species have been identified as important risks due to their negative impact on biodiversity. Negative impacts on native freshwater species from an increased number of pests, pathogens and invasive non-native species (INNS) on native UK freshwater species could increase, with warmer, wetter winters a significant driver. There is a lack of further regional evidence and so the GM risk magnitude scores are deemed to be consistent with the England CCRA.

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
N13 Opportunities to freshwater species and habitats from new species colonisations	Low	Low	Low	Low	The arrival of new species in the UK as the climate changes has the potential to enhance species richness and contribute to community adaptation to climate change. Climate change may support changes to aquatic and riparian species composition (e.g. fish and invertebrates, trees, macrophytes), presenting as both a risk and an opportunity depending on the species. There is a lack of further regional evidence and so the GM risk magnitude scores are deemed to be consistent with the England CCRA.
N18 Risks and opportunities from climate change to landscape character	Medium	Medium	High High	High High	This risk includes risks and opportunities relating to landscapes, landscape character and the historic environment and considers both prevention of landscape character changes and planning for inevitable projected changes. There is a lack of further regional evidence and so the GM risk magnitude scores are deemed to be consistent with the England CCRA.
I1 Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures	High	High	High	Very High	Infrastructure operates as a 'system of systems'. Therefore, vulnerabilities on one part of a network can lead to problems in other networks, with impacts felt far beyond the infrastructure sector. The spatial distribution of risk from cascading failures between infrastructure systems has been mapped, showing hotspot areas of infrastructure criticality in the UK, with Greater Manchester found to be a key hotspot area. GM has critical infrastructure assets on moorlands, which face increasing wildfire risks. GM is also increasing the electrification and digitisation of key, interconnected sectors and assets, including transport systems, which will increase vulnerability to cascading failures (e.g. (Metrolink, further roll-out of electric buses). GM 2050s risk is therefore deemed to be greater than the England CCRA3 score, at Very High
I2 Risks to infrastructure services from river, surface water and groundwater flooding	High	High	High	Very High	River and surface flooding is a perennial risk to UK infrastructure. Risks to energy infrastructure from flooding include the flooding of facilities, damage to power lines and disruption to power stations. Major flood events can lead to power outages, which can have knock-on impacts across different sectors including transport, water and digital/telecoms. Flooding can also directly damage

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					/ impact upon various assets. GM faces significant flood risk due to several interacting factors. Peak rainfall intensity and peak river flows are projected to increase in GM catchment areas. GM 2050s risk is therefore deemed to be greater than the England CCRA3 score, at Very High.
I3 Risks to infrastructure services from coastal flooding and erosion	Medium	Medium	Medium	Low	Sea levels are currently rising and the rate of rise is accelerating, including around the UK. Coastal flood and erosion risk to infrastructure services, including those associated with the energy, transport, water, telecoms and ICT sectors, will therefore increase. There may be low indirect impacts to GM as a result of this coastal risk. However, due to GM being in-land, the overall impacts from this risk are judged to be low.
I4 Risks to bridges and pipelines from flooding and erosion	Medium	Medium	Medium	High	Flooding, erosion or scour (the eroding of soil around foundations, including bridges) due to increased rainfall can lead to travel disruption, significant repair costs and the potential isolation of remote communities. EA guidance states that for strategic flood risk assessments, essential transport infrastructure must use the 'higher' range of values associated with EA peak river flow projections. For GM catchment areas, the 'higher' peak river flow values are above the standard national EA peak river flow allowance value. Due to the 'Higher' scenario peak river flow allowance values for GM's catchment areas being above the standard EA national allowance figure, the GM 2050s risk magnitude score is deemed to be higher than the England CCRA score, at 'High'.
I5 Risks to transport networks from slope and embankment failure	Medium	Medium	Medium	Medium	Slopes and embankments support transport infrastructure. Deterioration and failure of these assets, which are often associated with heavy rainfall and flood events, have significant negative impacts on transport networks through damage, travel delays and accidents. Whilst GM faces flood risks and has upland areas in its boundary and in neighbouring areas, the number of recorded landslides (and thus an indication of areas prone to landslips) is relatively low. Within GM, Bury, Oldham, Rochdale and Tameside have the greatest exposure of transport networks

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					in proximity of past landslide events. The GM risk scores therefore remains consistent with the England CCRA.
I6 Risks to hydroelectric generation from low or high river flows (risk)	Low	Low	Medium	Medium	Hydroelectric generation is vulnerable to both low river flows and extremely high river flows, which are dependent on rainfall amounts. Low flows reduce power output. Very high flows can damage generation equipment and the associated infrastructure. Hydroelectric power currently represents a small proportion of UK energy capacity, but may grow in the future. There is a lack of regional evidence available on assessing the future hydroelectric energy potential under different climate change scenarios and the current size of energy generation from hydro in GM is relatively small – therefore the GM risk scores remains consistent with the England CCRA.
I6 Risks to hydroelectric generation from low or high river flows (**opportunity**)	Low	Low	Medium	Medium	Hydroelectric generation is vulnerable to both low river flows and extremely high river flows, which are dependent on rainfall amounts. Moderate high flows have the potential to improve the output. There is a lack of regional evidence available on assessing the future hydroelectric energy potential under different climate change scenarios and the current size of energy generation from hydro in GM is relatively small – therefore the GM risk scores remains consistent with the England CCRA.
I7 Risks to subterranean and surface infrastructure from subsidence	Low	Low	Medium	Low	Infrastructure assets can be damaged due to subsidence. Most subsidence is a result of shrinkage and swelling of high plasticity clays. The North-West of England does not have high plasticity clays and so British Geological Society have classed this area as being 'highly unlikely' to experience shrink-swell subsidence. Therefore, the risk magnitude scores for this risk in GM is classed as Low.
I8 Risks to public water supplies from reduced water availability	Medium	Medium	High	Medium	The UK faces an increased demand for water in a changing climate as well as reduced supply during dry spells. However, the North-West England water resource zone (of which GM sits in) is projected to see a small supply-demand balance surplus by the 2050s (under 2°C GWL, central population growth by mid-

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					century). Therefore the risk magnitude scores for this risk in GM are classed as Medium.
I9 Risks to energy generation from reduced water availability	Low	Low	Medium	High	Thermal power generators that rely on freshwater for cooling are the main type of energy generation vulnerable to a reduced water supply as it could affect their ability to use water as a coolant. Whilst conventional thermal energy generation will reduce to meet net zero commitments, Trafford is working to develop a green hydrogen production hub, with significant associated water requirements. This therefore has the potential to increase GM energy systems' vulnerability to reduced water availability over the coming decades. The GM 2050s risk magnitude score is therefore deemed to be High.
I10 Risks to energy from high and low temperatures, high winds, lightning	High	High	High	High	The risks to energy infrastructure from extreme weather are already an issue in the present day. However, high temperatures in particular are projected to become more frequent and intense. High temperatures can affect the energy sector through several different mechanisms, including line sag, faults on the electricity network, reduced electricity generation, and others. Heatwaves and high temperatures are projected to increase across GM and England. The GM risk magnitude score is deemed to remain consistent with the England CCRA.
I11 Risks to offshore infrastructure from storms and high waves	Low	Low	Medium	Low	Offshore infrastructure includes equipment used by the oil and gas industry, wind, tidal and wave energy, and gas pipelines and power cables on or under the seabed. Vulnerabilities to these assets can occur from storms and high waves. There may be low indirect impacts to GM as a result of this coastal risk, for example if the infrastructure damaged was of wider regional importance or had implications for energy security in parts of GM. The 2050s GM risk magnitude score is deemed to be lower than the England CCRA, at 'Low'.
I12Risks to transport from high and low temperatures, high winds, lightning	Medium	Medium	High	High	Impacts from extreme weather on transport include heat-related buckling of rail lines, sagging of overhead cables, failure of signals, and the prevention of maintenance from being performed; road melt; wind, and lightning. Transport disruption from icy conditions is projected to decrease, but disruption due to high

