



RESIN

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RESIN

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Executive Summary

RESIN is a 3.5-year EU-funded interdisciplinary research project investigating climate resilience in European cities that launched on 6 May 2015. The project combines existing approaches to climate change adaptation and disaster risk assessment to develop guidelines and tools to support cities in adapting to a changing climate.

Four city assessment reports will allow the RESIN project partners and the RESIN cities, Bratislava, Bilbao, Greater Manchester (GM) and Paris, to assess which adaptation and Critical Infrastructure Protection (CIP) strategies, plans and measures are already in place or planned. This will enable a better understanding of the options and decision-support tools and products that may best be suited to the specific local context of each of these four European cities and which of them might best be tested within the course of the project. The reports will also enable the local government, the stakeholders in the cities as well as the RESIN partners to better understand each city's needs in the adaptation and CIP process.

GM is delighted to be part of the Climate Resilient Cities and Infrastructures (RESIN) project. The project focuses on urban climate change risk and resilience, with a particular focus on 'critical' infrastructure. It will help us to further our understanding of the potential impacts of extreme weather and climate change, and support action to build the climate resilience of our city. As one of the UNISDR's 'role model' resilient cities, GM recognises that building resilience is a continual process, not a fixed outcome. It is also significant that high level strategy documents, including the Greater Manchester Strategy, support the need to take action on this agenda. Extreme weather events disrupt our everyday lives in the present, and we recognise the need to increase our resilience both now and in the future to related risks and those linked to the changing climate. Doing so will help to safeguard the health and well-being of our citizens, protect our investments and, ultimately, ensure that GM is a good place to live and work.

This report outlines the work that has been done to date in the field of climate change adaptation and resilience in GM. It also looks at the characteristics of the city-region that may make it susceptible to harm from extreme weather events, and the factors that influence the city-region's capacity to adapt. Key messages include:

- There is demonstrable political commitment towards building resilience and adapting to the changing climate across the city-region;
- A complicated and evolving governance structure, with new powers for the Greater Manchester Combined Authority (GMCA), can support the climate change agenda locally;
- A legal and political mandate exists to act, with supportive policies and strategies at multiple levels of government;
- There is a complicated landscape of numerous public and private stakeholders involved in CIP and urban climate change adaptation and resilience more broadly;
- GM faces some significant deprivation issues in certain parts of the city-region that have a bearing on the vulnerability of some residents to the changing climate.

The data and statements are to the best of the current knowledge that exists within the GM RESIN team. Other data may exist, and GM's participation in the RESIN project provides the opportunity to reduce knowledge gaps as the project progresses.

1 Introduction

Greater Manchester (GM) was at the heart of the industrial revolution, becoming the world's first industrial city. This brought great wealth, but also substantial environmental and social problems. Over many years, much of the environmental damage arising from its industrial heritage, such as water quality and contaminated land, has been addressed.

As a result, parts of GM have been transformed in economic, social and environmental terms. However, the significant regeneration and economic growth, which has driven this transformation has not overcome all of GM's issues. A number of its communities are amongst the most deprived in the UK. Some parts of GM still suffers considerable negative environmental effects from the industrial legacy. There are also current pressures including loss of urban green spaces, air pollution and the impacts of extreme weather and climate change (AGMA/TEP 2008).

The ongoing efforts to transform GM and address its challenges need to be looked at in the context of a changing climate. GM's response to this challenge needs to be considered collectively by its ten constituent local authority districts (Fig. 1), who work in partnership with a number of public and private sector partners ranging from the emergency services, health, housing and service providers to infrastructure and utility companies and operators. GM influences and is influenced by processes operating in the wider region that the climate change agenda must consider, including flows of people (via transport networks) and resources (e.g. water from the Lake District).

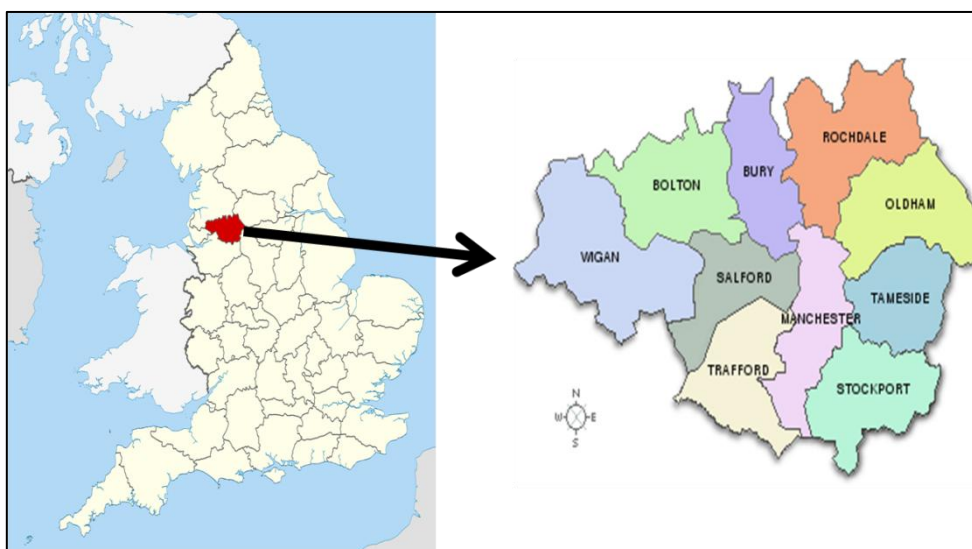


Fig. 1: Map of the ten GM districts in context of England (Matt Ellis, GMCA)

Even now, extreme weather events impact upon GM's citizens, economy and its ecosystems (see section 2.3).

GM's future climate risk is also expected to conspire with other economic, health and social factors. This will significantly affect some of our most vulnerable communities, putting them at higher risk from GM's changing climate. Crucially, GM's climate risk, if not understood and addressed, may undermine wider efforts and investments within the city to deliver its sustainable economic growth and social wellbeing aspirations. GM is not alone in needing to face this challenge. And, like many cities across the world, GM is starting to develop and share learning around how to prioritise and link action on climate change to a wider urban economic competitiveness offer.

GM therefore recognises that, alongside a pressing need to reduce greenhouse gas emissions, it must adapt and increase its' climate resilience, particularly of its critical infrastructure. So, it is notable that

both [Stronger Together - the Greater Manchester Strategy](#) and the [Greater Manchester Climate Change Strategy](#) reflect the imperative; to **'be prepared for and actively adapting to a rapidly changing climate'** (GMCA, 2012: 2) and to **'protect our communities from the extreme weather events which are now unavoidable'** (GMCA, 2013: 18).

GM is able to approach these emerging climate challenges from a position of strength and opportunity for the following reasons:

- The new style of local governance born out of many years of collaboration across the ten local authority districts that make up GM, such that they became the UK's first statutorily recognised [Combined Authority](#) in 2011.
- A range of powers being devolved from central Government, which will enable GM and its elected Mayor to have greater legislative, operational and fiscal control of local health, transport, housing and planning decision-making and budgets. Particularly relevant is an enhanced responsibility for local transport and a £300m housing investment fund for an additional 15,000 new properties over a ten year period.
- GM is England's first city region to begin developing a Spatial Framework which, when adopted in 2018, will become the statutory joint Development Plan for GM for the period up to 2035. This plan will guide investment in long-term economic, housing and infrastructure development, and addressing its environmental (including climate change) priorities.
- The long standing history of collaboration between GM and its districts, and GM with local universities and research partners on themes linked to climate change impacts and adaptation.
- The RESIN project providing the latest opportunity to further support the City's adaptation and resilience goals.

The remainder of GM's City Assessment Report sets out its climate adaptation and CIP baseline and the challenges and opportunities it faces in increasing its climate resilience. This report has been prepared both in the context of climate resilience as a stated priority for GM, and also for its role as a case study city within the RESIN project. The report includes:

- A summary of the climate risk GM is projected to face in the context of its key social, economic and physical/infrastructure characteristics;
- An overview of where GM is in its efforts to understand, plan and start to deliver climate adaptation and CIP actions to address future climate issues; and
- An indication of the emerging set of GM challenges, opportunities and needs around climate adaptation and CIP.

2 Greater Manchester’s socio-economic, physical and climate characteristics

This section looks in more detail at the economic, social, and physical characteristics of GM and their key relationships to the climate change risk and resilience. It also examines how GM’s climate is changing and how this process, interacting with the city regions other characteristics, will continue to affect the conurbation over the coming decades.

2.1 Social and economic characteristics

GM covers an area of 1,277 km² with a population of 2.7m, which is growing and will continue to grow, according to projections, although at a slower rate (Oxford Economics 2014). Table 1 provides an overview of the key statistics.

Area	1,277 km ²
Population	2.7 million
Population Growth (2001 – 2011)	19 %
Estimated population growth (2013 – 2037)	12.4 %
GVA (2014)	GBP 54 billion

Tab. 1: Key area and population statistics for GM. Sources: ONS 2014a; Oxford Economics, 2014.

People

A more detailed breakdown of GM’s demographic characteristics follows:

- Age** - Around 65% of GM’s population is between the ages of 16 – 64. Projections indicate an aging society. According to the projections, the older age group (over 65) will increase from 474,000 to 644,000 between 2021 and 2037.
- Health** - GM has seen the overall health of residents improve for several decades including an increase in life expectancy, a decline in infant mortality, and a fall in overall mortality rates (Public Health England, 2015). Despite these trends, health in GM is still below the UK average which indicates the need for continuing improvement in the overall health of residents. It should be noted that health inequality in the United Kingdom is correlated with high deprivation; thus reducing deprivation should reduce health inequalities (Marmot, 2010). People in poor health may be more vulnerable to extreme weather events and the consequences of infrastructure failure (e.g. reduced access to healthcare).
- Employment and Education** - The proportion of GM’s economically active population (between the ages of 16 and 65) has slightly increased from 70.0 per cent to 70.8 per cent between 2001 and 2011. Almost 8 per cent of GM’s population was unemployed at the last census (2011); this figure has increased by 2.9 per cent since the previous census (2001). The service industry contains the highest number of employee jobs across GM (just over one million employees) (See ONS 2015a).

