

# Greater Manchester Local Climate Impacts Profile (GMLCIP).


# Greater Manchester Local Climate Impacts Profile (GMLCIP) and assessing Manchester City Council's vulnerability to current and future weather and climate

A report on the development of a LCLIP for Greater Manchester and on the vulnerability assessment of Manchester City Council with reference to meeting the requirement of Level 1 of NI 188

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# Executive summary

Eco Cities is a joint initiative between the University of Manchester and Bruntwood, drawing on the expertise of the Manchester Architecture Research Centre, Centre for Urban Regional Ecology and Brooks World Poverty Institute. Eco Cities seeks, by the end of 2011, to provide Manchester with its first blueprint for an integrated climate change adaptation strategy. Stemming from this initiative and close collaborative working on issues relating to climate change adaptation, the University of Manchester is advising Manchester City Council on meeting Level 1 of National Indicator NI 188 *Adapting to Climate Change* by addressing issues surrounding current and future vulnerability to climate change in Greater Manchester. This report details the key outcomes of this work, and the development of a Local Climate Impacts Profile (LCLIP) for Greater Manchester.

The assessment of current vulnerability to climate and weather related events in Greater Manchester is achieved through the development of a LCLIP. Whilst current UK Climate Impacts Programme (UKCIP) LCLIP guidance (UK Climate Impacts Programme 2008) recommends that local authorities (LAs) consider weather events and their impacts over the last five years, the LCLIP developed for Eco Cities considers weather related events which have impacted on human health/well-being and/or infrastructure or have caused severe disruption to services over two time scales: since 1998 in as much detail as is possible and the principal events from 1945 to 1997. It also considers the severity of the events in assessing their relative impacts. Significantly, the LCLIP covers the whole of the Greater Manchester conurbation, not on individual local authorities.

The principal sources of data on past weather related events used to compile the Greater Manchester LCLIP (GMLCLIP) are from the local media, a review of relevant literature, and through reference to the LAs. An assessment was also made to media reports to weather reports from Ringway, which the nearest weather station to Greater Manchester with a continuous weather data set.

The GM LCLIP identifies 190 weather events between 1945 and 1997 and 137 events between 1998 and 2009. 43% of events resulted from precipitation causing flooding and 28% were the result of damage due to storm induced wind. The GM LCLIP demonstrates that flood is the principal cause of damage to property and infrastructure, but that human health is most severely affected by wind and heat. Summer storm induced pluvial flooding is now more prevalent that riverine flooding. Vulnerability to storm and heavy rainfall events has increased in the last 10-15 years. Further, whilst prolonged cold events and heavy snow falls in Greater Manchester are receding, they continue to cause severe disruption when they do occur.

The GM LCLIP provides some evidence of identifiable thresholds concerning the impact of weather events: days with a maximum temperature greater than 30.9ºC coincided with negative consequences of high temperature; days when precipitation exceeded 38mm resulted in flooding although many flood events happened when the daily precipitation at Ringway was in the region of 25-30mm and even lower; days with a maximum gust speed in excess of 60 knots had an impact. However, these findings are only indicative as not all weather related impacts have been identified and because the meteorological data is only from Ringway which is situated at the southern periphery of the conurbation. Further, knowledge of past weather related events is hampered by the lack of a systematic and inclusive approach to data collection by the Environment Agency, the insurance industry, the utility industry, emergency service agencies such as the police and fire services, and in particularly by Local Authorities.

With the opportunity to extent the analysis, the GM LCLIP could match impacts on human health and infrastructure to less extreme weather events than has so far been undertaken. It would also be useful to consider weather data from other stations within the conurbation, and to explore the change and frequency of extreme weather events in Greater Manchester over time. UKCIP 09 might provide sufficient data on climate change scenarios in the Northwest to allow for an assessment of the likelihood of some of the preliminary thresholds identified within the LCLIP being breeched. UKCIP climate predictions are based on changes in key climate variables between 1961 and 1990 and a future study should consider LCLIP events over the same time scale.

Future vulnerability to climate change is assessed by reference to UKCIP02 climate projections for Northwest England which indicate a small increase in maximum summer temperature by the 2020s. However, by the 2050s, Manchester could see peak summer temperatures similar to present day cities in Holland and Belgium, whilst by the 2080s, peak summer temperatures could be equivalent to those currently experienced in Berlin, Frankfurt and Rome. Peak temperatures in Central Manchester could reach 34ºC in the 2080s, with significant impacts on human comfort likely from the 2050s onwards. Winter minimum temperature also rises across the region, and even for the low emissions scenario there are very few places in the region with average minimum temperatures below freezing. Seasonal patterns of rainfall are set to change significantly. The average level of rainfall during the summer throughout the region is anticipated to decrease. By the 2080s, for the high scenario, virtually every summer will be drier than the 2003 summer in Manchester with up to 60% less rainfall that at present. Average winter rainfall is expected to increase by up to 30% towards the end of the century under the high emissions scenario. Significantly, the number of depressions moving across the UK from North Atlantic (particularly in winter) is predicted to increase leading to the possibility of more frequent and more intense storm events.

The effect of future vulnerability to weather and climate in Greater Manchester is further strengthened through consideration of completed and ongoing University of Manchester research projects. Adaptation Strategies to Climate Change in the Urban Environment (ASCCUE) highlights the importance of urban greenspace in moderating the effect of surface temperature, protecting biodiversity and in decreasing runoff. Ongoing climate change related studies at the University are determining the extent of the urban heat island effect and appropriate building design to adapt to increased heat in the urban environment.

Using the outputs of the LCLIP and the analysis of data on future climate change, the vulnerability of a selection of six of Manchester City Council's priority service areas is assessed in line with Local and Regional Partnership Board (LRAP) guidance for NI 188 (Local and Regional Partnership Board 2008). Current and future weather/climate related events and their potential impacts on the key functions of the service areas are considered. Key findings of the vulnerability assessment include:

- *Manchester Leisure Services* need to take a strategic view of the role of parks from a climate change adaptation perspective; consider the impacts of significantly increased use of parks and outdoor facilities; consider potential flooding in parks but also the potential use of these areas in flood mitigation; be aware of the need to provide human comfort in a warmer climate and the potential impacts of heat, wind and water on their infrastructure and their outdoor facilities.
- *Eastlands Homes (Registered social landlord with charitable status)* need to consider the impact of heat on human well-being, the increased possibility of flood in areas with social housing and wind related impacts on building maintenance.
- *Environmental Services (Green Spaces division)* will need to respond to a longer growing season and potential decrease in summer and autumn soil moisture content increasing stress to trees and grass verges, along with increase in storm/wind and precipitation related events impacting on management services. There will be a need to consider more adaptable tree species that are less water dependent.
- *Adult Social Care (Part of Social Services)* will need to take account of increased potential for heat stress and heat related illnesses for all vulnerable adults especially the elderly and disabled and potential extra protection of people with mental disabilities during storm events and to the physically disabled during flood events. Potential impacts of storm/wind and flood on infrastructure and increased problems of mobility due to flood will also impact on service provision.
- *Corporate Services (ICT- Technology and infrastructure section)* is vulnerable to climate related power failures and extreme heat breaching threshold temperature and causing a failure of the system.

- *Transport Services Unit in Chief Executive's Department (Highway Services and Transport Policy Unit)* must be aware that transport infrastructure is potentially vulnerable to storm/wind, heat and flood and that these impacts are likely to intensify in the future. Drainage issues due to increased flooding will impact on this department which is also potentially vulnerable to climate related power failure.

Population growth, increased mobility and tourism and increases in urban density will have an indirect impact over and above the direct effects of climate change on the provision of urban green spaces, leisure services, transport, social housing and adult care services.

The GMLCLIP demonstrates that LA services most at risk to flooding, wind/storm and heat are most vulnerable to the direct impacts of climate change. Manchester City Council needs to take a holistic view of how climate change affects vulnerability to the wider range of the Council's services and on other service providers working with the LA. Reducing vulnerability to urban flooding requires close liaison with the Environment Agency, the local utility company, the police and the fire services. Flooding also affects planning and civil contingencies. Reducing vulnerability to wind and storm involves planning and building control. Reducing vulnerability to heat requires the intervention of planning departments and of the Health Protection Agency. Reducing vulnerability to drought requires close liaison between the LA and the water utility company. Manchester City Council needs to engage with all departmental managers to ensure that a range of officers are actively involved in the assessment of vulnerability to climate change and the generation of strategic responses to related impacts within their respective departments.