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					temperatures is projected to increase across GM. GM has significant electrification of transport infrastructure, with further roll-out of bus electrification also underway; these transport assets are more vulnerable to potential disruption from power outages due to extreme weather. The GM risk magnitude scores are deemed consistent with the England CCRA.
I13 Risks to digital from high and low temperatures, high winds, lightning	Low	Low	Medium	High	Increasingly, infrastructure such as water, power and transport are controlled over the telecommunications networks. Failure of telecommunications can lead to reduced capacity in a wide range of other essential services. Climate related-risks to digital include: severe weather damaging assets; over-heating of assets including data centres; additional demands for cooling on energy networks increasing risk of brown outs. GM has the second highest number of data centres in UK, behind only London. Due to the significant potential impacts and the large digital sector in GM, the 2050s risk magnitude score for GM is deemed to be greater than the England CCRA score, at 'High'.
H1 Risks to health and wellbeing from high temperatures	High	High	High	Very High	High temperatures will lead to increased numbers of people becoming ill or dying across the UK. Climate change is already making extreme heat events more likely, and by the 2050s, the frequency of Met Office heatwave events are projected to double across GM, and maximum summer temperatures are projected to increase by between around 1.6°C. Risks to health from high temperatures are increased for people with pre-existing health conditions, older adults and the very young. GM has high levels of deprivation and poorer health outcomes than the national average, and so GM's population is more vulnerable to this risk. GM also has an ageing population, with Trafford, Wigan and Stockport projected to see greater increases in over 55s over the coming decades. GM has high employment levels in at-risk sectors with workers in outdoor and manual labour, including the Construction, Agriculture and Manufacturing & Industry sectors; GM also has high numbers of homeless people who are highly vulnerable to this risk. Digital exclusion can mean that people are less able to receive upcoming weather

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					warnings, heat alerts, and advice on staying safe in the heat: disabled people, and people aged over 75, are more likely to be digitally excluded in some way in GM. Some older residents and people with certain health conditions may be more likely to spend more time in their home, which can increase their exposure to high temperatures, especially for those who live in poor quality housing. Due to the combination of these factors, the GM 2050s risk magnitude score is deemed to be greater than the England CCRA score, at 'Very High'.
H2 Opportunities for health and wellbeing from higher temperatures (warmer summers and winters)	Low	Low	Low	Low	Possible beneficial outcomes from warmer summers may include an increase in use of outdoor space for both physical activity, leisure activities, cultural activities, and domestic tourism, as well as significant mental health benefits. Possible beneficial outcomes from warmer winters include a partial reduction in the burden of cold-related mortality as winters become warmer on average. The GM risk magnitude scores are deemed consistent with the England CCRA.
H3 Risks to people, communities and buildings from flooding and storms	High	High	High	Very High	The risk of flooding to people, communities and buildings is one of the most severe climate hazards for the population, both now and in the future. Both fluvial and surface water flooding are significant present-day challenges for GM from a water management perspective, and this risk is projected to increase as a result of climate change, with both peak rainfall intensity and peak river flows projected to increase. Currently, 3.9% of GM residential properties are at some risk of fluvial flooding, with the majority (2.5%) at Low risk (less than the ~9% of English households at some risk of fluvial flooding). Salford and Manchester districts have significantly higher numbers of households at fluvial flood risk. 8.5% of GM residential properties are at some risk of surface water flooding, slightly less than the 11% of English residential properties. Oldham, Rochdale, Tameside and Bury have the highest proportion of residential properties at surface water flood risk. GM also has a high proportion of combined sewers with implications for resilience constraints regarding Combined Sewer Overflows and sewer flooding risk. More intense hourly rainfall and increased autumn and winter rainfall will increase both

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					fluvial and surface water flood risk in GM, and NW England is projected to see one of the highest increases in winter storm frequency. Analysis using spatial modelling commissioned by GMCA has found the 25 LSOAs across GM with the highest number of households in a present-day surface water flood risk hotspot area; Salford CC has 10 of these 25 LSOAs with the highest number of households in risk hotspot areas, followed by Manchester City Council with 5 LSOAs. GM has a high proportion of LSOAs at high risk of **both** flooding **and** high levels of social vulnerability, which is projected to increase by 2050s. Older people can also experience greater impacts from flood events. Floods can restrict local medical services, including access to medicines and access to social care. Some older people can be highly vulnerable during an event, e.g. power cuts that impact medical equipment, or mobility scooters / stairlifts. The GM 2050s risk magnitude score is deemed to be Very High.
H4 Risks to people, communities and buildings from sea level rise	Low	Low	Medium	Low	This risk focuses on coastal change caused by erosion, coastal landslip, permanent inundation or coastal accretion that is of such severity that the long-term sustainability and viability of coastal communities is threatened. Parts of the south and east coasts of England and the west coast of Wales already face risks to their viability because of coastal erosion. Indirect impacts felt in GM may include increased internal migration from coastal communities to GM. Overall, the risk for GM by the 2050s is deemed to be Low.
H5 Risks to building fabric from moisture, wind and driving rain	Medium	Medium	Medium	Medium	Climate hazards that can damage building fabric include subsidence caused by drought and dry soil, excessive moisture due to flooding and heavy rain, and structural damage due to high winds. These can cause harm to occupant health and wellbeing and create significant repair costs for homeowners. Some research projects that North-West England will see one of the highest increases in winter storm frequency, (+15% under a 3°C global warming level), but we do not know whether these storms will be more severe than currently experienced. Wind-driven rain may increase as storm frequency potentially increases. There is a lack

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					of further regional evidence; therefore the GM risk magnitude scores remain consistent with the England CCRA.
H6 Risks and opportunities from summer and winter household energy demand (a) **Opportunity** - winter	Low	Low	High	High	Household heating demand dominates energy use in housing at present. Future heating demand will be reduced by climate change due to warmer winters. Heating Degree Days are projected to decrease by 14% in GM by the 2050s compared to the baseline period. The economic benefits of these reductions in energy demand are estimated to be significant and will bring disproportionally larger benefits for households in fuel poverty, of which GM has a significant proportion. The opportunity magnitude score is assessed as High for GM by 2050s.
H6 Risks and opportunities from summer and winter household energy demand (b) Risk - summer	Medium	Medium	High	Medium	This risk relates to the potential increased economic cost of cooling to households, as average and maximum summer temperatures continue to increase and heatwaves become more frequent and intense. Reduced heating demand may reduce winter fuel poverty, but 'summer fuel poverty,' where householders may not be able to afford cooling, could rise. However, changes in cooling demand with climate change are mostly projected for the South East of England, and passive cooling should, generally speaking, be sufficient to maintain comfort levels in all areas of the UK outside London and the South-East (although extreme heat events will lead to low comfort levels and potential health impacts (risk H1)). Therefore, the GM 2050s risk magnitude score is deemed to be Medium.
H7 Risks to health and wellbeing from changes in indoor and outdoor air quality	High	High	Medium	Medium	Certain weather patterns associated with climate change may exacerbate poor air quality. Climate change is also projected to increase levels of ozone, particularly in summer. As wildfire risk increases, so does the associated health impacts from the resulting significant increase in air pollution. The emission of pollutants is likely to outweigh the impacts of physical climate change: Air pollution emissions from combustion are falling rapidly and are expected to decline significantly under most Net Zero pathways. The GM risk magnitude scores remain consistent with the England CCRA.