In 2015, average weekly earnings across England’s north-west region (which includes GM), for

full-time employees working over 30 hours per week, were £488.80 per week. This is less than England's southern regions but higher than, for example, Yorkshire and England's north-east. The UK average is £528 (ONS 2015b).

Levels of educational attainment across GM vary. Around 25% of the population do not have any qualifications due to a range of factors including the tendency for older people to not have qualifications. The GM figure is slightly above the average for England and Wales (22.7%). Another quarter (24.2%) has a degree or higher qualification. Fig. 2 shows the full data against the national averages (ONS 2014b).

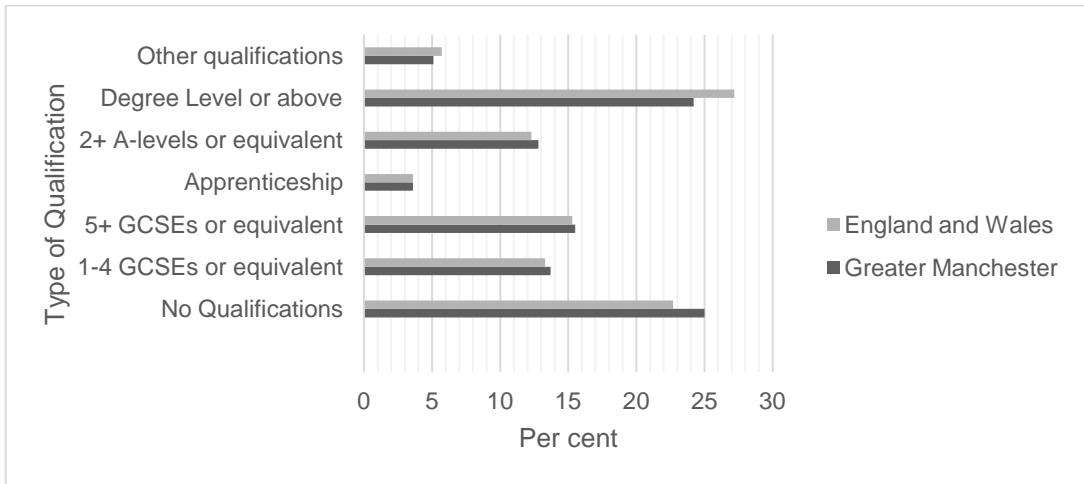


Fig. 2: Educational qualification distribution (Census 2011), GM compared with the England and Wales average. Source: Office for National Statistics, 2014b.

- **Ethnic diversity** - GM is ethnically diverse, although there are significant differences between the ten local authority districts. In terms of climate change, some communities may not be connected to the social networks that underpin resilient responses to extreme weather events, and therefore may be more vulnerable should events occur (Lindley et al. 2011). Issues include communicating flood warnings and resilience approaches where English is not the first language. In response, the local authority district of Rochdale, for example, has developed sewer flood risk information in Urdu and Bengali (Twigger-Ross et al. 2015: 76).



Fig. 3: Chinatown, Manchester during Chinese New Year celebrations. Source: Pete Birkinshaw, 2008, via [wikicommons](#). Licensed for reuse under a [CC-BY-2.0](#)

- **Deprivation** - Deprivation in England is based on an Index of Multiple Deprivation (IMD) with seven domains (weighted) including health, crime, living environment and income. The figures are relative to other local authorities in England; that is, local authority districts are ranked between 1 and 32,844. The rankings are divided into ten equal groupings (deciles) Figure 4 shows significant contrasts in the spatial distribution of deprivation across GM: 63% of GM wards have an IMD score above the English average. Deprivation is evident in levels of child and pensioner poverty, which are particularly acute in the Manchester local authority district (Greater Manchester Poverty Commission, 2012). When spatially represented, it can be seen that areas which fall within in the top ten per cent for deprivation in England are located in the urban centres to the north and east of GM, such as Manchester (particularly to the north of the district), Rochdale, Oldham and Bolton (Fig. 4). Many of the areas that are exposed to certain climate hazards (for example flooding) are also the residential locations of people who are less able to cope with and adapt to the current risk of extreme weather events, and the changing climate.

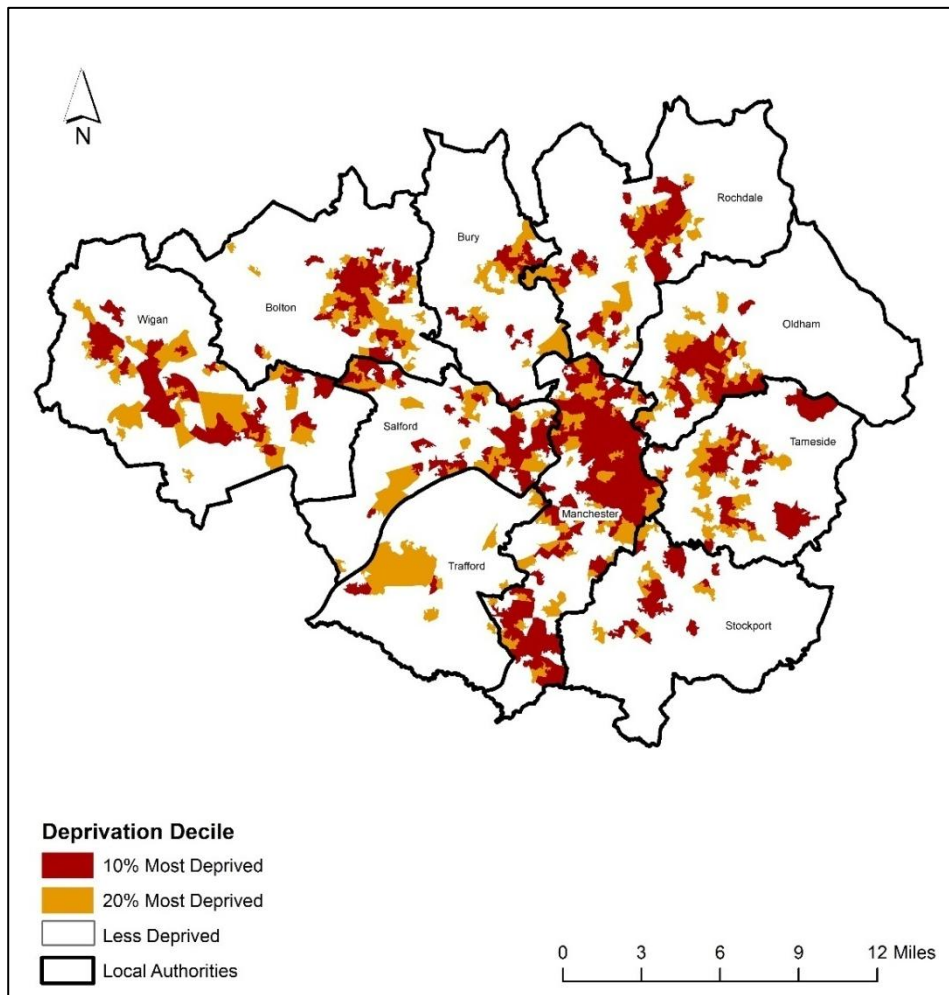


Fig. 4: Spatial distribution of deprivation across Greater Manchester based on the Indices of Deprivation 2015. The Indices of Deprivation 2015 have been published using the Open Government License (OGL) version 3.0, see www.nationalarchives.gov.uk/doc/open-government-licence/version/3/ The Indices of Deprivation 2015 have been constructed for the Department for Communities and Local Government (DCLG) by Oxford Consultants for Social Inclusion (OCSI).

Societal Vulnerability

The previous points highlight the parts of the population who may be more vulnerable to a changing climate. Whilst there is no single definition of vulnerability at GM level, national level research and information point to the identification of particular groups or characteristics of populations which affects their vulnerability to various impacts, especially from a changing climate. Certain factors may make people more vulnerable, such as social isolation, a short length of residency in an area and the tenancy status of residents. In addition, the specific circumstances people live in also make them more vulnerable than others. Amongst them are very young children and older people, people in poor health and with poor mobility and access, residents living in damp or inefficient housing and people on low incomes (see www.climatejust.org.uk). This has been explored for surface water flooding in GM within the EcoCities project (Kazmierczak and Cavan 2011).

Economy

GM's Gross Value Added (GVA) in 2014 was approximately £54 billion; this has increased from £34.9 billion in 1991.¹ GM, as a whole, outperforms England's north-west region (in which it is located) but does not outperform the UK (Oxford Economics 2014). In terms of delivering employment, the biggest increases between 2008 and 2014 were in professional and scientific activities as well as admin and support services. The highest decreases occurred in the manufacturing and construction sectors (Oxford Economics 2014). GM's economy consists of a large number of small-to-medium enterprises (SMEs)². There are 86,255 SMEs; their numbers are increasing across the north-west of England (ONS 2015a). It is likely that the number of SMEs will continue to increase. It should be noted that approximately 85% of SMEs have between 0 and 9 employees, which may pose issues for their capacity to address the risk of climate change on their business (ONS, 2015a).

2.2 GM's urban fabric and critical infrastructure features

Infrastructure planning and CIP are a national priority for the UK government. Nine sectors are regarded to be 'critical' at the national level: 'food, energy, water, communications, transport, health, emergency services, government, and finance' (Cabinet Office, n.d: 12). GM's draft [Spatial Framework](#) (2015) follows this, but adds 'social infrastructure'. For GM, CI is categorised as:

- Transport infrastructure – air (Manchester), rail, port (Salford) tram (metrolink), road, walking and cycling;
- Utilities infrastructure – gas, electricity, heat, digital connectivity, water and waste water;
- Social infrastructure – schools and education, health services, community facilities, recreation provision and green infrastructure³.