# Introduction and objectives

Eco Cities is a joint initiative between the University of Manchester and Bruntwood, drawing on the expertise of the Manchester Architecture Research Centre, Centre for Urban Regional Ecology and Brooks World Poverty Institute. Eco Cities seeks, by the end of 2011, to provide Manchester with its first blueprint for an integrated climate change adaptation strategy. Eco Cities is an international initiative, yet the Greater Manchester conurbation is a central focus of the project.

Several significant initiatives on climate change adaptation have emerged over the past year that strengthens the links between the University of Manchester and Manchester City Council on issues relating to climate change adaptation. Indeed, the University and the City Council are in the process of agreeing a Memorandum of Understanding to collaborate more closely on climate change issues. A key delivery mechanism for the Memorandum is the Eco Cities project. Manchester City Council approached the University to offer advice and assistance on working towards level 1 of National Indicator 188 which relates to climate change adaptation in local authorities. This report focuses on the outcomes of this engagement.

National Indicator 188 (NI188) "Adapting to Climate Change" aims to embed the management of climate risks and opportunities across LAs and their local strategic partnerships and encourages LAs to take appropriate adaptation actions where required. NI 188 requires LAs to report the level of preparedness they have reached against 5 levels of achievement (Table 1).

| | |
|---|---|
| Level 0 | Getting started |
| Level 1 | Public commitment and impacts assessment |
| Level 2 | Comprehensive risk assessment |
| Level 3 | Comprehensive action plan |
| Level 4 | Implementation, monitoring and continuous review |

Table 1 National Indicator 188 Levels of Achievement 0 to 4

An early objective of the Manchester 'node' of Eco Cities, which is of direct relevance to meeting level 1 of NI188, is to identify the principal extreme weather related events that have occurred in Greater Manchester (GM) in the past which have resulted in impacts that affect human health/well-being, have caused damage to the urban infrastructure or have severely disrupted services. Climate change projections and scenarios from United Kingdom Climate Impacts Programme (UKCIP) are based on the degree to which the climate will drive changes in current weather patterns. Adapting to these changes in weather will require a sound knowledge of past weather related events and their impacts which provide a baseline from which to consider the impact of future changes in weather and climate. Robust information about the location, the extent and the severity of the impacts of events caused by

extreme weather conditions in the past is thus a prerequisite to the formulation of adaptation strategies to climate change. UKCIP recommend that councils prepare for such events through the preparation of a Local Climate Impacts Profile (LCLIP).

The initial Eco Cities study to report on current vulnerability to climate change in Greater Manchester involves the preparation of stages 1.1 to 1.4 and stage 4.1 of Level 1 of a LCLIP for Greater Manchester. Table 2 provides details of the stages of the LCLIP process. To meet level 1 of NI 188 UKCIP recommends that LAs undertake a LCLIP. The work undertaken on the GM LCLIP by the University of Manchester is therefore of much value in meeting the requirements of NI188.

| | | |
|---|---|---|
| 1.1 | Study the local media | Assemble news of significant weather events and their consequences over the past five years. Ensure the report includes data on the weather (e.g. temperature, rainfall) |
| 1.2 | Extend the boundaries of journalistic information | The newspaper stories will not always be representative so make enquiries to extend the record. Informal enquiries around the council or local resource centres may provide information on other incidents. |
| 1.3 | Produce an initial data base | At the minimum you should catalogue:<br>• the weather events<br>• the consequences of each weather event<br>• any action taken by the council at the time |
| 1.4 | Produce headline messages | Your primary data base will already be extensive and complex. Produce a simple summary with 4 or 5 headline weather impacts. |
| 4.1 | Gather historical data | Certain decisions may be informed by knowledge of the more extended history of weather and climate in your locality. For example, with your new knowledge of critical thresholds etc. you can explore the pattern of similar events over the past 50 years. In some cases, historical weather events can be used as the basis for assumptions about what the future weather might look like. Historical weather datasets are available free from the Met Office, although there may be a financial Cost involved for more detailed information. |

Table 2 Local Climate Impact Profile Stages 1.1, 1.2, 1.3, 1.4 and 4.1.

The Eco Cities study uses the Greater Manchester LCLIP (GMLCLIP), and appropriate climate and weather studies, to develop an understanding of

current vulnerability to weather, including extreme weather events in Greater Manchester and to identify significant potential impacts associated with future weather and climate. The LCLIP developed for Eco Cities goes into considerably more detail on past events than those recommended by UKCIP to LAs for the development of a LCLIP by considering events, and their impacts, over two periods of time and by drawing comparisons between them. The Eco Cities GMLCLIP considers events which have occurred since 1945, and in particular those which have occurred since 1997 whereas UKCIP guidance to LAs only recommends the assembly of news cuttings of significant weather events and their consequences over the last five years.

University of Manchester (in conjunction with Red Rose Forest) is advising Manchester City Council on meeting Level 1 of NI 188. This requires reference to the guidance on NI 188 which has been developed by the Local and Regional Partnership Board (LRAP) to support local government and regional bodies on adapting to climate change. The aims of Level 1 are set out in Table 3.

| | |
|---|---|
| 1.1 | To demonstrate the leadership role of the authority by making a public commitment to respond to the threats and opportunities of a changing weather and climate |
| 1.2 | To develop an understanding of current vulnerability to weather, including extreme weather events |
| 1.3 | To identify significant potential impacts associated with future weather and climate |
| 1.4 | To ensure that relevant managers/elected members are aware of these and other potential impacts, and are preparing to address them |
| 1.5 | Supplementary aim: to develop and maintain a monitoring system to collect information on impacts of weather events |
| 1.6 | Supplementary aim: to develop and maintain a weather and climate database for evidence of past trends |

Table 3 Aims of Level 1 of National Indicator 188 Adapting to Climate Change (Source: LRAP 2008).

This report provides the relevant information for Manchester City Council to meet the requirements of sections 1.2, and 1.3 of NI 188 level 1 as prescribed by LRAP and detailed in Table 3, as well as providing the background information for the Council to meet aim 1.4.

The GMLCIP could be aggregated to each of the 10 GM LAs separately, but adaptation strategies to climate change such as flood storage basins and green/blue infrastructure cross GM LA boundaries. Figure 1 relates the physical geography of Greater Manchester to the LA boundaries in the conurbation, indicating that cross boundary adaptation strategies will ultimately be necessary where, for example, rivers cross LA administrative

boundaries. Therefore this report addresses current and future vulnerability in Greater Manchester as a conurbation.