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
H8 Risks to health from vector-borne diseases	Medium	Medium	Medium	Medium	Some diseases transmitted by insects and ticks (vectors) are likely to change in prevalence in the future due to warmer temperatures and milder winters, contributing to a changing of the distribution of the vector in the UK, and therefore of the associated health impacts. Due to a lack of further regional evidence, the GM risk magnitude score remains consistent with the England CCRA.
H9 Risks to food safety and food security	High	High	High	High	Increases in extreme weather patterns, variations in rainfall and changing annual temperatures will impact the occurrence and persistence of bacteria, viruses, parasites, harmful algae, fungi and their vectors in crops and livestock produced in the UK (and thus food safety). Climate change may also affect food security due to disruptions to the supply chain, arising from weather events and climate hazards both in the UK and abroad. There is a lack of further regional evidence and so the GM risk magnitude scores remains consistent with the England CCRA.
H10 Risks to health from water quality and household water supply, (a) water quality	Medium	Medium	Medium	Medium	Climate change may increase the risk of contamination of drinking water through increased runoff and more frequent flooding events that may overwhelm current water treatment approaches, potentially increasing virus and pathogen loads. Treatment failures have been reported in all UK countries associated with extreme weather events, particularly heavy rainfall. Private water supplies are most vulnerable to current and future climate hazards that affect water quality (outbreaks/contamination) and are particularly important for more isolated communities. The majority of GM is on mains water. Risks from wildfires include reservoirs suffering from significant contamination if ash and organics enter them from wildfires. The GM risk magnitude scores are deemed to be consistent with the England CCRA; despite our predominate use of mains water, the other risk factors such as flooding and wildfires are of significant importance in GM.
H10 Risks to health from water quality and household water supply, (b) water quantity	Medium	Medium	High	Medium	Reduced summer precipitation resulting from climate change will increase the likelihood of periods of water scarcity which, together with demand increases from economic and population growth, may lead to interruptions of household water supplies. This would have health, social and economic impacts, particularly for

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					vulnerable households. Private water supplies are most vulnerable to current and future climate hazards that affect water quantity (interruption of supply) and are particularly important for more isolated communities. As outlined in risk I8, North-West England water resource zone is projected to see a small supply-demand balance surplus. Given the supply-surplus forecast for the North-West, and the fact GM is predominately on mains water, the risk magnitude for GM is deemed to be medium by 2050s (lower than the risk magnitude for England).
H11 Risks to cultural heritage	Medium	Medium	Medium	Medium	This risk describes effects of climate change on cultural heritage, including moveable heritage (museum collections and archives), archaeological resources, buildings and structures, cultural landscapes and associated communities, and intangible heritage (folklore, traditions, language, knowledge and practices). GM has strong industrial and cultural heritage. The GM risk magnitude scores are consistent with the England CCRA.
H12 Risks to health and social care delivery from extreme weather	Medium	Medium	Medium	High	Climate change will impact upon health and social care services through the effects of floods, heatwaves and other extreme weather on hospitals and other health and care infrastructure. It will also lead to an increase in demand for services, as the negative effects of extreme weather impacts upon people's health and wellbeing more frequently due to climate change. This risk will likely further exacerbate existing inequalities, with people living with ill-health and some older people likely to be disproportionally impacted. Due to the high levels of poor health in GM (see risk H1), combined with high concentrations of health and social support sites at risk of flooding, and around 15% of the total healthcare facilities in north-west England projected to be in areas of high or acute levels of heat disadvantage, the GM risk magnitude score for 2050s has been assessed as High.
H13a Risk to delivery of education from extreme weather	Medium	Medium	Medium	Medium	Climate change is likely to cause increased disruption to education services as extreme events like flooding and extreme heat become more common. These sectors, which include schools, universities, nurseries and other early years settings, have seen disruption in recent years from flooding and heavy rainfall.

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					There is a lack of further regional evidence and so the GM risk magnitude scores are consistent with the England CCRA
H13b Risk to delivery of prison services from extreme weather	Medium	Medium	Medium	Medium	These sectors, which include prisons, courts and secure units, have seen disruption in recent years from flooding and heavy rainfall. Overheating is a key risk to prisons as high temperatures impact the welfare of inmates, staff and visitors. UK prisons are vulnerable to high temperatures due to their high levels of insulation and specific building materials. There is a lack of further regional evidence and so the GM risk magnitude scores are consistent with the England CCRA
H14 Risks to people, communities and built environment from wildfire *(new GM risk)*		Low		Medium	Wildfire can damage property and infrastructure assets, result in serious localised damage or loss of habitats and species, which may show varying degrees of recovery in the years afterwards, and can also cause serious localised air pollution, leading to implications for human health. GM and surrounding areas have already experienced significant wildfire events with widespread impacts. Conditions conducive to wildfires are projected to increase in GM by 2050s. GM also has significant populated areas at the 'urban-rural interface', (i.e. populated areas bordering moorland, grass scrubland, rural land) where rural wildfires can cause damage to urban properties and communities. It is therefore deemed important to add this as a risk in its own right for GM, with a 2050s risk magnitude score of Medium.
H15 Social inequalities exacerbated as a result of climate change, with disadvantaged and vulnerable groups facing disproportionate climate impacts *(new GM risk)*		Medium		High	People and communities are not all affected equally by the same climate-related event, such as heatwaves or floods. Some places are more likely to be exposed to floods or heatwaves, and some places have populations which are more socially vulnerable to such hazards. Disadvantaged groups can experience greater impacts from climate change, for example if they live in poor quality/overcrowding housing, which would exacerbate impacts from over-heating. GM has high levels of deprivation, closely linked to high levels of poor health, which (among other factors) increase the vulnerability of those populations to climate hazards. Other

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
					vulnerable populations It is therefore deemed important to add this as a risk in its own right for GM, with a 2050s risk magnitude score of High.
B1 Risks to business sites from flooding	High	High	High	High	Current and future risks to business sites and functions from flooding are significant. There are 7,800 non-residential properties at risk of fluvial flooding in GM, with Stockport, Salford and Manchester seeing the highest numbers. Bury (1.85%), Rochdale (1%) and Wigan (0.7%) have the highest percentage of non-residential properties at High risk of fluvial flooding in GM, compared to the England average of 0.63% of non-residential properties at High risk. 18,000 non-residential properties are at risk of surface water flooding in GM, with 4,000 at High or Medium Risk. 4.5% of England's non-residential properties at risk of surface water flooding are in GM. GM faces significant surface water and sewer flood risk due to several interacting factors. The manufacturing sector is expected to face high losses due to location-specific risks, particularly flooding, with relocation being a less viable option – a major sector of employment in GM, and the third largest sector by GVA. The GM risk magnitude score is therefore High.
B2 Risks to business locations and infrastructure from coastal change from erosion, flooding and extreme weather events	Medium	Low	High	Medium	A considerable amount of industrial and commercial activity and infrastructure exists along the coast for most of the UK. Damages to business locations and infrastructure can arise directly from coastal change caused by erosion, coastal landslip, permanent inundation or coastal accretion that is of such severity that the long-term sustainability and viability of these sites is threatened. Whilst GM is in-land, indirect impacts may include knock-on impacts from port disruption felt in the Manchester Ship Canal, impacting freight and logistics movements – with associated impacts on supply chains, which could cause economic risks in GM (more in risk B6). The GM risk magnitude score for the 2050s is deemed to be lower than the England CCRA, at Medium.