An [open data map](#) of key infrastructure and other environmental information has been produced by the GM Local Enterprise Partnership's (LEP) Infrastructure Advisory Board. This includes spatial information on various utilities and transport infrastructure networks within GM, including a range of information on public service facilities and a wider network of infrastructure. This, along with the natural environment information shown, represents an increasingly comprehensive spatial picture of many of the key and connected urban systems which operate and support the functioning of the conurbation in socio-economic and environmental terms. The map includes basic flood risk information but does not yet represent wider climate change impacts, and the impacts these would have on the current infrastructure (and its capacity) as presented.

This map has been delivered to provide underpinning evidence for economic growth and spatial land use plans. Further development of the open data mapping process is occurring which is starting to [map \(and identify new\) future development for housing and employment sites](#).

Transport infrastructure

GM has a mix of public transport options including bus, rail and light rail. Transport for Greater Manchester (TfGM) is the public body responsible for coordinating transport across GM including

¹ GVA for GM is measured by NUTS3 area and is divided into two main areas: Greater Manchester North (which includes Wigan, Bolton, Bury, Rochdale and Oldham) and Greater Manchester South (which includes Salford, Trafford, Manchester, Stockport and Tameside).

² An SME can be defined as a business with under 250 employees.

³ Green infrastructure is treated separately in other GM strategies, for example Manchester City Council has a Green and Blue Infrastructure Strategy.

planning, investments and maintenance. In terms of light rail, the Metrolink (Fig. 5) is in receipt of significant investment from TfGM (£1.4 billion) to increase the size of the network. Other investments are being made to improve the cycle network. TfGM are currently preparing their strategy - [Greater Manchester Transport Strategy 2040: Our Vision](#) – which is due for publication in 2016.



Fig. 5: Bury Tram at Market Street Station, Manchester. Source: Duncan Hull, 2012 via [Flickr](#). Licensed for reuse under a [CC-BY-2.0](#)

Additional transport investments include £560 million for the Northern Hub rail scheme (completed c. 2019). The UK Government has also designated the Manchester Airport Enterprise Zone and there is ongoing work at the port of Salford and the Manchester Ship Canal. These will deliver significant economic benefits, connect Greater Manchester to other global cities and will help to improve connectivity between areas within the conurbation to improve job access in the most deprived areas (GMCA, 2013) shown in Figure 4.

Utilities infrastructure

Utilities such as the communication and electricity networks have been mapped on [the GM Open Data infrastructure map](#). However, this does not contain information on the extent to which these items are resilient to extreme weather events, nor their susceptibility under the context of a changing climate. Section 3 provides details of national requirements, through the UK's Climate Change Act (2008), for the major utilities to report their progress on understanding climate change risk to their assets. The extent of the dependencies between utilities infrastructure with regard to climate change is currently not well known.

Social Infrastructure

The [EcoCities Spatial Portal](#) for GM maps social infrastructure, such as emergency services, hospitals, educational establishments and homeless shelters, in relation to GM's UHI and in terms of flood risk. Some of these elements are governed by existing guidance in order to make them more resilient to climate change, most notably through the National Health Service (NHS) Heatwave Plan, which is regularly updated. It is important to note that social infrastructures are elements at risk, but may also assist in increasing resilience by, for example, designating them as cooling centres during a heatwave, or as a central point of help when recovering from floods (see, for example, Kazmierczak 2012).

It is also notable that GM is increasingly seeing green infrastructure⁴ as critical infrastructure. For example, Manchester City Council's Green and Blue Infrastructure Strategy states that:

“Green and blue infrastructure will be a core component of Manchester’s plans to 2025. It is as important as our other types of infrastructure; energy, transport, water, waste, telecommunications and others.” (Manchester City Council 2015: 4)

Some green infrastructure assets have been mapped on the GM open data infrastructure map.

Other built environment assets

As at 2013, GM's current rate of house building is around 3,000 units per annum; however, the target is 9,200 per annum (GMCA 2013). The developing GM Spatial framework will examine whether the rate should be further increased.

GM, because of its long history of redevelopment, contains many different building types from different periods – in both the housing and commercial sectors. This has implications in a changing climate. A predominance of terraced housing (particularly in the north of the conurbation) may pose issues for the protection of individual homes from flooding as they are within interconnected blocks. Significantly, the proportion of semi-detached and detached houses, and properties that are owner occupied, decreases across GM neighbourhoods where the urban heat island (UHI) effect increases. This suggests that rented, high rise properties may be vulnerable to increasing temperatures (Kazmierczak 2012).

Industry and investment areas are often sited close to key pieces of infrastructure. So for example Media City and the Salford Quays regeneration are linked to the Manchester Ship Canal and there is significant associated activity (including a new Manchester Airport City Enterprise Zone) linked to Manchester Airport itself and its surrounding infrastructure. In the regional centre (central Manchester), many commercial office blocks are high rise with glazed curtain walling, which may have significant implications under increasing temperatures for the comfort of their occupants, and may therefore need to be adapted. There have also been large investments in energy efficiency retrofitting programmes, which will continue help GM realise its low carbon emissions targets (GMCA 2013).

2.3 GM's changing climate

Recent and future weather and climate trends

GM can be split into three distinct climate zones (Cavan, 2011) with different seasonal precipitation and temperature profiles:

⁴ Broadly defined as a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings. (European Commission 2013b) European Commission, 2013. Building a green infrastructure for Europe. European Union: Brussels. Doi: 10.2779/54125

Note: Green infrastructure may incorporate both landscape and water features, the latter of which may be termed 'blue infrastructure'. Other terms include 'green-blue infrastructure' and 'green and blue infrastructure'

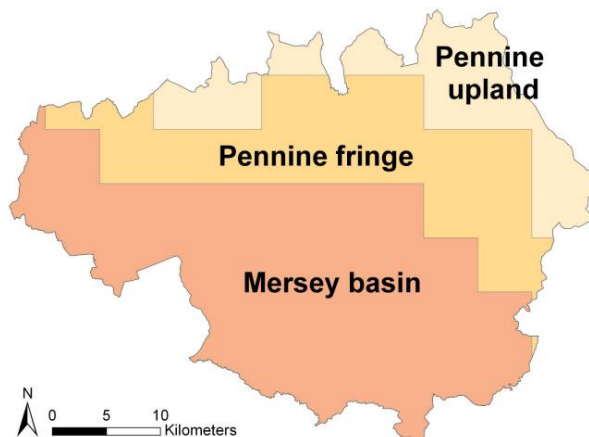


Fig. 6: The three climate zones of GM (Cavan 2010)

The areas closest to the Pennine upland tend to be cooler (and wetter) than the urban core around the Mersey basin:

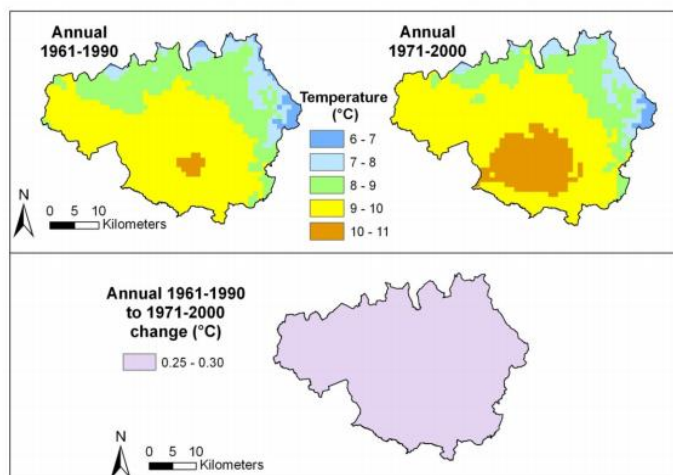


Fig. 7: Annual average daily mean temperature for GM, 1914-2000 (Cavan, 2010)

The overall trend in GM is towards a warming climate (Cavan 2010; Fig. 7). Historic reports of extreme weather events indicate that flooding is the most prevalent extreme weather event to have impacted on GM over recent decades, and that pluvial flooding in particular is becoming more common (Carter and Lawson, 2011).

Climate change projections

Cavan (2011) provides a full overview of climate projections for GM. The main headlines are:

- A greater number of cooling degree days⁵
- A decreasing number of heating degree days⁶

⁵ An annual measure of the extent to which temperatures suggest that buildings may require some form of cooling (e.g. air conditioning) is based on the daily temperature being above a specified threshold (22°C).

UKCIP website, 2011 (<http://www.ukcip.org.uk/glossary/>)

- Drier summers
- Wetter winters
- More frequent and intense extreme weather events, particularly strong winds, storms (although projections on future changes to these hazards are limited) and associated periods of high level short duration rainfall.

The projections highlight that GM may face a greater risk of flooding and heat stress over the coming decades.

2.4 Climate change implications for GM's society, economy, infrastructure and built environment

The expected changes to GM's climate, when viewed in the context of its social, demographic and physical characteristics, have some specific implications. Understanding these and the interplay between the climate and the socio-economic and physical urban on the one hand, and biophysical fabric characteristics of GM on the other, is essential in identifying and addressing its climate vulnerability.

The [EcoCities project](#) identified three areas of focus for acting on climate change adaptation in GM. These were:

- Safeguarding future prosperity;
- Protecting the most vulnerable in society; and
- Building the resilience of critical infrastructure.