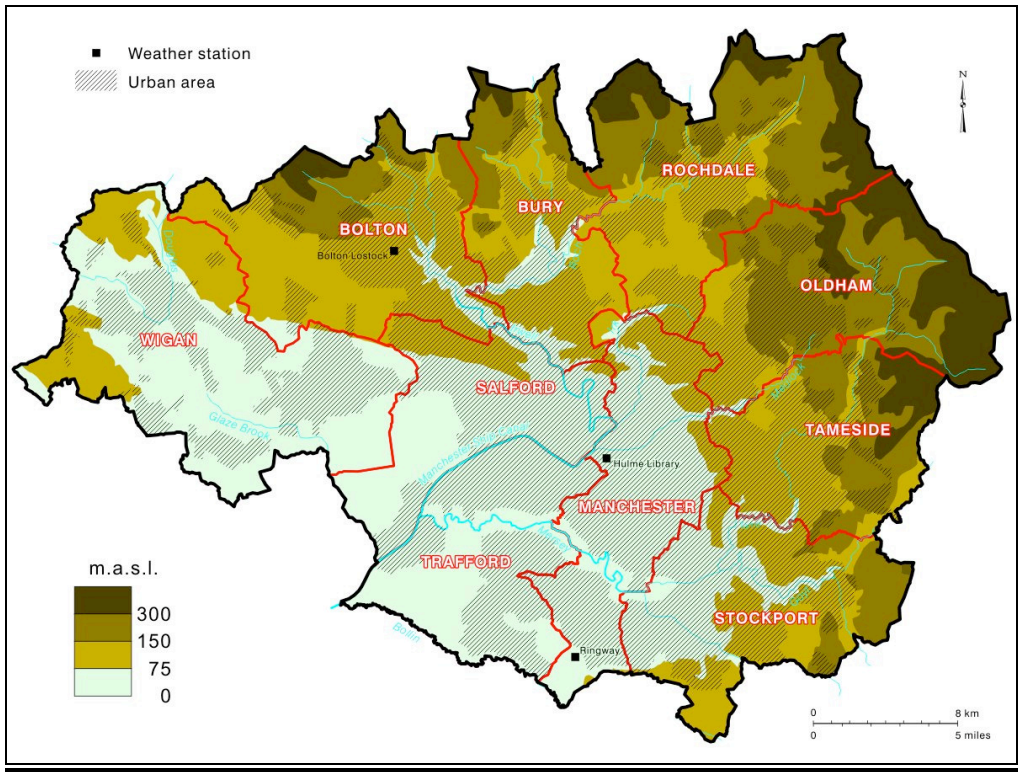


Figure 1: Greater Manchester: physical geography, LA boundaries and principal weather stations

The report is split into 4 sections which consider:

1 The consequences of extreme weather related events and the severity of their impacts and by providing insights into recent changes to the climate of NW England drawing on the findings of the GMLCLIP - current weather and climate.
2 Existing regional climate studies and what data/organisations/systems would be useful in helping to understand future weather and climate (review of appropriate UKCIP data) and the identification of potential impacts; including a review of data/organisations useful in helping to understand and to monitor future weather and weather related impacts - future weather and climate.
3 The assessment of vulnerability of key service areas within Manchester City Council to current and future impacts of weather and climate - vulnerability assessment.
4 Conclusions and recommendations arising from this study.

# 1. Current weather and climate

NI 188 Level 1 requires the development of an understanding of current vulnerability to weather, including extreme weather events. Current vulnerability has been assessed via the development of the GMLCLIP and by analysis of UKCIP data on recent trends in the climate of the Northwest Region. The key findings of this analysis are presented below, with a particular focus on the GM LCLIP. Section 3 utilised this data to assess the vulnerability of a selected list of Manchester City Council's priority service areas to trends in current weather and climate.

## 1.1 Regional climate studies

The seminal study of climate in the North West Region is:

> Tufnell, L. 1997 North West England and the Isle of Man *In* Wheeler, D. and Mayes, J (eds) *Regional Climates of the British Isles,* Routledge, London, 181-204. This study details the climatic patterns which drive the region's weather.

The latest study on climate variables is in the first of the UKCP09 scientific reports:

> 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.

The key findings from this report covering climate change in the Northwest between 1961 and 2006 are summarised in Table 4.

| | Spring | Summer | Autumn | Winter | Annual |
|---|---|---|---|---|---|
| **Mean Temperature (ºC)** | 1.44 | 1.45 | 1.07 | 1.81 | **1.40** |
| **Daily max temperature (ºC)** | 1.67 | 1.63 | 1.13 | 1.93 | **1.55** |
| **Daily min temperature (ºC)** | 1.25 | 1.31 | 1.03 | 1.70 | **1.29** |
| **Days of air frost** | -5.9 | -0.1 | -3.2 | -13.1 | **-24.4** |
| **Total precipitation (% change)** | 6.3 | -13.2 | 5.6 | 43.0 | **8.8** |
| **Days of rain > 1mm** | 0.4 | -1.1 | 2.9 | 6.8 | **7.5** |

Table 4 Changes in key climate variables in Northwest England (1961-2006)

It is clear from the data included in Table 4 that the Northwest region has experienced significant change in its climate over the past four decades. Increases in temperature, particularly over the winter months, are marked. Seasonal changes in rainfall are also apparent, with the summer months becoming drier and the winter months considerably wetter. The report also found a significant increase in the number of severe storms over the UK as a whole since the 1950s.

## 1.2 GMLCLIP methodology

The aim of the LCLIP method was to collect data on weather related events in Greater Manchester which have resulted in impacts on human health/well-being, infrastructure of any kind, or cause severe disruption to services. Data has been sought in as much detail as possible from 1998 to the present day and on the principal events which occurred between 1945 and 1997 which have resulted in:

- Flooding
- Heat stress
- Storm damage and tree falls
- Lightning damage and wild fires
- Weather related transport damage and delays
- Ground instability (land slides and subsidence)
- Poor air quality due to fog and smog
- Drought
- Extreme cold (hypothermia and ice damage)

The events have also been classified according to the severity of the impact on an ascending scale.

- *Severity level 1:* Minimal disruption to services such as delays/cancellations, no known impacts on health/well-being.
- *Severity level 2:* More severe disruption to services and impacts on the public such as minor flood events, minimal impacts on health/wellbeing
- *Severity level 3:* Substantial disruption to services and impacts on the public such as medium flood events and wind damage, localised impacts on health/wellbeing
- *Severity level 4:* Severe disruption to services and impacts on the public such as multiple flood events affecting many properties, widespread impacts on health/wellbeing including injuries requiring hospitalisation.
- *Severity level 5:* Extreme events causing widespread and prolonged disruption to services, severe impact on health/wellbeing, including death.

### 1.2.1 Sources of data:

In compiling the LCLIP, five key sources of data were utilised:

1. Media reports in the local press.
2. Literature review, including strategic flood risk assessments.
3. Consultation with local academics and a local amateur weather forecaster, the insurance industry, the Greater Manchester Fire and Rescue Service, Manchester CC Civil Contingencies, the Environment Agency, the Health Protection Agency, NHS Northwest and the Northwest Public Health Observatory.

4. Data supplied by AGMA LAs who were asked to collate data from their civil contingencies, education, highways, social services, drainage, media and archive departments.
5. Matching media reports to weather reports from Ringway where precipitation exceeded 30mm/day, wind exceeded 60 knots, day time heat exceeded 30ºC and where night time temperatures were below -12ºC. These parameters were established in consultation with the Met Office Regional Advisor- Northwest England.

The data base of recorded weather events has been enhanced with information on the prevailing weather patterns at the time of the most serious events. This was supplied by Alan Goodman, the Met Office Regional Advisor- Northwest England. Claire Smith, Climatologist at University of Manchester has extracted daily data for Ringway from the British Atmospheric Data Centre (BADC) for the period 1960-2004 and considered the feasibility of defining weather related thresholds likely to result in events which will impact on human health/wellbeing, infrastructure and housing or have caused disruption to services in the Greater Manchester area.

1.2.2 Caveat to the methodology:

Whilst the data base covering past weather related events produced for the Eco Cities project by University of Manchester is representative of best practice as currently prescribed by UKCIP to meet the requirements of a LCLIP for the purposes of NI188, there are certain limitations in the methodology. These include:

- The press is inconsistent in recording weather related events. As well as depending on the whims of journalists, the recording of such events will also be influenced by the amount of other newsworthy events at the time. Also, local events which took place on a Saturday could be under-recorded because the next edition of the Manchester Evening News is not until Monday PM.
- It is not always possible to extrapolate the precise location of the event from media reports. For example, an event is invariably recorded as having taken place “in Salford”, “in the Irwell Valley”, “across north Manchester”.
- Many LA officers charged with the delivery of an LCIP have experienced difficulty in obtaining records of past weather related events from within their respective departments. The recording of past weather related impacts by LAs is haphazard, a weakness that should ideally be addressed if LCLIPs are to become more thorough in the future.
- Severity of the impacts of the event is the author’s assessment of the severity of the impact regardless of the prevailing weather. It is limited by the extent and the accuracy of media reports and thus by the author’s subjectivity. It is acknowledged that this scale is subjective and depends on the opinions of the authors, but it is nevertheless intended to bring an additional layer of detail to the analysis.