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
B3 Risks to businesses from water scarcity	Low	Low	Medium	Medium	Water is used by businesses for cooling and heating, washing products, dissolving chemicals, suppressing dust and also as a direct input to products; and by employees for drinking and washing. As outlined in risk I8, by 2050s North-West England water resource zone is projected to see a small supply-demand balance surplus. Water-intense manufacturing sub-sectors such as chemicals and chemical products, basic metals, paper and paper products, beverages and food products are more vulnerable to water scarcity. As outlined in risk B1, the manufacturing sector is an important sector in GM. Energy generation may take precedent for water abstraction over business need in times of drought; as outlined in risk I9, as the Trafford Green Hydrogen hub increases capacity, its water requirements will be very high and thus this may have knock-on impacts on businesses. Although there is a projected 2050s water supply-surplus forecast for the North-West, the projected large water requirements of Trafford green hydrogen hub (risk I9), the relatively large manufacturing sector in several GM boroughs, and a significant employment count dependent on water-intense manufacturing sub-sectors, means the GM risk magnitude score is deemed to be consistent with the England average, at Medium for the 2050s.
B4 Risks to finance, investment and insurance including access to capital for businesses	Medium	Medium	Medium	Medium	Risks to the UK's financial stability from the climate are currently moderate but expected to increase due to the scale of physical damage affecting assets, products, and services in the UK and abroad. Flooding is the most significant domestic risk for the financial system with financial impacts on insurance, mortgages and investment. Increasing flood risks may lead to higher premiums or a lack of insurance cover, which in turn can hinder access to finance, as Asset Finance for example requires goods to be insured against all risks. More broadly, risks to businesses (in particular SMEs) also include not being able to access finance in general, as financial institutions are increasingly incorporating climate risk assessments and ESG criteria into their lending criteria. The GM risk magnitude scores are deemed to be consistent with the England CCRA.

Risk or Opportunity	England: Present Day Risk Score	GM Present Day Risk Score	England: 2050s, 2°C GWL, Risk Score	GM 2050s, 2°C GWL, Risk Score	Risk Description and Greater Manchester (GM) Risk Score Summary
B5 Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments	Low	Low	Medium	Medium	High temperatures can have negative impacts on employees' health and wellbeing, productivity, and ability to commute to work. Flooding can cause significant travel/commuting disruption. Hot weather and flood events are both projected to increase in frequency and intensity. The GM risk magnitude score is deemed to be consistent with the England CCRA.
B6 Risks to business from disruption to supply chains and distribution networks	Medium	Medium	Unknown	Unknown, but high priority	Extreme events are already a significant cause of supply chain disruption across all sectors. Climate change is likely to contribute to an increase in exposure to supply chain disruption by driving an increasing frequency of adverse weather events and evolving climate hazards both in the UK and overseas. This risk is particularly difficult to assess and quantify as it requires business-specific deep-dive risk assessments to fully understand. However, the potential impacts arising from this risk to supply-chains and wider disruption are significant, and therefore this risk is classed as having an Unknown risk magnitude, but is of a high priority.
B7 Opportunities for business from changes in demand for goods and services	Low	Low	Medium	High	Climate change will affect the production costs, comparative advantage, and demand for certain goods and services in the UK. There are some business opportunities arising from the impacts of climate change, including through shifts in demand for certain goods and services. GM is well-placed to take advantage of opportunities from changes in demand for goods and services, with strong advanced manufacturing, digital and knowledge sectors. The GM 2050s risk magnitude score is deemed to be higher than the England CCRA score, at High.

Risks identified by the UK CCRA3 under the theme of International Dimensions are listed below. These have not been included in **Table 7** as they have not been re-assessed for Greater Manchester, as these are national-level risks and are unlikely to be influenced greatly by local/regional context and activity. The International Dimensions risks have therefore been included in the GM CCRA using the UK-level CCRA risk magnitude scores.

'International Dimensions' Risk or Opportunity	**Present Day Risk Score (UK Score)**	**2050s, 2°C GWL, Risk Score (UK Score)**
ID1 Risks to UK food availability, safety, and quality from climate change overseas	High	High
ID2 Opportunities for UK food availability and exports from climate impacts overseas	Low	Low
ID3 Risks and opportunities to the UK from climate-related international human mobility	Low	Low
ID4 Risks to the UK from international violent conflict resulting from climate change on the UK	Low	Medium
ID5 Risks to international law and governance from climate change overseas that will impact the UK	Low	Medium
ID6 Opportunities from climate change (including arctic ice melt) on international trade routes	Low	High
ID7 Risks from climate change on international trade routes	Medium	Medium
ID8 Risk to the UK finance sector from climate change overseas	Low	Medium
ID9 Risk to UK public health from climate change overseas	High	High
ID10 Risk multiplication from the interactions and cascades of named risks across systems and geographies	High	High

Stakeholders agreed to include 2 additional risks that were not in the UK CCRA3, which have been added to the GM CCRA and highlighted in the table above. These are: ‘Risk H14: Risks to people, communities and buildings from wildfire’, and ‘Risk H15: Social inequalities exacerbated as a result of climate change, with disadvantaged and vulnerable groups facing disproportionate climate impacts’.

Stakeholders also agreed for ‘wildfires’ to be added to Risk N5 and Risk H3. Risk N5 now states: ‘N5 Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions, including temperature change, water scarcity and wildfires.’ Risk H3 now states: “H3 Risks to people, communities and buildings from flooding and storms.”

Stakeholders also agreed that ‘Risk H13 Risk to delivery of education and prison services from extreme weather’ be split out into ‘Risks to delivery of education from extreme weather’, and ‘Risks to delivery of prison services from extreme weather’ as these risks will be managed by very different groups and will require different approaches to manage these risks.

5. Next Steps

This report provides the evidence base for understanding present day and future climate risks and opportunities in Greater Manchester. It will inform the development of a future Climate Change Adaptation Strategy and Action Plan for Greater Manchester. This Strategy and Action Plan will provide the strategic direction to realise our vision of a well-adapted, resilient and climate-ready Greater Manchester, outline appraised adaptation actions, and seek to integrate adaptation into relevant projects, policies and plans.

Appendix A: Methodology

The methodology taken to produce this GM CCRA is outlined below. This broadly follows the climate adaptation framework developed by Adaptation Scotland and the EU Urban Adaptation Support Tool, which are both seen as good practice amongst Local Government adaptation plan development.[43] [44]

The Adaptation Scotland framework outlines 5 stages that make up the adaptation process, shown in **Figure 1A** below. This GM CCRA forms a key part of Stage 2: 'Understand the impacts of climate change', and will be a key input used to inform Stage 3: 'Identify and prioritise actions'.

Figure 1A. Adaptation Framework.

- **Step one: Getting Started**
  - This involved raising awareness of the need for climate adaptation within the GMCA, including amongst key decision makers, to enable the climate adaptation work programme to be signed off.
  - It also involved discussions with key directorates and service areas within the GMCA at an early stage, to demonstrate how climate change may impact their work areas.