Extreme weather events and climate change may **disrupt economic prosperity**. Therefore, in order to protect the up-front investments as well as realising their future value, it is necessary to ensure that infrastructures and the built environment more generally (and the economic activity this underpins) are made increasingly resilient to extreme weather-related phenomena. It should be noted that SMEs are a group who are currently particularly vulnerable to extreme weather events and may lose out, due to loss of earnings for example, if there is a flood (Wedawatta and Ingirige, 2012).

Also the significant variability in levels of social vulnerability (including its spatial distribution) across GM, means that certain groups (and locations) may be less able to prepare for, respond to, and recover from extreme weather events as well as adapt to the changing climate (Lindley et al., 2011). Robust analyses of these trends and subsequent policy responses at the GM level, within spatial planning and infrastructure planning for example, can underpin local activities and priorities that seek to increase the resilience of vulnerable neighbourhoods to the changing climate. Understanding the proximity to critical infrastructure that may be at risk of extreme weather events and climate change, as well as the potential knock-on implications and cascading affects across sectors and spatial scales, may help to increase the resilience of the most vulnerable in society.

GM's infrastructure helps to support good quality of life and economic prosperity. It follows that these key policy objectives may be negatively impacted upon as the risk to infrastructure from certain extreme weather events increases as a result of climate change. Recent studies by the University of Manchester have provided insights into related issues. The FINA project looked specifically at the risk

⁶ An annual measure of the extent to which daily temperatures suggest that buildings may require some form of space heating is based on the daily temperature being below a certain threshold (15.5°C).

UKCIP website, 2011 (<http://www.ukcip.org.uk/glossary/>)

of flooding to GM's transport infrastructure (Carter 2015). This identified that the most severe flood events impacting on GM's main highways network occur during the autumn and winter months, and that although these events occur across the conurbation there are certain locations where events appear to be more frequent. On the rail network a pattern emerges with a spike of flood events in July and August. Spatially, these events tend to cluster at particular points on the network. A twin-track approach is needed in response to these events and related risks; firstly identifying and reducing risks associated with current extremes and secondly responding to the challenges linked to the changing climate.

A further study made a spatial assessment of extreme weather and climate change risks to key sectors that are central to GM's current and future prosperity (Carter and Kazmierczak 2013). This focused on GM's strategic employment sites, science and innovation assets, critical infrastructure, future housing development areas and town centres. This assessment demonstrated that risks to these sectors varies considerably across GM. Risk differs according to location (and therefore likelihood of exposure to hazard events) and the significance of the sector or asset to GM's future prosperity (and therefore the severity of consequences associated with exposure to a hazard event). This study emphasises that, given many weather and climate change hazards are spatial in nature, there is real value in assessing related risks spatially where data and resources permit this approach. This can support the development of targeted strategies and actions to address prominent local risks.

3 State of adaptation and critical infrastructure protection planning and activity in GM

Critical to taking action to increase GM's resilience to a changing climate is developing an understanding of its current baseline situation. This is both in terms of the city's understanding of how the changing climate will affect it and how its plans, strategies, investments and efforts to address the challenge of a changing climate are progressing. This needs to be seen in the context of projected climate hazards and how these affect the particular social, economic or physical characteristics of GM. In building this baseline, we need to understand more about:

- **Evidence:** GM's baseline evidence on climate related risk, particularly the ability to spatially define the risk factors.
- **Policies and plans:** The extent of coverage of climate change adaptation and CIP issues within relevant plans, strategies and other relevant programmes. It is also important to understand how well integrated these are.
- **Supporting delivery:** The network of stakeholders/actors and organisations for supporting and communicating of climate risk, adaptation and resilience issues.
- **Implementation:** How much physical delivery of measures is occurring 'on the ground' to increase GM's climate resilience.

A more detailed standalone report analysing and presenting GM's climate adaptation and CIP research, policy and stakeholder landscape has been produced (Carter, Connelly, Ellis 2016). However, an overarching picture on the current status of these areas is outlined below.

3.1 EVIDENCE: Existing climate change risk and vulnerability data and assessments

GM, its constituent Municipalities and a wider group of stakeholders operating within and beyond its boundaries, have contributed greatly to building understanding of the climate-related risk and vulnerabilities that the city region faces from a changing climate. Studies have focused at national/regional, GM and down to local scales. They have looked at particular climate hazards and impacts, receptors as well as including those affecting from vulnerable groups. These are at range of levels from national to local and cover from research focussed activities through to specific pieces of work delivered to fulfil statutory and locally driven requirements. This evidence landscape is described in more detail in the standalone GM research, policy and stakeholder commentary document (Carter, Connelly, Ellis 2016). Key data and evidence sources related to understanding and assessing extreme weather and climate risk in GM are summarised below.

National level risk information

- The [UK Climate Risk Assessment \(CCRA\) 2012](#) – Produced by the UK Government this publication is a first of its kind for the UK, the CCRA sets out the main risk and opportunities for the UK arising from climate change.
- [Progress in preparing for climate change 2015](#) – This is a three part report published by the

[Committee on Climate Change](#) (an independent, statutory body established under the Climate Change Act 2008) under sections 36 and 59 of the Climate Change Act. It covers both progress towards meeting carbon budgets and progress on adaptation to climate change. It includes the CCC's first ever statutory assessment of the National Adaptation Programme.

- [Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities](#) (Sept.2011) – Published by the Environment Agency, this package of information includes river basin district specific guidance on increased fluvial flows, rainfall intensity and other climate related risk for Lead Local Flood Authorities (LLFA's) based on UKCP09 climate change projections
- [ClimateJust](#) (2014) – Developed by the Joseph Rowntree Foundation, this website and mapping tool highlights the people and places that are likely to be most vulnerable to the impacts of flooding and heat waves, producing evidence for local authorities to take action to deliver socially just responses to climate change.

Regional level risk information

- [A Summary of Climate Change Risks for North West England](#) (2012) – Produced by Climate Change North West ([now a part of Climate UK](#)), informed by the UK CCRA and other local information, this report further illustrates what climate change may mean for the region's people, businesses and other organisations, highlighting where there is a stronger case/need for local action.
- [Economic Impacts of increased flood risk associated with climate change in Northwest England](#) (2009) – Commissioned by the North West Development Agency, this URS report assesses the economic impacts of climate change on flooding in the North West of England compared to the current situation, with a key focus on the business sector and a consideration of damage saving costs flood defence works.
- [Climate Change Impacts on Key Sectors and Public Services in Northwest England](#) (2009) – Commissioned by the North West Development Agency, this ARUP's report is based on climate projections produced by the UK Met Office (UKCP09), and provides a risk assessment of these against 18 key public and private sectors and also includes associate sector specific awareness raising and briefing materials.
- [NW Flood Risk Management Plan](#) (still to be published) – this jointly produced Environment Agency and Lead Local Flood Authority plan sets out where and how to manage flood risk in the North West so as to provide maximum benefit to people and the environment. Within this plan, the impact of climate change on flood risk management activities is considered.
- [Climate Change and the Visitor Economy](#) (2005) - Commissioned by Sustainability Northwest and produced by the University of Manchester, this report looked at how climate change may impact upon the visitor economy in the north-west England and how the interactions between climate change, visitor behaviour and environmental capacity needed to be considered by policy makers to ensure a climate proof visitor economy. The Manchester city centre was covered as a case study.

Research focussed on GM

- [Adaptation Strategies for Climate Change in the Urban Environment](#) (ASSCUE) (2003-2006) - The ASSCUE Project furthered the understanding of the impacts of climate change in GM

through three 'exposure units' of human comfort, urban greenspace and the built environment. It used a risk based approach to go beyond impact assessments and provided enhanced information to underpin the development of conurbation and neighbourhood scale adaptation strategies. The risk assessment methodology (Lindley et al., 2006) used a set of urban morphology units (representing different land use types) as its spatial framework.

- [Sustainable Cities: Options for Responding to Climate Change Impacts and Outcomes](#) (SCORCHIO) (2008 – 2011) - SCORCHIO developed tools to help planners, designers, engineers and users to adapt urban areas to the changing climate, with a particular emphasis on heat and human comfort. The project used projections from the UK Climate Impacts Programme (UKCIP) to provide new and better predictions of changes to the climate at a finer spatial scale (see Smith et al., 2011). SCORCHIO delivered a better understanding of the GM urban heat island, at a unit of analysis suitable for decision makers.
- [Green and Blue Space Adaptation for Urban Areas and EcoTowns](#) (GRaBS) (2008 – 2011) - GRaBS improved stakeholder and community understanding and involvement in planning, delivering and managing green infrastructure in new and existing urban mixed use development, based on positive community involvement techniques. This included raising awareness of existing good practice with regards to green infrastructure as a climate change adaptation response (Kazmierczak and Carter, 2011).
- [ECOCITIES](#) (2009 – 2012) - EcoCities provided a blueprint for developing a climate change strategy for GM, as well as a GIS-based spatial portal that gathered together information on climate projections, critical infrastructure locations, and social vulnerability (see Carter et al. 2015).
- [I-TREES](#) - The i-trees project investigated and demonstrated the contribution of green cover to climate change resilience and adaptation objectives. Trees, green walls and green roofs were scientifically measured in order to demonstrate they can have on ground surface temperature, capture of dust and fine sooty particles, and water retention.

GM level/cross authority studies/reports

- [GM Ecosystems Services Study](#) (2014) – Produced by Red Rose Forest (using Natural England funding), this study Maps GM's priority Ecosystem Services (ESS), setting out pinch points and issues which are critical and need to be addressed in order for those services to be maximised. Some of the highest priority ESS are climate service related, particularly concerning heat and flood management.
- [Evidencing and spatially prioritising CC in GM](#) (2013) – Commissioned by the GMCA, this University of Manchester study, considers the national level CCRA risk factors at a more local scale in GM, evidencing, and where possible spatially prioritising, weather and climate change risk to the delivery of the Greater Manchester Strategy (which drives growth and development in GM).
- [Flooding of Transport and Infrastructure Networks and Assets Report](#) (2014) – Commissioned by the GM Civil Contingencies and Resilience Unit, this University of Manchester study enhanced the understanding of flooding to transport infrastructure networks and assets in Greater Manchester to strengthen responses to related risks.
- [GM Strategic Flood Risk Assessment](#) (level 1 and level 2 district level reports (2010-11) – produced by the ten GM districts, the GM wide Strategic Flood Risk Assessment (SFRA) and the joint district detailed level two SFRA) are technical pieces of work which independently

analysed of the risk posed by flooding from all sources in GM and its ten constituent districts and provided evidence to inform future sustainable development.