## 1.3 Findings:

*1.3.1 Relating events to impacts*

The GMLCIP data base is a living document and will be added to throughout the lifetime of the Eco Cities project. However, the GMLCIP is now at the stage at which valuable insights can be drawn into the impacts of weather and climate in Greater Manchester. Alongside being of use to Manchester City Council in developing their adaptation strategies, it will be shared with the Association of Greater Manchester Local Authorities (AGMA) who will be able to utilise it to take forward NI188 requirements and climate change adaptation work across the conurbation

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By end March 2009 the data base comprised 190 weather related events between 1945 and 1997 and 137 events between 1998 and 2009 and initial analysis of the LCLIP database highlights several significant findings. To best assess the relative impact (the consequences) of each type of event, the quantity (the number) of events in each category is multiplied by the severity of the events and then averaged. The causation of the events is also considered in the light of key climate variables in Northwest England between 1961 and 2006 (Table 4):

- *Climatic events in GM: distribution by type of all events in the LCLIP according to relative impacts (quantity x severity)* (Figure 2):
    - 1945 – 1997: 38% Flooding, 28% storm/wind, 18% cold/snow/ice, 10% Fog/smog/air pollution, 5% heat, 1% other (drought, air quality)
    - 1998-2007: 48% flooding, 28% storm/wind, 14% cold/snow/ice, 5% heat, 3% fog/smog, 2% other (wild fire, drought, air quality)
    - The effects of recent climate change are reflected in the decrease in cold related events since 1997 which is be attributable to the increase in mean temperature and the increase in flooding since 1997 which is attributable to the increase in total precipitation (Table 4). The decrease in fog/smog related events is primarily due to the effect of the clean air acts of the 1960s.

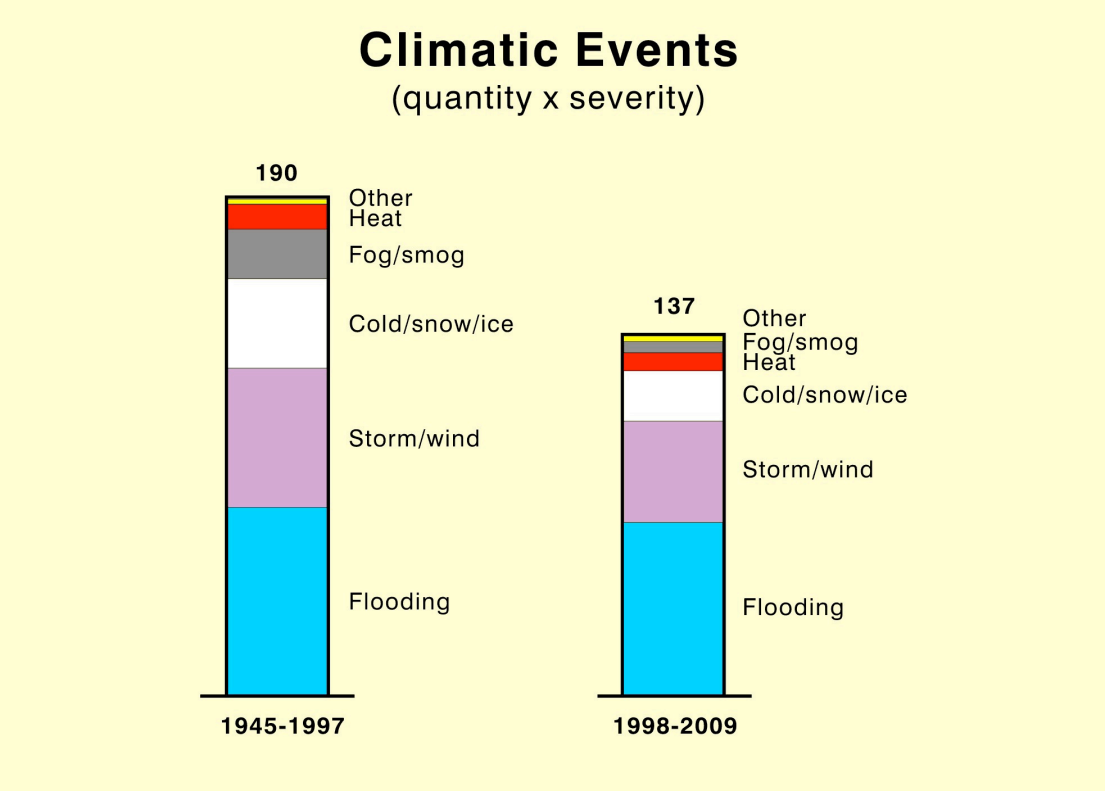


Figure 2 Climate events in Greater Manchester

- *Cold weather events:* The last very serious cold related event (Figure 3) pre 2009 was in 1995, but the ability of snow/ice to disrupt services has not diminished despite reduced severity of the impact.
    - 1998 – 2009: 19 events (av. 1.90 per annum), av. severity 1.78
    - 1945 – 1997: 33 events (av. 0.66 per annum), av. severity 2.91
    - The effects of recent climate change are reflected in the increase in the amount of these events which is attributable to much greater levels of winter precipitation. There has also been a substantial decrease in their severity, which can be attributed to the increase in mean winter temperature and the decrease in days of air frost over the region (Table 4).

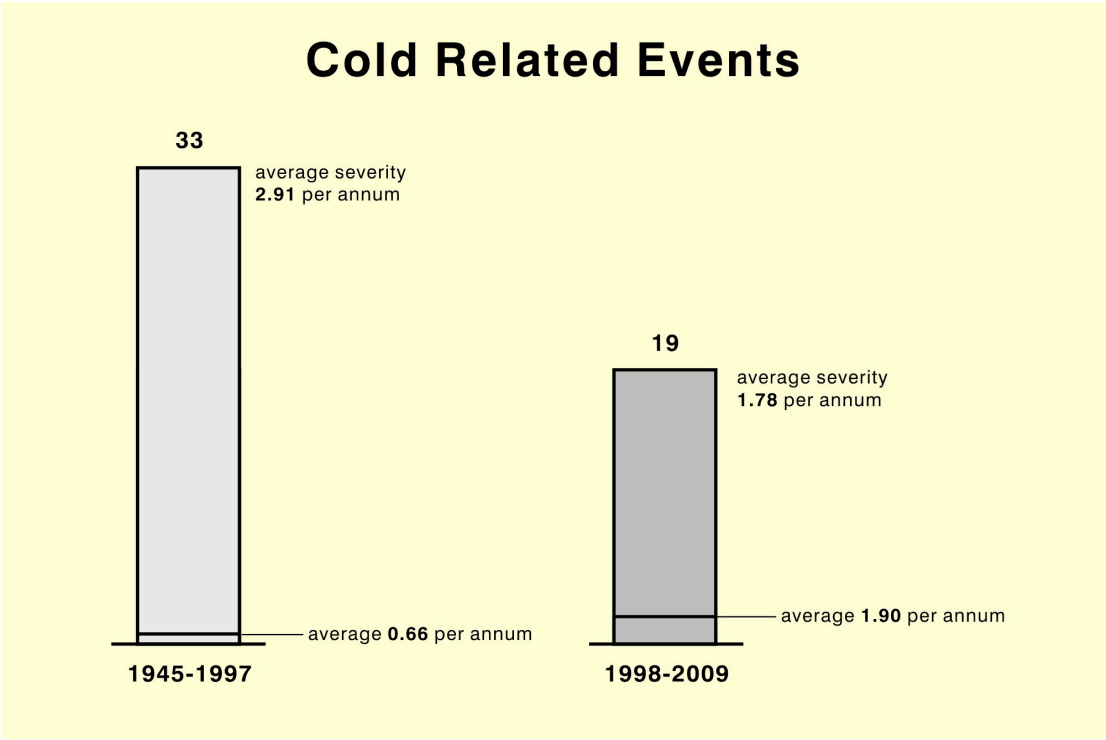

Figure 3 Cold related events in Greater Manchester

- *Storm (wind) events* (Figure 4): These events are becoming more frequent but their impact appears to have been less severe in recent years, possibly due to improved building standards and arboreal services and also less pedestrians on the streets in suburban areas:
    - 1998 – 2009: 17 events (av. 1.70 per annum), av. severity 2.37
    - 1945 – 1997: 43 events (av. 0.86 per annum), av. severity 2.83
    - UKCIP are unable to model wind although they have stated that severe wind and storm events have increased significantly since the 1950s (Jenkins et al 2008). The GM LCLIP would seem to confirm an increase in their frequency since 1998.