[43] Adaptation Scotland (2020) Public Sector: The Framework, link
[44] European Climate Adaptation Platform Climate-ADAPT (2024) Urban Adaptation Support Tool, link

    - This stage will be a continuous element of work, seeking to raise awareness of the climate adaptation programme amongst all relevant stakeholders, both internally and externally.
- **Step two: Understanding the impacts of climate change**
    - Research was undertaken to understand how past weather-related events have impacted Greater Manchester and the North-West, to better understand how we may be impacted by such events in the future as they become more frequent and/or intense. It gives an indication as to the financial, societal, and environmental impacts that may be experienced.
        - Output: Summary of past weather-related events in Greater Manchester and their associated impacts (Appendix B: Summary of past weather-related events in Greater Manchester).
    - Greater Manchester's baseline climate was assessed, and how this has changed over the 20th century
        - Output: Baseline climate data and climate trends data produced for Greater Manchester (Chapter 2: How has our climate changed already?
    - The evidence base for projected climate change in Greater Manchester and the associated medium and long-term impacts was assessed, primarily using Met Office UKCP18 data, alongside spatial data from GMCA-commissioned modelling, Climate Just and others
        - Outputs: Climate Projections spatial layers; Summary of climate projections for GM (Chapter 3: How will our climate change in the future?
- **Step three: Assessment of climate risks for Greater Manchester**
    - Using the UK CCRA3 as a key resource, climate risks and opportunities relevant for GM were identified, and presented at a workshop with stakeholders from across a range of areas, all of which will be impacted by climate change, and/or will have some responsibility for managing climate impacts and risks within their sectors and organisations going forward.
    - These workshops were comprised of attendees from the following:
        - Greater Manchester Local Authorities and the Greater Manchester Combined Authority, including from
            - Public Health
            - Planning
            - Housing
            - Emergency Response
            - Civil Contingencies
            - Education
            - Digital
            - Highways
            - Investment

        - Natural Environment
        - Business
        - Ageing
        - Neighbourhood and Community
        - Sustainability and Environment
    - Greater Manchester NHS, including
        - Emergency Preparedness, Resilience and Response
        - Public Health
        - Net Zero and Sustainability
    - Transport for Greater Manchester, including
        - Resilience
        - Carbon
    - Greater Manchester Resilience Unit
    - Natural England
    - Environment Agency
    - British Red Cross
    - Greater Manchester Business Growth Company
    - Greater Manchester Business Board
    - Private housing developers
    - Social Housing Providers
    - National Farmers Union
    - United Utilities (regional water company)
    - Electricity North West (regional electricity company)
    - Manchester Climate Change Agency
- Local and regional evidence was gathered via desk-research and these stakeholder workshops to identify relevant evidence to analyse the implications of the climate risks and opportunities for Greater Manchester. This was used to support the risk magnitude assessment for Greater Manchester. The climate risks and opportunities that were assigned a different risk magnitude score to the UK CCRA3 are shown in **Table 7.**
    - International Dimensions risks in the UK CCRA3 have not been reassessed for Greater Manchester, as these are national-level risks and are unlikely to be influenced greatly by local/regional context, activity and/or policy.
- *Vulnerability has been considered through existing assessments and was considered during stakeholder workshops on the potential for the most significant, or widespread economic, social or environmental impacts on receptors.*

- Stakeholders agreed to include 2 additional risks that were not in the UK CCRA3, which have been added to the GM CCRA. These are:
    - ‘Risk H14: Risks to people, communities and built environment from wildfire’, and

        - ‘Risk H15: Social inequalities exacerbated as a result of climate change, with disadvantaged and vulnerable groups facing disproportionate climate impacts’.
    - Stakeholders also agreed for ‘wildfires’ to be added to Risk N5. Risk N5 now states: ‘N5 Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions, including temperature change, water scarcity *and wildfires.’*
    - Stakeholders agreed for ‘and storms’ to be added to Risk H3. Risk H3 now states: ‘H3 Risks to people, communities and buildings from flooding and storms.’
    - Stakeholders also agreed that ‘Risk H13 Risk to delivery of education and prison services from extreme weather’ be split out into ‘Risks to delivery of education from extreme weather’, and ‘Risks to delivery of prison services from extreme weather’ as these risks will be managed by very different groups and will require different approaches to manage these risks.
    - Relevant evidence (desk-based, stakeholder / expert input) to understand the impacts of these risks and opportunities specific to Greater Manchester was also assessed, and supported the development of the GM CCRA Evidence Base report (link to report TBC). Climate risks and opportunities, as well as their risk magnitude scores, were identified for Greater Manchester.
    - The risk magnitude score for 10 climate risks has been increased for the GM CCRA, compared to the national UK CCRA3. 12 risks and opportunities have had their risk magnitude lowered for the GM CCRA compared to the national CCRA.
    - Climate risks deemed not relevant to Greater Manchester have also been removed. These are coastal or ocean-related and have been deemed to likely have minimal direct or indirect impacts upon Greater Manchester, and include:
        - N10 Risks to aquifers and agricultural land from sea level rise, saltwater intrusion
        - N14 Risks to marine species, habitats and fisheries from changing climatic conditions, including ocean acidification and higher water temperatures.
        - N15 Opportunities to marine species, habitats and fisheries from changing climatic conditions
        - N16 Risks to marine species and habitats from pests, pathogens and invasive species
        - N17 Risks and opportunities to coastal species and habitats due to coastal flooding, erosion and climate factors
        - H4 Risks to people, communities and buildings from sea level rise
        - B2 Risks to business locations and infrastructure from coastal change from erosion, flooding and extreme weather events

    - Outputs: Greater Manchester Climate Change Risk Assessment, **Table 7.**
- **Step four: Validate with stakeholders**
    - The climate risks and opportunities identified for Greater Manchester, and their risk magnitude scores, were confirmed with further discussions with key stakeholders.
    - Risks with high or very high risk magnitude scores are assigned as High Magnitude risks and opportunities for present day **(Table 5)** and 2050s (**Table 6**).
    - GM CCRA finalised and published.

Appendix B: Summary of past weather-related events in Greater Manchester

Table 1A. Summary of past weather events in Greater Manchester

Weather Event	Hazard	Areas Affected	Impacts
2022 summer heatwave	Extreme Heat	Greater Manchester-wide	According to ONS data on Excess mortality during heat-periods, from the 1st June to 17th August 2022 there were approximately **70 excess deaths in Greater Manchester**, out of a total of 3,555 excess deaths for England.[45] Extreme heat events can also lead to significant impacts on NHS elective surgery. A study found that the 2022 summer heatwave resulted in a fifth of UK hospitals being forced to cancel operations during the three days of the extreme heatwave (16 – 19 July 2022).[46] In 2022/23 there were 1,361 over-heating events[47] in GM's hospitals, 20% of the England total. [48] The majority of such events were seen in the Wrightington, Wigan and Leigh Trust. According to the CCRA3 Technical report, the number of heat-related deaths in the UK could increase to 7,040 deaths per year by 2050.[49] A study by the Met Office found the return time for a 40°C threshold under a 'natural' environment with no human induced climate change was 1 in 1,000 years.[50] [51] However, **due to human induced climate change, the present-day return time for a 40°C threshold is now 10 times greater,** at around 1 in

[45] ONS (2022) Excess mortality during heat-periods, England and Wales, link
[46] University of Birmingham (2023) 2022 heatwave struck off surgery in fifth of UK hospitals, link
[47] Overheating occurrences triggering a risk assessment, recorded under the Estates Returns Information Collection, Summary page and dataset for ERIC 2022/23; link
[48] Hospitals within the NHS GREATER MANCHESTER Integrated Care Board
[49] Betts, R.A. and Brown, K.(2021) Introduction. In: The Third UK ClimateChange Risk Assessment Technical Report [Betts, R.A.,Haward, A.B. and Pearson, K.V.(eds.)]. Prepared for the Climate Change Committee, London, link
[50] Met Office (2020) Chances of 40°C days in the UK increasing, link.
[51] Met Office (2022) UK and Global extreme events – Heatwaves, link