- [Catchment Flood Management Plans](#) (CFMPs) (2009) – These Environment Agency produced plans cover all four of GM's river catchments (Irwell, Upper Mersey, Mersey Estuary and Douglas). They cover all forms of inland flooding, including a consideration of climate change, and aim to enable the Environment Agency and its partners to plan and agree future flood risk management activity.
- [Towards a Green Infrastructure Framework for Greater Manchester](#) (Sept 2008) – Commissioned by the AGMA, this report looks at how green infrastructure (GI) might be embedded into the city regions spatial planning process. The goal is to enable and sustain growth to provide GM with a “route-map” approach to GI planning, including its role in climate resilience.

Local/Municipality level studies

- [Local Climate Impact Profiles](#) (LCLIP) – These were produced by the 10 GM districts as part of the central government's National Indicator 188, which encouraged climate change adaptation planning in local government. 9 out of 10 GM local authority districts had completed LCLIP's by 2009/10. LCLIP's are a simple process designed to help organisations, in this case local authorities, to assess their exposure to damaging weather events.
- [Preliminary Flood Risk Assessments](#) (required under 2009 Flood Risk Regulations) – Produced at a GM district level they consider flooding from surface water runoff, groundwater and ordinary watercourses and include consideration of climate change. PFRAs are used to identify areas that are at risk of significant flooding. These areas are called flood risk areas. Lead local flood authorities are responsible for and have prepared the PFRAs and identified the flood risk areas. All 10 GM districts have produced these documents and they can be downloaded [here](#).
- [Local Flood Risk Management Strategies](#) (LFRMS) as required under the Floods and Water Management Act 2010 – Produced by GM's districts as Lead Local Flood Authorities, these LRFMS must: assess local flood risk; set out objectives for managing local flooding; and list the costs and benefits of measures proposed to meet these objectives, and how the measures will be paid for. Building on evidence provided by PFRA's, these must consider the implications of climate change on local flood risks and delivery of flood risk management objectives/measures locally.

3.2 POLICIES AND PLANS: Existing adaptation and critical infrastructure protection plans and strategies

A number of plans and strategies, covering a range of scales and produced by a variety of stakeholders (see below), address the issue of climate adaptation and critical infrastructure protection. These range from higher level policy / strategy documents to more formal climate change adaptation strategies. Depending on the plan or strategy and the driver behind it (i.e. whether they are statutory or legislative), these documents contain differing levels of coverage of climate adaptation and resilience issue(s) and subsequent approaches to managing them. This policy and legislative landscape is described in more detail in the standalone GM research, policy and stakeholder commentary document (Carter, Connelly, Ellis 2016). But the following summary provides a snapshot, of our current understanding of coverage in GM:

National/sector level Plans and Strategies

- The [National Adaptation Programme](#) (NAP) 2013 – Produced by the UK Government, this is a register of actions aligned to risks identified in the national Climate Change Risk Assessment. The NAP is split into themes including Built environment; Infrastructure; Healthy and resilient communities; Agriculture and forestry; Natural environment; Business and local government. It looks most closely at the most urgent risk factors and sets out actions for a range of actors, including local stakeholders or organisations with a role / remit within GM around increasing local resilience to climate change.
- The [Heatwave Plan for England](#) 2015 – Produced by Public Health England (an executive agency of the Department of Health), the Heatwave plan for England aims to prepare for, alert people to, and prevent, the major avoidable effects on health during periods of severe heat in England. It recommends a series of steps to reduce the risks to health from prolonged exposure to severe heat. These steps are targeted at the NHS, local authorities, social care, and other public agencies; individuals, local communities and voluntary groups. Alongside the key emergency planning guidance for heatwaves, it also recognises that a co-ordinated, multi-agency and long-term approach is needed to protect people and infrastructure from the effects of severe hot weather, for example through 'greening the built environment'.

GM level plans and strategies (including emerging/currently developing)

- [The Greater Manchester Strategy – Stronger together](#) (2013) – Produced by the Greater Manchester Combined Authority (GMCA), this strategy sets out GM's plans for reforming public services and its drive for economic growth and prosperity. The vision is of a city region which is self-reliant and self-sustaining whilst delivering growth, a good quality of life, low carbon economy and a commitment to sustainable development alongside an outstanding natural environment. Explicit in this is the need to adapt to a changing climate with clear statements around the need to address the impacts of a changing climate and extreme weather as well as commitments to implement recommendations EcoCities work on climate change adaptation and more generally investing in green and blue infrastructure for the climate resilience services it provides (p47).
- [GM Climate Change Strategy](#) (2011) – This GMCA strategy aims to address the challenges and opportunities presented by climate change. It covers both mitigation and increasing our resilience to a changing climate. And through its strong objective (p. 6) to 'be prepared for and actively adapting to a rapidly changing climate', it creates a common framework to provide direction and co-ordination for plans and programmes already in place at Greater Manchester and at the district level, linking them to all the priorities in the overarching Greater Manchester Strategy (see above).
- [GM Climate Change Implementation Plan](#) (2012-15) - This plan was produced by the GMCA (and its Low Carbon Hub (and is currently being [refreshed](#) autumn 2015). The current published plan covers the period 2015-20 and outlines the key actions and commitments needed between 2012 and 2015 to deliver GM's Climate Change Strategy. These are not just plans for public bodies, they are plans which every organisation, business and neighbourhood in Greater Manchester can contribute to, and benefit from. Both the original (pp. 11; 18) and refreshed implementation plan (p. 26) includes priorities and actions around climate resilience.
- The emerging [Greater Manchester Spatial Framework](#) (GMSF) – produced by the GMCA. This will be a joint statutory spatial plan of the Mayor and the 10 GM districts to manage the supply of land for jobs and new homes across Greater Manchester. The GMSF has a central role in

delivery of the 3 primary priorities of the GMS (creating conditions for growth, increasing productivity and increasing independence and self-reliance of citizens). The GMSF will be a core (but not only) element of delivery of these priorities through ensuring that GM has the right land in the right places to deliver the homes and jobs needed up to 2035, along with identifying the new infrastructure (such as roads, rail, Metrolink and utility networks) required to achieve this. Very importantly, the GMSF will aim to address the environmental capacity of GM, setting out how this will be enhanced and protected so that growth and development is sustainable. This will include how new growth and its design and location may need to consider and respond to GM's changing climate and the wider resilience agenda.

- [Greater Manchester Transport Strategy 2040](#) – Produced by Transport for Greater Manchester (TFGM), this sets out a vision for the transport network that GM needs by 2040 to deliver “World class connections that support long-term sustainable economic growth and access to opportunities for all”. This strategy aims to transform GM into a sustainable, low-emission city region that is more resilient to the effects of climate change.
- [GM Community Risk Register \(CRR\) 2014](#) – Produced by the [GM Local Resilience Forum \(GMLRF\)](#), publication of a CRR is a requirement of the Civil Contingencies Act 2004 which requires the GMLRF to set out the key emergency risks facing GM from a wide range of sources. It sets out GM's risk profile with flooding and severe weather, and identifies these as some of the most significant risks facing GM.
- Greater Manchester Resilience Forum Strategy and Work programme (2015-17) – This document sets out a programme of work, research and other related activity associated with managing the key risks outline in GM's CRR.

Critical Infrastructure specific plans and strategies (with GM footprint/coverage)

The UK's 2008 Climate Change Act gives central government the power to ask certain organisations to produce reports on:

- the current and future predicted impacts of climate change on their organisation
- their proposals for adapting to climate change

This applies to organisations that are responsible for essential services and infrastructure, including energy, water or transport companies within GM. A full list of all organisations invited to report can be downloaded [here](#). Establishing the position of these organisations concerning their planning to respond to climate change, both generally and specifically within GM, is critical to understanding how well CIP is taking account of key climate change as part of their risk management processes. Organisations in GM (or covering GM as part of a wider spatial remit for critical infrastructure) have followed this process. This has led to [first round reports](#) or [second round progress reports](#) from the following organisations who have particular relevance to critical infrastructure resilience in Greater Manchester:

- United Utilities (Water and Sewerage company covering the NW of England)
- Electricity North West
- Highways Agency
- Network Rail
- Manchester Airport

- National Grid

Legal and financial frameworks for supporting planning and implementation

In addition to the range of resilience plans and strategies identified above, there are a range of legislative and statutory frameworks and drivers in the UK which directly support local areas such as GM and the organisations within them to plan for and implement action to address climate resilience issues.

These are outlined in brief below, including brief details of how they support planning and implementation. However, whilst the GM (and the UK more generally) benefits from this framework through driving planning and action, it doesn't always require or support specific levels of adaptation or CIP at the local level. So, for instance, whilst some issues and actors are required (in some cases by law) to plan and take necessary action, for others (including for local authorities) this is left down to a decision about local risks, available resources or balancing climate risks issue alongside other issues.