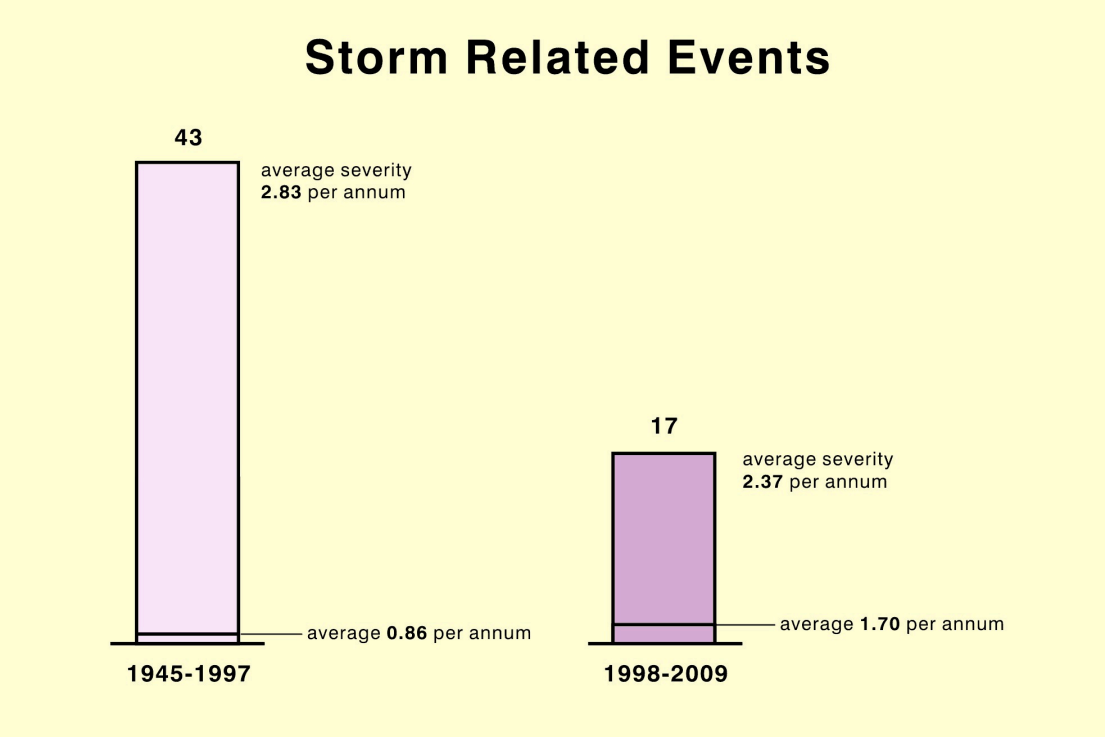


Figure 4 Storm related events in Greater Manchester

- *Pluvial/riverine flooding (identifiable events):* These events have become more prevalent than riverine/brook flooding since the 1990s (Figure 5). Most pluvial flood events happen during the summer months (April-September).
    - 1998 – 2009: 31 pluvial events (av. 3.1 per annum), 17 in summer
    - 1998 – 2008: 21 riverine events (av. 2.1 per annum), 11 in summer
    - 1945 – 1997: 19 pluvial events (av. 0.38 per annum), 14 in summer
    - 1945 – 1997: 33 riverine events (av. 0.63 per annum), 16 in summer
    - The effects of recent climate change reflect the increase in all flood events which can be attributed to the overall increase in precipitation, and in particular to the considerable increase in winter precipitation. Jenkins et al (2008) found a significant increase in the number of severe storms over the UK as a whole since the 1950s, and this is likely to be partially attributable to the increase in pluvial flooding since 1998 (Table 4).

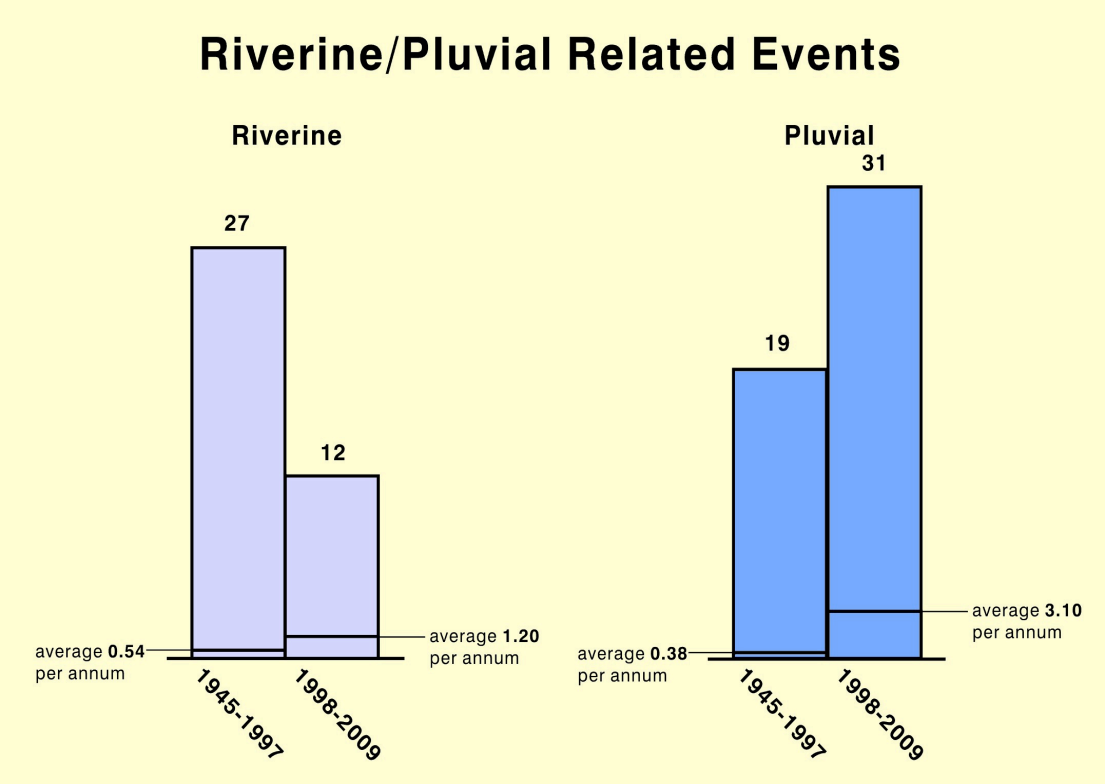

Figure 5 Riverine/Pluvial flooding events in Greater Manchester

- *Pluvial flooding (identifiable events)* (Figure 6) has become more severe and more frequent since 1998:
    - 1998-2009: 31 events (av. 3.10 per annum), av. severity 2.61
    - 1945-1997: 19 events (av. 0.38 per annum), av. severity 2.37
    - The effects of recent climate change are reflected by the increases in pluvial flooding which could be attributable to increases in precipitation, although urban infill and the increase in storm events are also significant contributory factors to this increase.