Weather Event	Hazard	Areas Affected	Impacts
			100 years, and by 2100 could be as little as every 3 or 4 years under a very high emission scenario (RCP 8.5). Under a medium-high emissions scenario (RCP 6.0), the return period for a 40°C threshold by 2100 is projected to be around 1 in 15 years.
Summer 2018 heatwave and drought	Wildfire	Winter Hill, Bolton and Saddleworth Moor, Oldham. Significantly elevated $PM_{2.5}$ was observed in Oldham, Manchester, Bolton, Wigan, as well as further afield.	Summer 2018 saw prolonged high temperatures and low rainfall. Significant wildfires broke out in Saddleworth Moor (Oldham) and Winter Hill (Bolton). Impacts included: • Collectively, 11km^2 of upland moor was burned at Winter Hill and Saddleworth Moor, with 57 fire engines and over 200 firefighters required to tackle the fires. Impact on air quality forced the evacuation of 34 homes and the closure of 4 schools.[52] • The impact of mortality due to exposure to $PM_{2.5}$[53] from the fires on the economy was found to be £21.1 m.[54] • Biodiversity and habitat destruction, which will take years to recover. 180ha of internationally significant blanket bog and 20 ha of dry heath/grassland damaged at RSPB Dove Stone.[55] • Estimated to have released 17,798t CO216 – 26,281tCO2 from soil carbon losses and another 19,800t CO2 from near-natural bogs, resulting in total emissions of 37,598t - 46,081t CO2.[56] **The North-West is projected to experience warmer, wetter winters and hotter, drier summers. Analysis from UK-CRI and UKCP18 projects that the risk of wildfire in the Winter Hill and Saddleworth areas could increase from less than ~4.5 days/year in the 2020s, to ~6.5days/year by the 2050s, and >10days/year by 2080s.[57]**
Boxing Day Floods, 2015.	Flooding (primarily river flooding, with	Primarily Northern parts of GM	2,255 properties affected by internal flooding, with 1, 649 properties flooded in 3 principal locations; Salford (750), Radcliffe/Redvales (670), and Littleborough/Rochdale (229).[58]

[52] Moorland fires and fire service funding – Briefing for MPs, from GMFRS and GMCA
[53] Particulate matter with a diameter less than 2.5 µm
[54] A M Graham et al (2020) Impact on air quality and health due to the Saddleworth Moor fire in northern England; Environ. Res. Lett. 15 074018, link
[55] RSPB (2018) The Saddleworth fire and the importance of restoring our peatland habitats in tackling climate change - Blog, link.
[56] UK Parliament Committees (2019) Written evidence submitted by the Game & Wildlife Conservation Trust (GWCT) (PLD0024) link
[57] Using the Wildfire: FFMC 99th percentile metric (Days with Fine Fuel Moisture Code component of the Met Office Fire Severity Index above the 99th percentile over the period 1981-2010, calculated by season).
[58] GMCA (2016) Flood Investigation Report Greater Manchester, 26 December 2015 link

Weather Event	Hazard	Areas Affected	Impacts
	some surface water flooding)		The Environment Agency estimated an average financial residential insurance claim of approximately £50,000; for GM this equates to a total value of **more than £112m**.[59] This does not include homes that were uninsured or underinsured. 31,200 properties were without power, with 143 properties without power for 2 days. Seven electricity sub-stations were damaged. **Damage to infrastructure totalled £11.5m**. Infrastructure impacts included: • Several bridges were damaged or destroyed. • Railway assets were damaged across the region • Road closures and diversions put in place • Environment Agency assets damaged • Bury wastewater treatment works was flooded and a number of the treatment processes were affected • Flood water in Rochdale caused power failure to multiple Water Treatment Works Environmental impacts included: • Water quality likely to have been affected due to a combination of combined sewer overflow discharges, inundation of waste water treatment works and waste materials and fine sediments and other contaminants being washed into watercourses. • **The winter storms seen in the UK in 2015 were made at least 40% more likely because of climate change.[60,61]**

[59] Environment Agency (2018) Estimating the economic costs of the 2015 to 2016 winter floods link
[60] Met Office – Effects of Climate Change, link
[61] Friederike E L Otto et al 2018 Environ. Res. Lett. 13 024006, link

Weather Event	Hazard	Areas Affected	Impacts
Storm Ciara, 8th February 2020	Storms	Greater Manchester-wide	• Electricity North West reported 2,000 homes in the region were without power overnight due to a fallen tree. • Fallen trees affected Metrolink lines with no services able to operate between Rochdale and Shaw and Crompton, and Bury and Whitefield, as well as St Werburghs Road and East Didsbury in either direction. • Northern Trains cancelled more than 140 trains across the north of England • The Environment Agency issues 30 flood warnings across Greater Manchester.[62]
Storm Dennis, 15th February 2020	Storms	Greater Manchester-wide	• Storm Dennis destroyed a bridge crossing the River Irwell in Salford • Roads in Stockport were closed due to flooding • Rochdale Road was closed after a building was deemed unsafe.[63]
Storm Christoph, January 2021	Storms and flooding	Greater Manchester-wide, in particular south Manchester	Manchester: • The River Mersey reached unprecedented levels which resulted in the evacuation of 3,000 properties across Didsbury and Northenden. • A Major Incident was declared, there was a significant risk of flooding for Didsbury and Northenden areas of Manchester, and the evacuation of 3000 properties took place, including 3 settings housing vulnerable residents. • The flood waters came within millimetres of breaching the flood basin. • Over 240 city council staff along with partners and volunteers were involved in the response over the 4 days.[64]
June 2016 heavy rainfall	Flash / surface water flooding	Greater Manchester-wide	Stockport:

[62] BBC News (2020) Storm Ciara: Greater Manchester travel chaos and power cuts link
[63] Manchester Evening News (2020) Storm Dennis takes out River Irwell bridge in Salford as heavy rain and strong winds hit the region, link
[64] Manchester City Council Report for Information (2021) Approach to Flood Prevention and Management, link

Weather Event	Hazard	Areas Affected	Impacts
			• Received equal to or above 200% of the long-term average June rainfall in June 2016. 295 properties reported flooding across the month, with many properties flooding on more than one occasion. • Flooding also caused disruption to road users as highways were closed, along with disruption to the rail services as the Stockport to Disley line was also closed for two weeks following a landslip at Middlewood Station. • Stockport Council also estimated over £950,000 worth of flood damages, investigation and repair work to highway, parks, greenspaces and public rights of way as a result. [65] Oldham: • Internal property flooding affected 57 properties, of which 5 were businesses and 52 were residential properties. [66]

[65] Preliminary flood risk assessment: Stockport Metropolitan Borough Council (2017), link
[66] 8th and 10th June 2016 Flood Investigation Report, Oldham council (2017), link

Appendix C: Greater Manchester Climate Projections

Table 8. Climate Projections Summary for Greater Manchester.