This can and does, both within GM and elsewhere, lead to varying levels of coverage and capacity to plan and take action on the various different adaptation and CIP issues by different actors across different scales. Some initiatives ultimately lead to capital investment (i.e. through asset management plans of utilities), whilst others are required to do little or nothing at all. The supportive framework operating in GM is broadly as follows:

- [Civil contingencies Act](#) (2004) - The Civil Contingencies Act (2004) deals with a variety of hazards including terrorism and extreme weather events. The Act requires '[Local Resilience Forums](#) (LRF)' to be made, comprising of key stakeholders involved in risk and resilience. Each LRF must keep a 'Community Risk Register' which outlines key risks, the potential impacts and the emergency response strategy.
- [Climate Change Act](#) (2008) - Part Four of the Climate Change Act (2008) deals with adaptation. There are three main points. Firstly, the UK Government is committed to undertaking a [national climate change risk assessment](#) (CCRA) every five years which forms the basis for [the National Adaptation Programme](#) (NAP); the first NAP was produced in 2013. Secondly, an impartial body, the Adaptation Sub-Committee, was formed to scrutinise legislation and to shape the methodology for the CCRA. Thirdly, providers of functions at a national level (i.e. most critical infrastructure providers) are obliged to report on their organization's progress towards adapting.
- [Floods and Water Management Act](#) (FWMA) (2010) and [Flood Risk Regulations](#) (2009) - The Flood Risk Regulations (2009) was the main legislative instrument for transposing the EU Floods Directive into UK policy. Allied to this, the FWMA (2010) devolves responsibility for flood risk management to more local levels and sets out responsibilities. The national Environment Agency is responsible for strategic overview of all flood and coastal erosion risk management, and with responsibility for managing river and coastal flooding. However, the FWMA requires all unitary authorities and county councils, known as 'Lead Local Flood Authorities' (LLFA's), to be responsible for managing local flood risk from surface water run-off, groundwater and ordinary watercourses, and to produce a strategy for managing that risk. The FWMA requires all flood risk management authorities to co-operate across administrative boundaries. Part of the act allows for local authorities to require sustainable drainage systems for new developments although this is not yet in force.
- The [Localism Act](#) (2011) and the [National Planning Policy Framework](#) (NPPF) (2012) - The Localism Act (2011) devolves power away from national government. It gives more freedom to local government along with powers for neighbourhoods and individuals to get involved in planning and decision-making. As part of this, there is a legal obligation for local authorities to

cooperate across boundaries when preparing plans. The NPPF (2012) requires that climate change must be taken into account when preparing flood risk assessments. In addition, the NPPF outlines the role of infrastructure within the development plan process.

- The [Water Act \(2014\)](#) - The Water Act (2014) has updated the duties required of the water service regulator to 'further the resilience objective' of maintaining the long-term supply of water and sewage systems in relation to: 'environmental pressures, population growth and changes in consumer behaviour'.

3.3 SUPPORTING DELIVERY: The stakeholder landscape in Greater Manchester

GM (and the UK) has wide range of parties with interests, roles and responsibilities (sometimes statutorily driven, for example by the Climate Change Act of 2008) for addressing various areas of climate risk, both in terms adaptation and critical infrastructure protection. These responsibilities vary in terms of spatial scale (local, GM, regional or even national), the timescales over which the issues are viewed (current and potential future risks) and the mechanisms for planning and taking account of resilience issues as the climate changes. There is also a difference between stakeholders in terms of the nature of the role they play, which can broadly split into policy, practice and research. This wider stakeholder landscape is described in more detail in the standalone GM research, policy and stakeholder commentary document (Carter, Connelly, Ellis 2016), and is summarised below.

Integration of adaptation and critical infrastructure protection plans and strategies

The complexity of the stakeholder landscape for climate change adaptation and CIP presents challenges for the integration of plans, strategies and working approaches. This is true for actors responsible for wider and longer term adaptation and for those involved in CIP both in the short and longer term. However, recognition is growing that this agenda is one which benefits from closer integration, both between adaptation and critical infrastructure protection.

For example, driven by the Civil Contingencies Act 2004, a wide range of partners come together as part of GM's Local Resilience Forum (GMLRF). [Membership](#) of the GMLRF comprises a defined range of category 1 and 2 responders (the main agencies involved in the response to the majority of emergency situations and "co-operating" bodies) and partners from the voluntary sector. Whilst focussed on planning, preparing and responding to civil emergencies and their aftermath (often called disaster risk recovery or DRR) this group is increasingly looking taking a more integrated and longer term perspective of emerging and evolving risk. This includes how from climate change risk impacts both on DRR and how wider 'resilience' can be developed to climate change and other threats.

Groups like the GMLRF are also starting to formally integrate and work with other GM governance bodies. These include the GM Floods and Water Management Board, who work with other statutory agencies and groups to collectively understand and manage flood risk in GM, both now and in the future.

GM is also starting to work more closely, albeit initially focussed on infrastructure capacity, to support growth and development, with a range of critical infrastructure providers through the GM Infrastructure Advisory Group. The infrastructure providers on this group are all required to report, under the Climate Change Act (2008), on their preparedness for and plans to address climate change risk factors. However, further work is required to understand the true level of integration between the various stakeholder groups active in this area. It is not clear if the level of integration and current cross group/organisation working represents all that would be necessary to ensure GM's work on climate

change adaptation and CIP is sufficient, or if there are further areas of opportunity for joining more closely associated organisations, plans and strategies.

Political commitment

GM, its constituent Municipalities and politicians, through their commitments and roles internationally (i.e. EU Covenant of Mayors) and at a domestic level (i.e. UK [Core Cities](#) group) have had long standing and strong political commitment and leadership around environmental protection, sustainable development and, more latterly, climate change mitigation and adaptation. This has seen political commitment and leadership being made at an international, national and local level linked to increasing adaptation and resilience including:

- All ten GM districts jointly signed up to UNISDR's Resilient City Campaign with GM being accepted as [a role model city](#) (one of only 45 globally). This is promoting resilience activities in GM and increasing local level understanding of disaster risk to make cities more resilient, including to the impacts of climate change.
- GM is a signatory to [Mayors Adapt](#) (which has now been [integrated](#) with the Covenant of Mayors for Climate and Energy). The Covenant of Mayors Initiative on Climate Change Adaptation has been set up by the European Commission to engage cities in taking action to adapt to climate change. This has committed GM to developing a comprehensive local adaptation strategy or integrating adaptation to climate change into relevant existing plans.
- The ten individual districts, via GM, participate in [Climate Local](#). This is a Local Government Association initiative, supported by the Environment Agency Climate Ready service, to drive, inspire, and support council action on climate change, both to reduce carbon emissions and to increase resilience to a changing climate.
- Commitment and leadership at a Municipality level is driven by local priorities and risk but also availability of resources. Progress here therefore understandably shows more local differentiation concerning both the scale and area of focus. The following examples are a selection of approaches and initiatives being made at the GM district level, and illustrate the range of activity covering strategy through to planning and practical action:
 - **Local Climate Change action planning in the City of Manchester** – In 2009 the local authority district of Manchester came together with the University of Manchester, Friends of the Earth and TFGM and collaborated with a wider group of stakeholders to develop the City's wider collective action on climate change: [Manchester: A Certain Future](#). This created a climate change plan for the city, which was refreshed in 2013. It is now setting up new forms of governance, engagement and delivery, and this very exciting initiative is demonstrating how to galvanise collective imagination and action within the Manchester local authority district area.
 - **Flood risk and wider Integrated water management activity in Rochdale** – The Rochdale local authority district has taken a lead role in flood and water management issues on behalf of the ten GM local authority districts. This has led to active partnership working with the EA and United Utilities on a range of flood risk and Water Framework Directive management issues. This has included surface water management and capital investment in flood alleviation schemes and ecological improvements including the re-opening the River Roch in Rochdale town centre. Community flood resilience projects underway in Wardleworth, Heywood and Littleborough, working with the EA, UU and National Flood Forum and 4 Green Infrastructure Action Plans, have been produced and approved for each of the four Township areas in the Borough.

- **Howard Street SUDs** - Piloting new and innovative forms of nature based climate resilience and sustainable water management solutions – This partnership between Red Rose Forest, the Environment Agency and United Utilities has enabled a connected tree trench (20m long, 2m wide, 1.65m deep) planted with three extra-heavy London Plane trees to be constructed. In a first for the UK, rainwater is being diverted into an underlying modular system called Silva Cells filled with a bio-retention soil mix and then diverted back into the sewer. The quantity and quality of rainwater runoff is being monitored, both going into and exiting the tree pit. The project will demonstrate the impact that a large volume tree planting trench can have on the quality of contaminated rain water and the speed at which it re-enters the engineered drainage network.

Communication throughout planning processes/stakeholder engagement

Figure 8 sketches out GM’s governance structure, which shows the range of public and private stakeholders involved in the delivery of policies and strategies for GM. The private sector is represented through the Greater Manchester Local Economic Partnership (GM LEP) and the Business Leadership Council (BLC). Policies are split into thematic groups including low carbon and health and well-being. Representatives from the ten local authorities work with GM level bodies to deliver services such as transport and waste disposal.