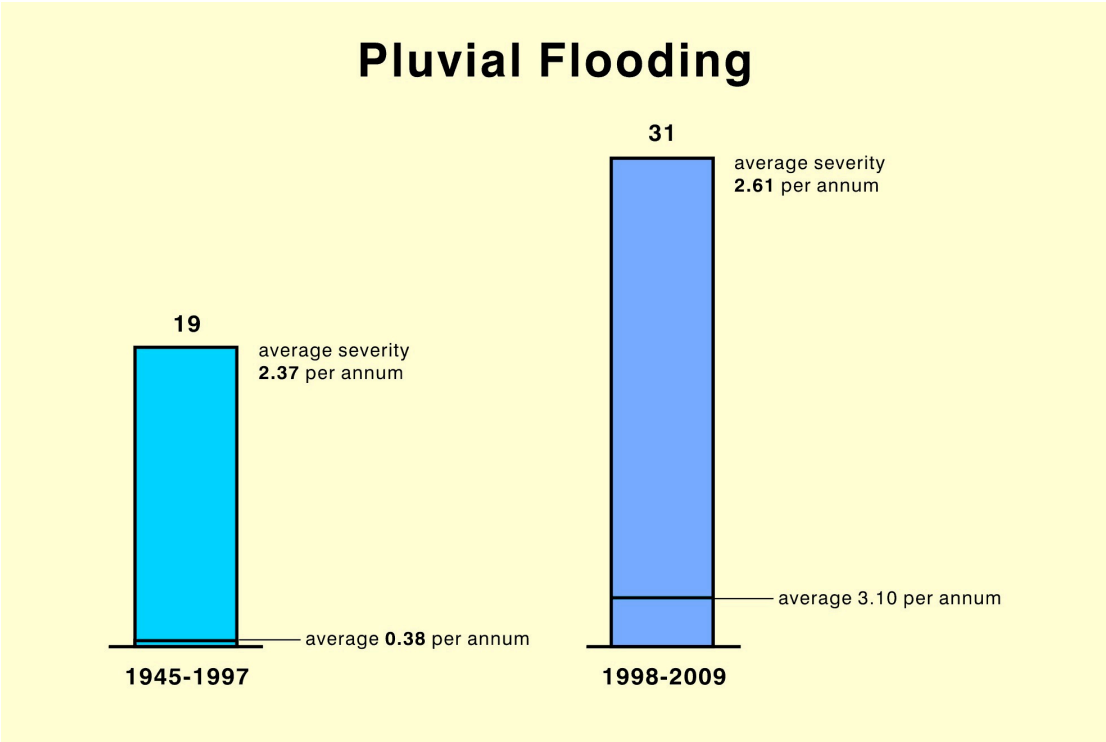


Figure 6 Pluvial flooding events in Greater Manchester

- *Riverine/brook flooding (identifiable events)* was considerably more severe in the past than it has been since 1998:
    - 1998 – 2009: 21 events (av. 2.10 per annum), av. severity 2.0
    - 1945 – 1997: 33 events (av. 0.63 per annum), av. severity 3.15
    - The effects of recent climate change are reflected by the increase in riverine/brook flooding since 1998 which can be attributed to increased precipitation (Table 4). The decrease in the severity of these flood events is no doubt a reflection of the success of flood prevention measures throughout Greater Manchester in recent years.

- *All forms of flooding:* All flood events have been mapped (Figure 7), and in 3 time series: 1945 – 1970 (Figure 8), 1971 – 1998 (Figure 9) and 1999 to 2008 (Figure 10). Figure 10 has also been extrapolated to demonstrate pluvial and riverine flood events separately. These maps confirm that the north of GM (Irwell catchment) is now more vulnerable to flooding than the south (Mersey catchment), that riverine flooding on the Mersey has decreased considerably since the opening of the Sale and Didsbury temporary flood storage basins in the 1970s and that pluvial flooding has become increasingly prevalent since the 1970s.

A series of overarching conclusions can be drawn from the findings of the GM LCLIP. These include:

- Human health in terms of severe injury is most severely affected by storm/wind.

- Infrastructure and human well-being, including mental health, is most severely affected by flood damage.
- Pluvial flooding is now more severe than riverine flooding in Greater Manchester
- The July 2006 heat wave is the only occasion on which heat was reported to have had an impact on human health in the Northwest Region and the source of this information was not included in media reports.
- Fog disrupts travel more than flooding
- Moreland wild fires are a peri-urban impact. Whilst they appear to be on the increase (Bolton MBC) there is insufficient data in the LCLIP to substantiate this claim.
- The only records of drought in GM are in 1984 (severity level 3) and 2003 (severity level 1).

Subsidence does not appear in the LCIP and is commented on under section 3 below.