	Indicator	Baseline 1981-2010	GM Projected Change: 2040s, medium-high emissions	GM Projected Change: 2050s, medium-high emissions	GM Projected Change: 2080s, medium-high emissions	GM Projected Change: 2040s, high emissions	GM Projected Change: 2050s, high emissions	GM Projected Change: 2080s, high emissions
Climate Averages	*Mean annual temperature*	*Approx. 9°C*	Increase by 0.9°C	Increase by 1.2°C	Increase by 2.4°C	Increase by 1.4°C	Increase by 1.8°C	Increase by 3.5°C
	Mean annual rainfall	*Between 800mm and 1200mm, for southern and northern GM respectively*	Increase by 1.7%	Increase by 1.4%	Increase by 1.5%	Increase by 1.6%	Increase by 1.4%	Increase by 1.8%
Hot Weather	*Average Maximum*	*Between 19 and 20°C (Northern*	Increase by 1.2°C	Increase by 1.6°C	Increase by 3.5°C	Increase by 1.8°C	Increase by 2.4°C	Increase by 4.9°C

	Indicator	Baseline 1981-2010	GM Projected Change: 2040s, medium-high emissions	GM Projected Change: 2050s, medium-high emissions	GM Projected Change: 2080s, medium-high emissions	GM Projected Change: 2040s, high emissions	GM Projected Change: 2050s, high emissions	GM Projected Change: 2080s, high emissions
	Summer Temperatures	*and Southern GM, respectively)*						
	Number of Hot days/year (temp >25°C)	*Between 4 and 10 events/year (Northern and Southern GM, respectively)*	Between 7 and 14 events/year (Northern and Southern GM, respectively)	Between 8 and 19 events/year (Northern and Southern GM, respectively)	Between 18 and 40 events/year (Northern and Southern GM, respectively)	Between 9 and 18 events/year (Northern and Southern GM, respectively)	Between 12 and 28 events/year (Northern and Southern GM, respectively)	Between 28 and 59 events/year (Northern and Southern GM, respectively)
	Number of Met Office Heatwaves / year	*Approx. 1 heatwave per year on average*	Between 1.3 and 1.8 heatwave events per year	Between 1.6 and 2 heatwave events per year	Between 3.5 and 4.3 heatwave events per year	Between 1.7 and 2.5 heatwave events per year	Between 2.2 and 3.2 heatwave events per year	Between 4.1 and 4.8 heatwave events per year

	Indicator	Baseline 1981-2010	GM Projected Change: 2040s, medium-high emissions	GM Projected Change: 2050s, medium-high emissions	GM Projected Change: 2080s, medium-high emissions	GM Projected Change: 2040s, high emissions	GM Projected Change: 2050s, high emissions	GM Projected Change: 2080s, high emissions
			(Northern and Southern GM, respectively)					
	Number of Tropical Nights/year (nights>20°C)	*Zero*	0.1/year	0.2/year (or 1 in 5 years)	2.6/year	0.3/year (or 1 in ~3.5 years)	0.75/year	9 / year
	Cooling Degree Days (CDDs: a day-by-day sum of number of degrees by which the mean	*16 CDDs*	27 CDDs	33 CDDs	73 CDDs	36 CDDs	47 CDDs	123 CDDs

	Indicator	Baseline 1981-2010	GM Projected Change: 2040s, medium-high emissions	GM Projected Change: 2050s, medium-high emissions	GM Projected Change: 2080s, medium-high emissions	GM Projected Change: 2040s, high emissions	GM Projected Change: 2050s, high emissions	GM Projected Change: 2080s, high emissions
	temperature is above 22°C)							
Cold Weather	*Minimum Winter Temperature Change*	*Between 0.8 °C and 1°C (for Northern and Southern GM, respectively)*	Increase by 0.8°C	Increase by 1.1°C	Increase by 2°C	Increase by 1.2°C	Increase by 1.6°C	Increase by 2.9°C

	Indicator	Baseline 1981-2010	GM Projected Change: 2040s, medium-high emissions	GM Projected Change: 2050s, medium-high emissions	GM Projected Change: 2080s, medium-high emissions	GM Projected Change: 2040s, high emissions	GM Projected Change: 2050s, high emissions	GM Projected Change: 2080s, high emissions
	Number of Frost Days/year (annual number of days where the minimum daily temperature is below 0°C)	*Between 44 and 51 days/year (Southern and Northern GM, respectively)*	Between 28 and 48 days/year (Southern and Northern GM, respectively)	Between 27 and 45 days/year (Southern and Northern GM, respectively)	Between 18 and 31 days/year (Southern and Northern GM, respectively)	Between 25 and 41 days/year (Southern and Northern GM, respectively)	Between 25 and 37 days/year (Southern and Northern GM, respectively)	Between 13 and 23 days/year (Southern and Northern GM, respectively)
	Heating Degree Days (a day-by-day sum of number of degrees by which the mean	*2247 HDDs*	1996 HDDs	1937 HDDs	1661 HDDs	1884 HDDs	1789 HDDs	1441 HDDs

	Indicator	Baseline 1981-2010	GM Projected Change: 2040s, medium-high emissions	GM Projected Change: 2050s, medium-high emissions	GM Projected Change: 2080s, medium-high emissions	GM Projected Change: 2040s, high emissions	GM Projected Change: 2050s, high emissions	GM Projected Change: 2080s, high emissions
	temperature is less than 15.5°C).							
Rainfall	*Summer Rainfall*	*Between average of 211 mm and 249 mm rain for summer months (for Northern and Southern GM, respectively)*	Decrease by 7%	Decrease by 10%	Decrease by 22%	Decrease by 11%	Decrease by 16%	Decrease by 30%

	Indicator	Baseline 1981-2010	GM Projected Change: 2040s, medium-high emissions	GM Projected Change: 2050s, medium-high emissions	GM Projected Change: 2080s, medium-high emissions	GM Projected Change: 2040s, high emissions	GM Projected Change: 2050s, high emissions	GM Projected Change: 2080s, high emissions
	Autumn Rainfall	*Between average of 258mm and 326mm rain for autumn months (for Northern and Southern GM, respectively)*	Increase by 7%	Increase by 8%	Increase by between 11% and 13% (for Eastern and Western GM, respectively)	Increase by 8%	Increase by between 9% and 10% (for Eastern and Western GM, respectively)	Increase by between 14% and 16% (for Eastern and Western GM, respectively)
	Winter Rainfall	*Between average of 223 mm and 317 mm rain for winter months (for*	Increase by between 2% and 4% (for Southern and	Increase by 4% and 6% (for Southern and Northern	Increase by 10% and 12% (for Southern and Northern	Increase by 4% and 6% (for Southern and Northern	Increase by 6% and 9% (for Southern and Northern	Increase by 14% and 18% (for Southern and Northern

	Indicator	Baseline 1981-2010	GM Projected Change: 2040s, medium-high emissions	GM Projected Change: 2050s, medium-high emissions	GM Projected Change: 2080s, medium-high emissions	GM Projected Change: 2040s, high emissions	GM Projected Change: 2050s, high emissions	GM Projected Change: 2080s, high emissions
		Southern and Northern GM, respectively)	Northern GM, respectively)	GM, respectively)	GM, respectively)	GM, respectively)	GM, respectively)	GM, respectively)
Drought	*Soil Moisture Deficit (Average annual maximum cumulative difference between rainfall and potential evaporation in soil).*	*123mm*	151mm	164mm	235mm	170mm	193mm	290mm

Appendix D: Information on climate projections

What is the UKCP18 data that we use to identify climate projections?

UK Climate Projections[67] is a climate analysis tool that forms part of the Met Office Hadley Centre Climate Programme.

It is a series of datasets that demonstrate how the climate may change in the future, based on scientific modelling.

Data is available at the 25km, 12km, or 2.2km scale depending on the variable.

UKCP18 shows climate change projections up until the year 2100.

The data is updated regularly, '18' is just the year of its original release.

The data is available as lower, median and upper values – taken from the ensemble of climate models that make up the UKCP18 projections. We have used the median values in this assessment.

The data is available for different Time Periods, and different greenhouse gas Emissions Scenarios (low, medium, medium-high and very high).

What are Emissions Scenarios?

Emissions Scenarios = 'Representative Concentration Pathways' (RCPs).[68]

Different RCPs assume different emissions of greenhouse gases to the end of the 21st Century. They include a wide range of assumptions regarding population growth, economic development, technological innovation and attitudes to social and environmental sustainability.

We have used RCP6.0 (medium-high) and RCP8.5 (very high) scenarios.

[67] Met Office: UK Climate Projections (UKCP) link
[68] Met Office (2018) UKCP18 Guidance: Representative Concentration Pathways link

Table 2A. RCPs and the associated estimated change in global temperatures.