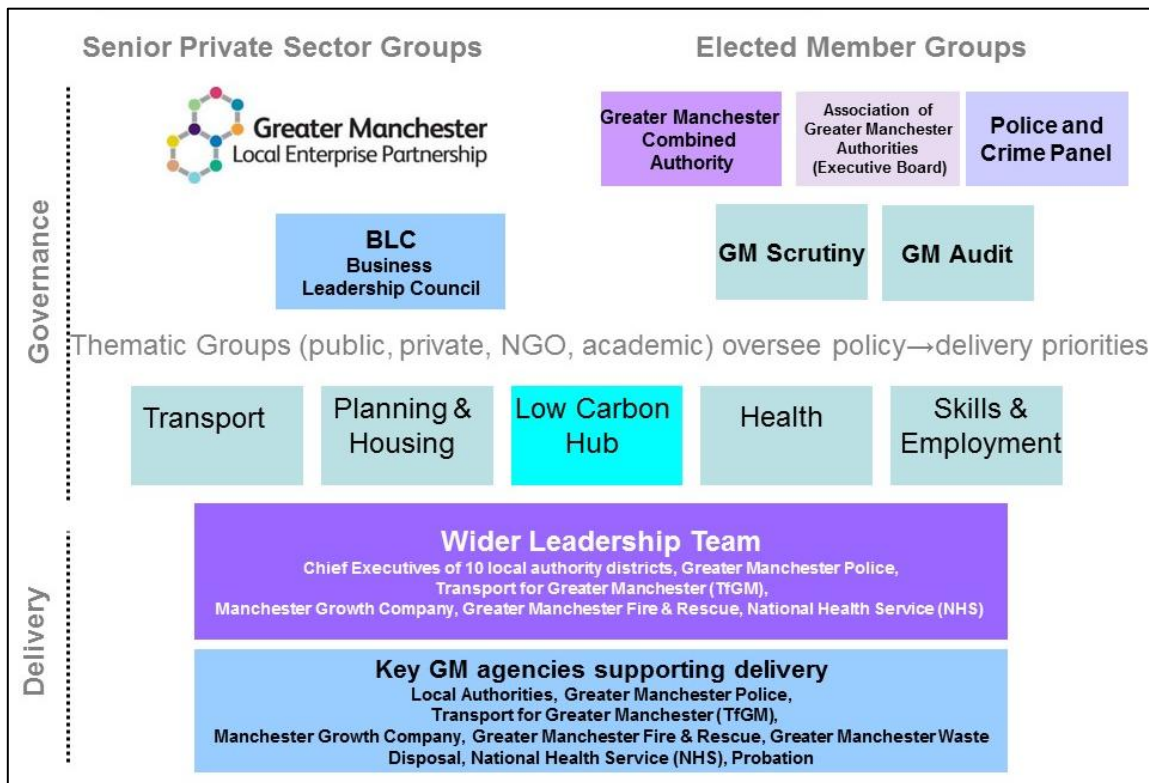


Fig 8: Governance structure of GM. Source: Greater Manchester Combined Authority

A wide range of the plans and strategies outlined in section 3.1 above, either required by law or for reasons of democratic due process and scrutiny, will involve and be underpinned by communication, consultation and stakeholder engagement throughout the process.

Some, for example the GM Combined Authority, will consult on all strategies. GM districts will do likewise for local strategies, spatial planning processes and GM will involve considerable consultation

and engagement on climate and other issues through the ongoing development of its Spatial Framework and the GM Climate Change Implementation Plan.

There are also other fora which provide a range of communication and engagement routes with a variety of relevant actors and stakeholders on issues relating to adaptation and critical infrastructure protection. These include:

- GM Floods and Water Management Board
- GM Local Resilience Forum (GMLRF)
- District Officer level technical groups (Flood Risk Officers Group, Planning Officers Group)
- The Natural Capital Group (GM's Local Nature Partnership)
- The Low Carbon Hub Board
- The GM Infrastructure Advisory Group

However, the range, reach, requirements and timescales of these engagement mechanisms are varied. The multiple opportunities for communication and engagement via these various routes will not cover a comprehensive or consistent set of CC issues, infrastructures or spatial and temporal scales. The ability to respond and influence activity concerning adaptation and resilience issues is not a requirement and is, in practice, driven by resources (which may be limited), capacity to understand/input or even a perceived or real lack of remit of one group over another. This presents a challenge for efforts both to communicate and engage throughout various sometimes disparate processes. But it also challenges the ability to link up and integrate information and expertise, and ultimately to increase understanding and action.

3.4 IMPLEMENTATION of adaptation and critical infrastructure protection measures

It is currently not possible to identify the exact extent of the implementation of adaptation or CIP measures in GM. This is not because nothing is happening, but because of a lack of collective oversight and understanding of the activities of a range of actors within the RESIN team. So, for example, even if, as is the case for some infrastructure providers/stakeholders, there are statutory plans and adaptation reports, access to or sight of these and any associated implementation programmes is not currently or readily available across GM or the RESIN project team. This is further complicated by the fact that some stakeholders are pan-GM in their focus so implementation may be set out in wider plans and strategies.

It is therefore hard to measure progress towards increasing infrastructure resilience in GM for the following reasons:

1. Implementation of adaptation and CIP measures –we do not have full information on past, present and future planned activities and the extent to which these consider and build in climate resilience.
2. A lack of sight on implementation more generally hinders our ability to understand how and if there are links between the implementation of adaptation and (critical) infrastructure protection measures across different assets and sectors.
3. The wide ranging number of actors, and their differing roles and remits, including geographic coverage means that developing a current understanding of the role and involvement of

stakeholders in implementing measures is unclear.

4. The current wide ranging financial framework and incentives for implementing measures, and its sufficiency in driving implementation, is hard to ascertain due to the complex picture.
5. More, generally communication throughout implementation processes, and importantly monitoring and evaluation of adaptation and CIP measures, is difficult due to the aforementioned complexity and lack of clarity generally around who is doing what, how they are linked and what is actually being delivered in terms of climate resilience uplift on the ground.

4 Main challenges and opportunities with regards to adaptation and critical infrastructure protection

4.1 Challenges

Although progress has been made in developing research outputs, building supportive policy and strategy frameworks, creating stakeholder networks and generating political commitment, GM still faces significant challenges regarding building urban climate resilience.

Firstly, whilst a great deal of research activity has occurred, GM still needs to better understand how the changing climate will impact on GM spatially and in terms of the specific characteristics of its socio-economic make up, its environment, its urban fabric and critical infrastructure. This is necessary in order to develop and prioritise adaptation options to build resilience. Secondly, we have a complex and interlinked (but not necessarily fully integrated) mosaic of stakeholders within and outside of GM who all share responsibility for planning and taking action to adapt and increase resilience as the climate changes. A better understanding is needed of this stakeholder landscape, particularly if there are any stakeholders who are either missing and/or need to link and work more closely together on climate resilience issues. This knowledge will help to ensure that the right individuals and organisations are engaged when responses are developed. Finally, we need to ensure that our understanding and coverage of climate change adaptation and CIP is embedded into a wide range of delivery and investment programmes covering a range of sectors and spatial scales. We must start to see investments and interventions occurring that physically increase the resilience of GM to the changing climatic conditions it will experience over the coming decades. In effect, we need to turn awareness and understanding of climate risk into action on the ground. These issues, and other related themes, are looked at in more detail below:

1. The extent and nature of climate related risk is not yet fully understood due to the complexity of interconnections between the changing climate, land use and natural processes.
2. Records have not been systematically kept of the incidence and consequences of extreme weather events impacting on critical infrastructure (and other locations and assets) located within and serving GM. This makes it difficult to generate a strategic picture of priority sectors, locations and hazard events that are of greatest relevance to the conurbation. The passing of the Flood and Waters Management Act (in 2010) has started to address this issue in the context of flooding.
3. There are issues and uncertainties concerning the accuracy of data and prediction tools, particularly regarding future flooding projections data, which is generally recognised as GM's

key hazard. This makes it challenging to develop adaptation and resilience responses, particularly regarding hard infrastructure investments that operate over long time horizons.

4. The infrastructure network (and the urban system more generally) is highly interconnected, which makes it challenging to gain a clear picture of the drivers behind and multiple consequences of climate-related events to critical infrastructure.
5. Planning and implementing adaptation strategies and actions is a very complex process as there are multiple interconnected actors, sectors and timescales involved.
6. There is a lack of information and understanding on adaptation in terms of who is doing what, who is responsible for what, and where progress is taking place. For example, it is not clear who is responsible for investing in and maintaining sustainable urban drainage systems (SUDS).
7. There is a lack of knowledge on adaptation responses that have been/are being/are planned to be undertaken by critical infrastructure providers that provide services upon which GM depends. This makes it difficult to comprehensively understand GM's current and near term future status regarding critical infrastructure resilience.
8. This lack of understanding on climate risk and ongoing adaptation actions (and decisions and actions that reduce capacity to adapt) presents a challenge to developing a strategic view of adaptation and resilience building.
9. Funding available to local authorities and other public sector agencies working in this field has to compete with a range of other statutory priorities. This is occurring against a challenging background of wider public sector funding pressures, which is having an impact on capacity of key organisations to develop and deliver adaptation and resilience responses.
10. There is a complex system of governance and ownership regarding GM's critical infrastructure networks and assets, which makes it difficult to develop and implement integrated cross-sectoral adaptation and resilience responses.

4.2 Opportunities

Although GM faces significant challenges in becoming better adapted and more resilient to the changing climate, challenges which it shares with many other cities, it does benefit from certain characteristics that can support this process. These are often local in nature.

- GM has a history of collaborative working across the ten districts that make up the conurbation, which can provide a platform to support engagement of other partner organisations involved in adaptation and critical infrastructure activities. This can, in principle, encourage a more joined up approach to adaptation that crosses sectors, stakeholder groups and spatial scales.
- There are existing legislative frameworks and statutory requirements produced at the national level, including the Climate Change Act (2008) and the Flood and Water Management Act (2010), which if applied effectively can support adaptation and resilience work locally.
- There is potential for growth in businesses and sectors providing Low Carbon and Environmental Goods and Services in GM. This could help to create jobs and economic growth, whilst also developing approaches and technologies to adapt and build resilience in GM.
- Over recent years, GM has secured greater political commitment for the adaptation and resilience through initiatives including Mayors Adapt, the Covenant of Mayors and the UNISDR Resilient Cities programme. This provides a crucial building block for action on this agenda.