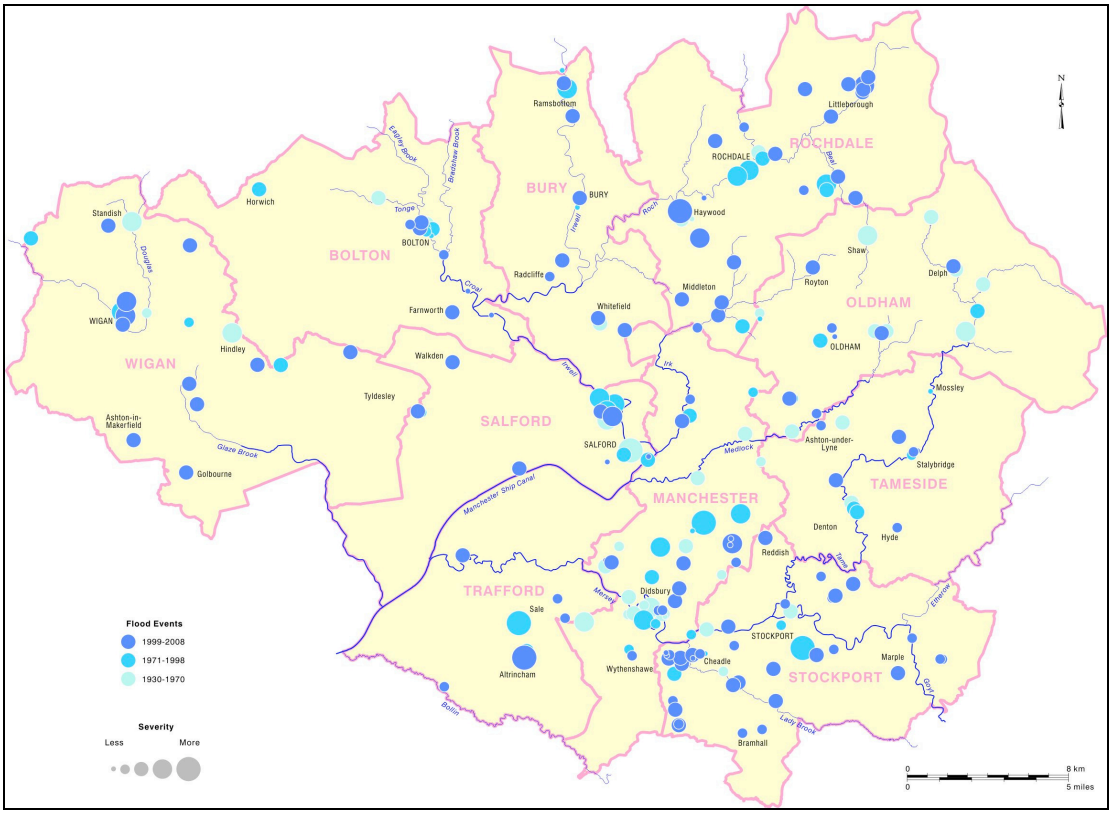

Figure 7 Flood events in Greater Manchester 1945 to 2008

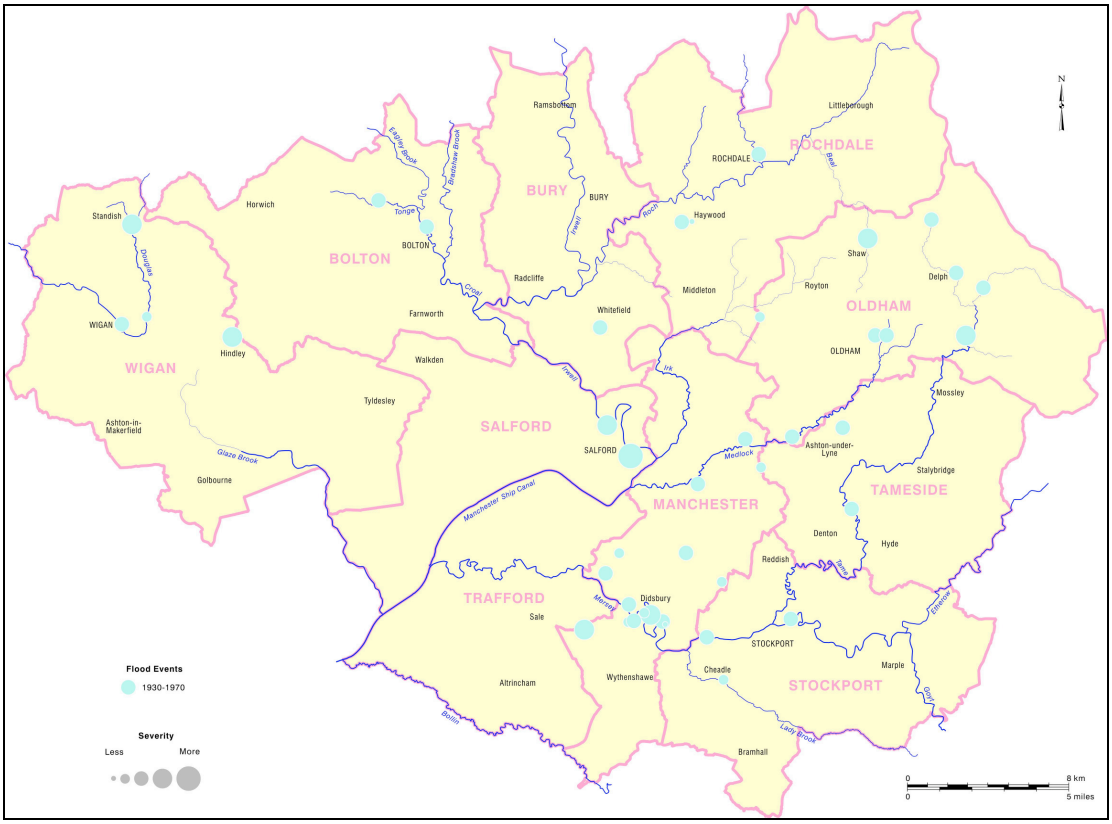


Figure 8 Flood events in Greater Manchester 1945 to 1970

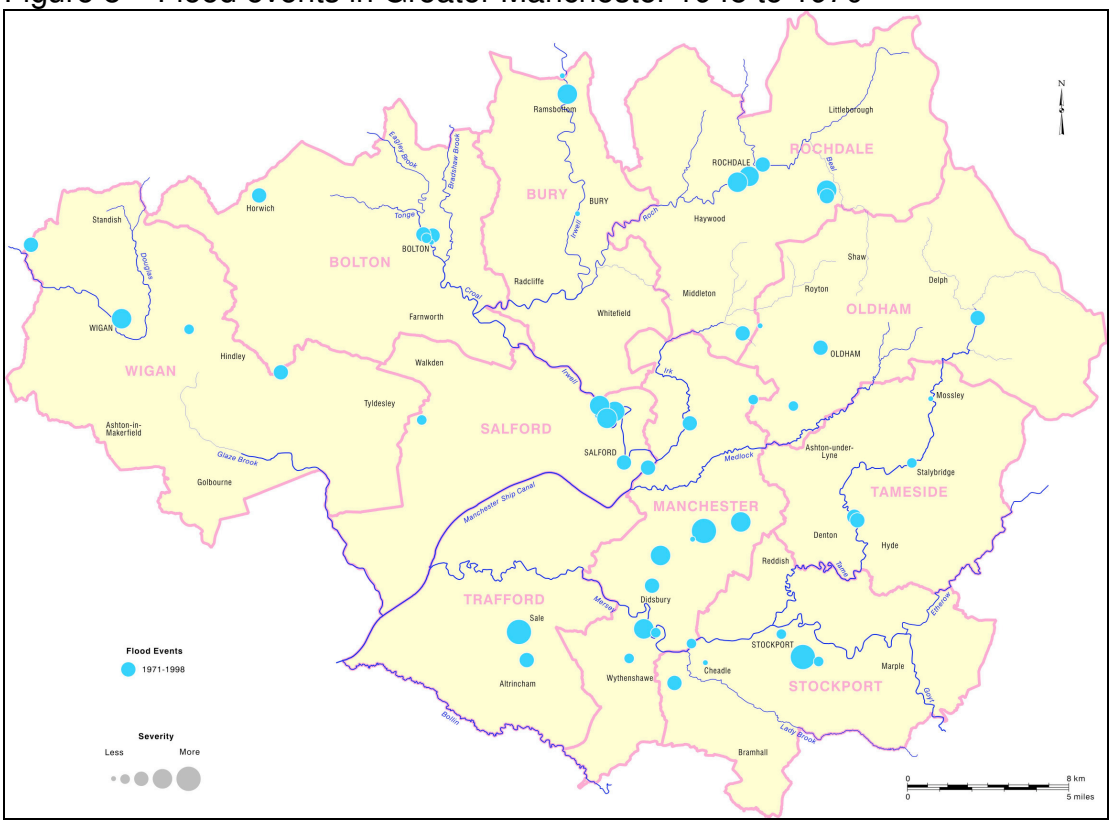


Figure 9 Flood Events in Greater Manchester 1971 – 1998

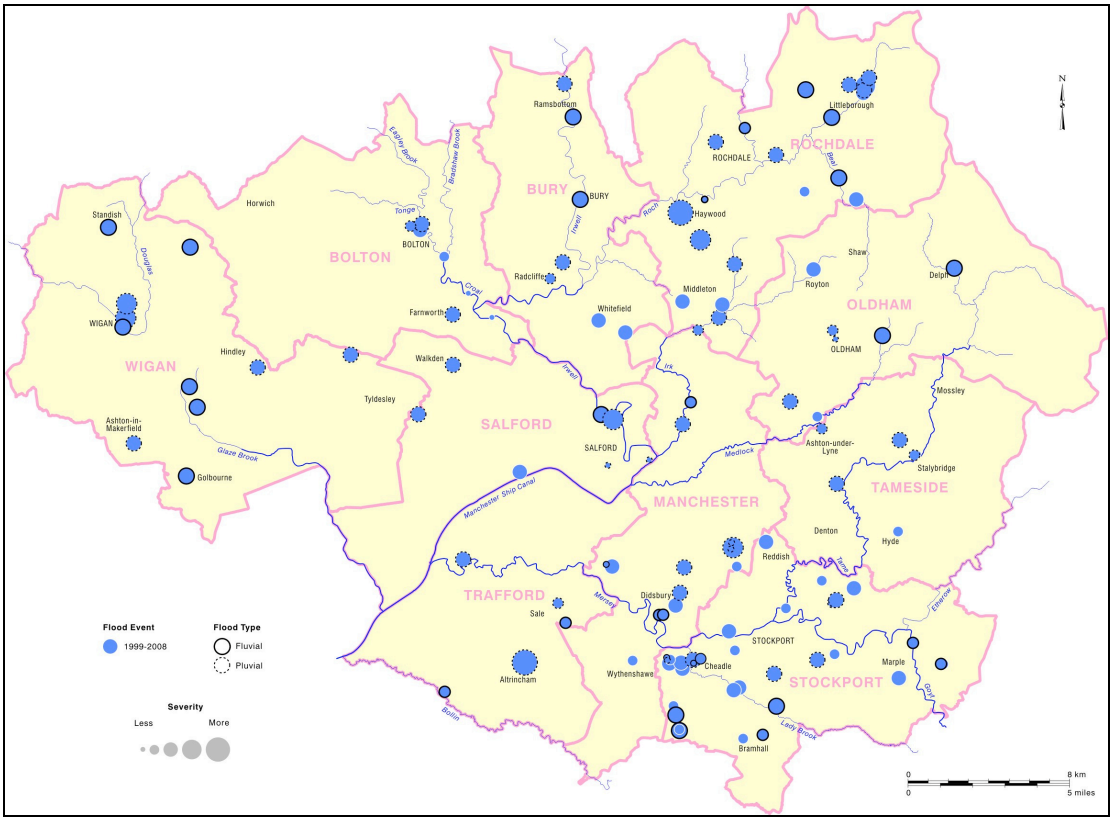

Figure 10 Flood events, by type, in Greater Manchester 1998 – 2008

*1.3.2 Relating impacts to the prevailing weather:*

An additional objective of the GM LCLIP is to try to establish weather thresholds capable of triggering events capable of having an impact on human health/wellbeing and/or on infrastructure or could cause severe disruption to services. Where possible the weather prevailing at the time at Ringway has been match to events identified in the LCLIP with a severity of 3 or over. Ringway, located at the southern extremity of the conurbation is the sole location in Greater Manchester for which continuous meteorological data is available.

a) Alan Goodman, Met Office Regional Advisor, considered the impacts identified in the GM LCIP data base with a severity of 3 and over and matched them to the weather patterns prevailing at the time. His preliminary (subjective) assessment points to:

- Fewer very heavy (+40mm/day) rainfall related events causing an impact
- More heavy (20-40mm/day) rainfall related events causing an impact
- Trend towards more intense storm events causing an impact
- Fewer heavy snowfall/prolonged cold events causing an impact
- That many weather events did not result in a reported impact and also that many reported impacts were not matched by a weather event within the agreed parameters.

b) At a workshop held in Oxford on 31/3/2009, UKCIP (Metcalf, 2009) emphasised the relevance of raising awareness of weather event thresholds which could trigger significant impacts. In order to address this issue within this project, Claire Smith, climatologist at University of Manchester has investigated the possibility of establishing thresholds, using weather data from the Met Office station at Ringway. Her preliminary findings based on an objective survey of daily data from Ringway point to some evidence of identifiable thresholds in the data.