RCP	Carbon emissions scenario	Change in temperature (°C) by 2081-2100
RCP2.6	Low	1.6 (0.9 – 2.3)
RCP4.5	Medium	2.4 (1.7 – 3.2)
RCP6.0	Medium-high	2.8 (2.0 – 3.7)
RCP8.5	High	4.3 (3.2 – 5.4)

Why have we used these Emissions Scenarios?

Estimates based on the assumption of current national climate policies suggest a median warming level in the region of 2.7°C by 2100, compared to pre-industrial levels (see Figure 2A below). [69]

This reduces to 2.5°C with targets in Nationally Determined Contributions (NDCs), and 2.1°C when binding long-term or net-zero targets are included.

The medium-high emissions scenario RCP6.0 most closely aligns to this global warming level (as shown in Table 2A above).

RCP8.5 is a High emissions scenario. It assumes a significant increase in greenhouse gas emissions. RCP8.5 is particularly useful for allowing for risk analysis in the absence of further decarbonisation, and demonstrating possible impacts from runaway climate change / carbon feedback loops. For projects that have a very high sensitivity to potential climate impacts, e.g. flooding or extreme heat, RCP8.5 is a

[69] Climate Action Tracker (2023) Temperatures, link

useful emissions scenario to use to ensure projects are 'climate-proof.' The Climate Change Committee also advises organisations to:

"Adapt to 2°C, assess for 4°C." [70]

RCP8.5 is projected to give a change in temperature by 2081-2100 of 4.3°C (range of 3.2°C – 5.4°C). Therefore, RCP8.5 most closely aligns to a 4°C warming by 2100, again justifying the inclusion of RCP8.5 as an emissions scenario.

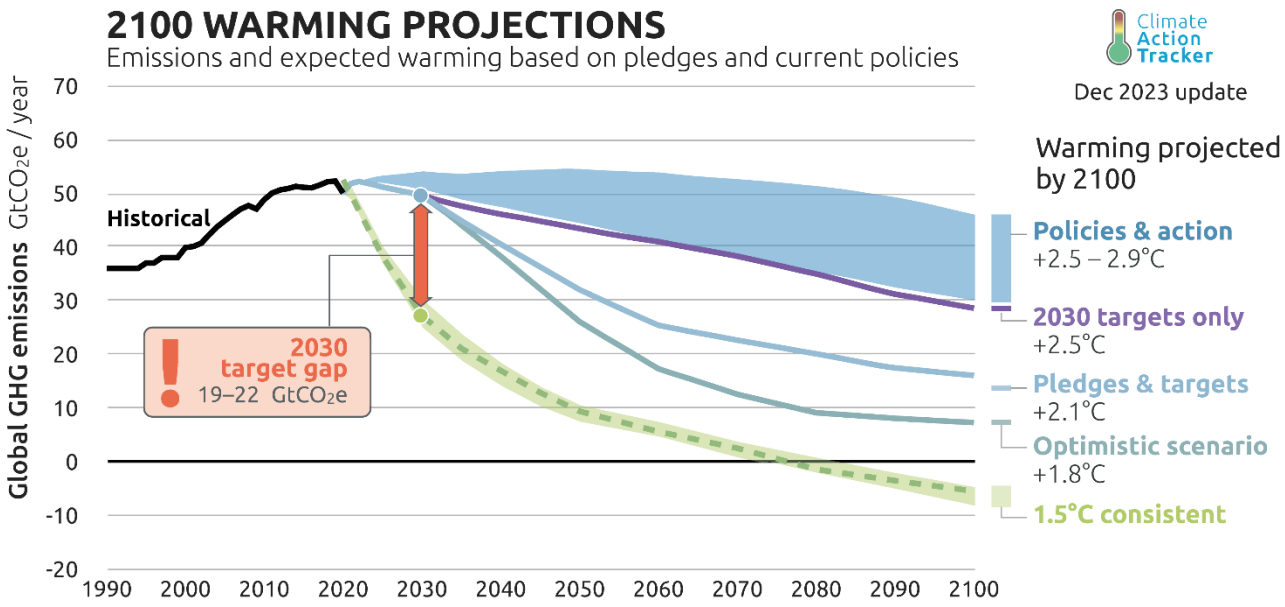


Figure 2A. Climate Action Tracker (2023) Global Temperatures.

What Time Horizons have we chosen to map?

UKCP18 data can also be accessed for various time horizons. These cover 30-year spans, and are classed as follows:

- 2010 – 2039 = 2020s
- 2020 – 2049 = 2030s
- **2030 – 2059 = 2040s**

[70] Climate Change Committee (2021) Independent Assessment of UK Climate Risk, Advice to Government For The UK's Third Climate Change Risk Assessment (CCRA3) link

- **2040 – 2069 = 2050s**
- 2050 – 2079 = 2060s
- 2060 – 2089 = 2070s
- **2070 – 2099 = 2080s**

It is good practice to select mid-century time horizons to align with medium (2040s) and long-term (2050s) regional plans, alongside an end of century time horizon (2080s) which helps show the full extent of projected climate change associated with each emissions scenario.

What are Global Warming Levels?

Climate projections models like UKCP18 can also model different increases in global temperatures (called Global Warming Levels, or GWLs), rather than different increases in greenhouse gas emissions (as is done for the RCP scenarios).

The GWLs used in modelling are usually an increase in global temperatures of 1.5°C, 2°C, 2.5°C, 3°C and 4°C by the end of the 21st century, compared to pre-industrial levels.

The benefits of this approach is that the model does not have to assume or estimate the greenhouse gas emissions increase and the expected time period by which this will occur. However, for local authorities and other organisations wanting to understand and plan for the different climate hazards that may occur by different time periods, this is less helpful.

For this reason we have primarily accessed the UKCP18 data using the RCP greenhouse gas emissions scenario approach, where we can estimate what climate impacts we will experiencing by what time frame.

However, UKCP18 data relating to Drought Severity is most accessible using Global Warming Levels only, and so for this hazard the spatial data is only available for different GWLs.

Estimating Future Surface Water Flood Risk

A GMCA-commissioned project modelled present-day surface water flood risk at a granular level. Using data on: past incidents of surface water flooding; Risk of Surface Water Flooding with a 1% annual probability of occurring; other modelled data from the regional water company, and property data, a heat map showing present-day surface water risk was produced (areas in red or amber are modelled as being a potential surface water risk hotspot area).

Projecting future surface water flooding risk is difficult as it depends on a combination of these factors. Intense rainfall is a key driver of surface water flooding. Therefore, to get an understanding of future surface water flooding risk in Greater Manchester, we also need to understand how rainfall intensity is projected to change over the 21st century.

Environment Agency climate change allowances (CCA) are predictions of anticipated change for peak river flow and peak rainfall intensity in the future, under different climate change scenarios (peak river flow: central, higher and upper; peak rainfall intensity: central and upper). Peak rainfall intensity for relevant Management Catchment Areas (MCA) under different climate change scenarios and by the 2050s are shown in table below.

Scenario	Irwell MCA	Upper Mersey MCA	Lower Mersey MCA	Douglas MCA
Central, 3.3% Annual Exceedance Rainfall Event	+25%	+20%	+20%	+25%
Upper End, 3.3% Annual Exceedance Rainfall Event	+35%	+35%	+35%	+35%
Central, 1% Annual Exceedance Rainfall Event	+25%	+25%	+25%	+25%
Upper End, 1% Annual Exceedance Rainfall Event	+40%	+40%	+40%	+40%

This increase in peak rainfall intensity will bring significant associated pluvial (surface water) flooding risks, in particular in existing surface water hotspot areas.