- There are established and active connections between GM planners and decision makers in the public sector and universities, research consultancies and community groups working on issues linked to climate change adaptation and resilience. This provides a platform for knowledge exchange and collaborative working. This platform has already delivered positive outcomes including research outputs influencing climate-related strategies and policies.
- There is the potential to more closely integrate ‘hard’ critical infrastructure and green infrastructure to achieve synergies. Here it is notable that there has been increasing recognition over recent years in GM that green infrastructure can be seen as a form of critical infrastructure that provides crucial services for the city and it’s wider region. Manchester’s Green and Blue Infrastructure Strategy makes this point.
- Identifying, assessing and communicating the multiple social, economic and environmental benefits that can be achieved from critical infrastructure adaptation and resilience approaches could provide a route into achieving wider support for and engagement in related strategies and actions.
- If a clear and evidenced argument can be made that building adaptation and resilience measures into existing and planned critical infrastructure can enhance the economic competitiveness of Greater Manchester, this would help to generate wider support for related initiatives amongst political and private sector decision makers. In effect, this would help to support the development of a ‘business case’ for action.
- GM is currently engaged in a process of ‘devolution’ of powers from the national to local level in areas including transport, housing and spatial planning. This presents an opportunity for integrating adaptation and resilience thinking and action into local agenda setting and investment strategies.

4.3 GM’s achievements in terms of adaptation and critical infrastructure protection to date

It is helpful to identify GM’s key adaptation and CIP achievements in order to demonstrate progress. These include:

1. **Developing a GM Climate Change Strategy** that recognises adaptation as an important agenda, and includes a relevant high level objective on this theme. The Greater Manchester Strategy, which is the key overarching framework guiding development and growth across the conurbation, also recognises the importance of the adaptation and resilience agenda.
2. The **political commitment generated around the agenda provides an important platform for future progress**, and for turning knowledge and understanding of climate risk into action ‘on-the-ground’.
3. **Local universities, research consultancies and community groups have undertaken relevant research** and activity in this field for over a decade. This provides a useful resource to support ongoing and future adaptation and resilience work.
4. **Extensive work of the GMLRF and its supporting staff** who have driven a package of work and initiatives that have started to consider climate resilience alongside wider DRR and community risk and resilience issues. This has seen GM sign up as a role model city within the UNISDR’s resilient cities campaign and participate in the EU funded U-SCORE project, which is developing a ‘city resilience scorecard’.

4.4 GM's needs for adapting to climate change impacts and protecting (critical) infrastructure

Based on this overview of challenges and opportunities facing the adaptation and resilience agenda in GM, it is possible to identify four overarching needs that would help to progress this agenda locally. These concern critical infrastructure, and progressing adaptation and resilience goals relating to other sectors and themes.

1. **GM needs to better define what needs to be done**, over what timescales and in which locations, so as to prioritise action. This is particularly important as resources, especially in the public sector, are becoming increasingly limited for adaptation and resilience activity so targeted strategies and actions are needed.
2. **GM needs to recognise, identify and actively promote the co-benefits associated with taking action to build resilience**, which cross many socio-economic and environmental issues. This can help to support action in an era of falling public sector budgets.
3. There is a **need to take adaptation and resilience messages and related high level strategic and policy commitments and embed these into a wide range of plans and programmes**. Support will then be needed to help enable a wide range of actors to implement these plans and programmes.
4. There is a **need to plug into and influence ongoing strategies and programmes that connect to adaptation and resilience**, given the current impacts of climate change. Stakeholders who are responsible for developing and implementing existing strategies and programmes should therefore be identified and subsequently involved in adaptation and resilience processes. This could initially be supported by an analysis of existing and forthcoming policies, plans and programmes that are relevant to adaptation and resilience, both from a perspective of advancing and hindering related goals.

References

- Cabinet Office. n.d. Section A: Introduction, Definitions and Principles of Infrastructure Resilience (Guidance). Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/78902/section-a-natural-hazards-infrastructure.pdf
- Cavan, G. 2010. Recent changes and trends in Greater Manchester's climate, EcoCities Project, Manchester. Available at: http://media.adaptingmanchester.co.uk.ccc.cdn.faelix.net/sites/default/files/Recent_changes_and_trends_GM_climate.pdf
- Cavan, G. 2011. Climate change projections for Greater Manchester, EcoCities Project, Manchester. Available at: http://media.adaptingmanchester.co.uk.ccc.cdn.faelix.net/sites/default/files/Climate_change_projections_GM_final.pdf
- Carter, J. G., Connelly, A. 2011. Adapting to climate change: a Greater Manchester policy perspective, EcoCities Project, Manchester. Available at: <http://media.adaptingmanchester.co.uk.ccc.cdn.faelix.net/sites/default/files/EcoCitiespolicyreview.pdf>
- Carter, J.G., Lawson, N. 2011. Looking back and projecting forwards: Greater Manchester's weather and climate, EcoCities Project, Manchester. Available at: <http://media.adaptingmanchester.co.uk.ccc.cdn.faelix.net/sites/default/files/EcoCitiesLookingbackprojectingforwards.pdf>
- Carter, J.G and Kazmierczak, A. 2013. Evidencing and Spatially Prioritising Weather and Climate Change Risks in Greater Manchester. Centre for Urban and Regional Ecology, The University of Manchester.
- Carter, J.G. 2015. Flooding of Transport Infrastructure Networks and Assets in Greater Manchester. Centre for Urban Resilience and Energy, University of Manchester.
- Carter, J.G., Cavan, G., Connelly, A., Guy, S., Handley, J., Kazmierczak, A., 2015. Climate change and the city: Building capacity for urban adaptation. *Progress in Planning*, 95, 1–66. Available at: <http://www.sciencedirect.com/science/article/pii/S0305900614000397>
- Carter, J.G. Connelly, A, Ellis, M. 2016 GM's climate adaptation and CIP research, policy and stakeholder landscape.
- GMCA 2012. The Greater Manchester Climate Strategy 2011-2020. Available at: http://media.ontheplatform.org.uk/sites/default/files/gm_climate_change_strategy_2011_0.pdf
- GMCA 2013. Stronger Together, Greater Manchester Strategy 2013. Available at: file:///C:/Users/Admin/Downloads/GM_Strategy_Stronger_Together.pdf
- Kazmierczak, A., Carter, J., 2010. Adaptation to climate change using green and blue infrastructure: A database of case studies. Available at: http://www.grabs-eu.org/membersArea/files/Database_Final_no_hyperlinks.pdf
- Kazmierczak, A., Cavan, G., 2011. *Surface water flooding risk to urban communities: Analysis of vulnerability, hazard and exposure*. *Landscape and Urban Planning* 103(2), pp. 185-197.
- Kazmierczak, A. 2012. Heat and social vulnerability in Greater Manchester: a risk response case study. EcoCities project, Manchester. Available at: <http://www.adaptingmanchester.co.uk/sites/default/files/EcoCitiesHeatandPeople.pdf>
- Lindley, S.J., Handley, J.F., Theuray, N., Peet, E. and McEvoy, D. 2006. Adaptation strategies for climate change in the urban environment: assessing climate change related risk in UK urban areas. *Journal of Risk Research*, 9(5), 1-26.
- Lindley, S.J., O'Neill, J., Kandeh, J., Lawson, N., Christian, R., O'Neill, M., 2011. Climate change,

- justice and vulnerability. Joseph Rowntree Foundation, York [UK]. Available at:
<https://www.jrf.org.uk/report/climate-change-justice-and-vulnerability>
- Manchester City Council. 2015. Manchester's Great Outdoors: a green and blue infrastructure strategy for Manchester. Manchester City Council, Manchester.
<http://media.onthepatform.org.uk/sites/default/files/Manchester%20Green%20and%20Blue%20Strategy%202.pdf>
- Marmot, M., Allen, J., Goldblatt, P. et al. 2010. Fair society, healthy lives: the Marmot review – strategic review of health inequalities in England post-2010:
<http://www.instituteofhealthequity.org/projects/fair-society-healthy-lives-the-marmot-review>
- Public Health England. 2015. Public Health Outcomes Framework. Available at:
<http://www.phoutcomes.info/public-health-outcomes-framework#gid/1000044/par/E12000004>
- ONS. 2014a. 2012-based Subnational Population Projections for England
<http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-335242>
- ONS. 2014b. Local Area Analysis of Qualifications Across England and Wales. Available at:
<http://www.ons.gov.uk/ons/rel/census/2011-census-analysis/local-area-analysis-of-qualifications-across-england-and-wales/rpt---local-area-analysis-of-qualifications-across-england-and-wales.html?format=print>
- ONS. 2015a. National and regional profiles: Employment and Unemployment. Available at:
<https://www.nomisweb.co.uk/reports/lmp/gor/contents.aspx>
- ONS. 2015b. Statistical bulletin: Annual Survey of Hours and Earnings, 2015, Provisional Results. Available at: http://www.ons.gov.uk/ons/dcp171778_424052.pdf
- Oxford Economics. 2014. Greater Manchester Forecasting Model. Available at:
http://neweconomymanchester.com/stories/1775-greater_manchester_forecasting_model
- Smith, C. L., Webb, A., Levermore, G. J., Lindley, S. J., Beswick, K. 2011. Fine-scale spatial temperature patterns across a UK conurbation. *Climatic Change* 109, no. 3-4, 269 – 286.
- TEP/AGMA. 2008. Towards a Green Infrastructure Framework for Greater Manchester. Available at:
http://www.greeninfrastructurenw.co.uk/resources/1547.058_Final_Report_September_2008.pdf
- Twigger-Ross, C., Orr, P. Brooks, K., Sadauskis, R., Deeming, H., Fielding, J., Harries, T., Johnston, R., Kashefi, E., McCarthy, S., Rees, Y. and Tapsell, S. 2015. Flood Resilience Community Pathfinder Evaluation: Final Evaluation Report. Available at:
<http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18744>
- Wedawatta, G & Ingirige, B. 2012, 'Resilience and adaptation of Small and Medium-sized Enterprises to flood risk', *Disaster Prevention and Management: An International Journal*, 21(4), pp.4