- Every day with a maximum temperature greater than 30.9ºC coincided with a news article reporting the negative consequences of high temperature
- Virtually every day when precipitation exceeded 38mm resulted in flooding. That said, many flood events happened when the daily precipitation at Ringway was in the region of 25-30mm and even lower.
- Days with a maximum gust speed in excess of 60 knots had an impact. However, on a number of occasions, days when wind speeds were defined by the Met office as Gale Force (force 8 on the Beaufort scale: speeds in excess of 34km/h over a period of at least several minutes) also resulted in impacts.

- It must be emphasised that these findings are only indicative and are by no means conclusive. This is because not all weather related impacts will have been identified by the LCLIP and because the meteorological data is from Ringway only. This has particular implications for climatic conditions which have a high spatial variability (e.g. precipitation) and for impacts that are confined to the north of the conurbation such as gales that might not necessarily be picked up in the Ringway data. In fact there were many wind related impacts in the data base, generally in the north of GM, which did not coincide with the report of gales at Ringway, no doubt due to localised topographical (particularly altitude) differences.

**1.4 Extending the data base, further research and lessons learnt:**

More precise collation of past weather related events would require seeking to match impacts to less extreme weather events than has so far been undertaken. It would also be advisable to conduct a similar analysis based on data from stations other than Ringway, particularly those to the north of the conurbation (Figure 1). This would necessitate an extensive and meticulous investigation of all LA and media sources. Clearly such an investigation would also be enhanced by the cooperation of the insurance and the utility industry, the police, and “on the ground” verification. Such a study could provide the data required to extend insight into the establishment of thresholds over and above those considered so far under section 1.3.2 above.

Data on weather events relating to impacts lends itself well to further, more robust statistical analysis (e.g. Chi-Square, Extreme Value Analysis) and this

would be a logical next step for research. It would also be useful to explore the change and the frequency of extreme weather events in Greater Manchester over time. UKCIP 09 is due to be published June/July 2009. It is hoped that it will include sufficient data on climate change scenarios in the Northwest to allow for an assessment of the likelihood of some of these preliminary thresholds being breeched. This would be of much value in the development of adaptation strategies to respond to future impacts of climate change.

The data base could also usefully be extended through the inclusion of events which have not actually impacted on human health and well-being and on infrastructure but which have the potential to do so in the future. Events such as flooding from brooks and culverts which have so far only caused minimal impacts, will potentially be much more severe in the light of future climate projections.

Time constraints have precluded the inclusion of detailed source information on road and school closures due to weather events. This is despite an attempt having been made to acquire data on these events from the relevant authorities. Also, the inclusion of medical data could add a further dimension to the assessment of vulnerability and this could usefully be explored in greater depth. Data on emergency admissions since 2003 was obtained from NHS North West and on hospital episodes due to hypothermia, drownings and heatstroke since 2001 from the Northwest Public Health Observatory but unfortunately confidentiality issues and the spatial aggregation of the data precluded the possibility of making either a direct link or a statistical association to weather related events in Greater Manchester.

The two time series in collection of the data (principal events between 1945 and 1997 and from 1998 to the present day in as much detail as possible) were selected with the Eco Cities project in mind. The principal local press in Greater Manchester has mostly been digitised since 1998 and it was felt that this was the period for which comprehensive data could be easily and successfully obtained but that it would be useful to have a feel on events which had occurred since 1945. It was only subsequent to having decided on these timescales that a serious attempt was undertaken to match the impacts to the prevailing weather. UKCIP climate predictions are based on changes in key climate variables between 1961 and 1990 and given the opportunity for further research, it would be useful to compare LCLIP events and their impacts between 1960 and 1990 with those that have occurred between 1991 and the present day.

# 2. Future weather and climate

NI 188 Level 1 calls for the identification of significant potential impacts associated with future weather and climate. Future vulnerability to climate change in Greater Manchester is assessed by reference to the climate change scenarios reported by UKCIP (Hulme et al 2002), which provide the most comprehensive overview of potential changes to the climate of the UK currently available. The UKCIP scenarios have been interpreted in a Northwest England context by Glynn (2005) and McEvoy et al (2006), and by several completed and ongoing studies undertaken at University of Manchester. The key findings of these studies are reported below. Section 3 utilises this data to assess the vulnerability of a selected list of Manchester City Council's priority service areas to possible trends in future weather and climate.

## 2.1. UKCIP scenarios

The seminal study of future climate change scenarios in the Northwest Region is:

> Glynn, S., 2005 *Climate Change in the Northwest and its impacts: a summary document.* The Northwest Climate Group for Sustainability Northwest, available to download at www.cliamtechangenorthwest.co.uk

This report extends Hulme M *et al* (2002) *Climate Change Scenarios for the United Kingdom: the UKCIP02 scientific report* to the Northwest regional level. UKCIP's principal findings for the Northwest region are based on data from Ringway modelled at a scale of 50 km². Climate change scenarios for the Northwest region, compared with the averages for 1960 to 1990, are summarised in Table 5. The most significant potential effects of climate change in Northwest England include:

- A small increase in maximum summer temperature by the 2020s with relatively little difference between the high and low emissions scenarios. However, it is estimated that by the 2050s, Manchester could see peak summer temperatures similar to present day cities in Holland and Belgium, while by the 2080s, peak summer temperatures could be equivalent to Berlin, Frankfurt and Rome
- Winter minimum temperature rise across the region and even for the low scenario there are very few places in the region with average minimum temperatures remaining below freezing.
- The average level of rainfall during the summer throughout the region is anticipated to decrease. By the 2080s, for the high emissions scenario, virtually every summer will be drier than the 2003 summer in Manchester which was exceptionally dry when seen in the context of past events.

- Average winter rainfall is expected to increase by as much as 60% under the 2080s high emissions scenario.
- Aside from seasonal changes in precipitation patterns, increases in rainfall intensity are thought to be likely throughout the year. Therefore, although summers look set to become drier, intense high volume rainfall events could become more common.
- The number of depressions moving across the UK from North Atlantic (particularly in winter) is expected to increase leading to the possibility of more frequent and more intense storm events. However, there remains much uncertainty over predicting associated details, for example the path of storm tracks.

| | **2020s (2011-2040)** | **2050s (2041-2070)** | **2080s (2071-2100)** |
|---|---|---|---|
| **Changes in annual temperature** | 0 to 1ºC | 1 to 3ºC | 1 to 5ºC |
| **Changes in maximum summer temperature** | 0 to 2ºC | 1 to 4ºC | 2 to 6ºC |
| **Changes in summer rainfall** | 0 to 20% decrease | 10 to 30% decrease | 10 to 60% decrease |
| **Changes in winter rainfall** | 0 to 10% increase | 0 to 20% increase | 10 to 60% increase |
| **Changes in annual snowfall** | 10 to 30% decrease | 30 to 60% decrease | 40 to 100% decrease |
| **Changes in summer and autumn soil moisture content** | Not available | Not available | 20 to 50% decrease |
| **Changes in sea level** | Not available | 7 to 36cm | 9 to 60cm |

Table 5 UKCIP02 climate projections for Northwest England compared with the average for 1960 to 1990

Some studies have gone into greater detail on particular impacts. For example McEvoy et al (2006) produced scenarios for average summer maximum temperature for Greater Manchester using data supplied by UKCIP and the Met Office (Figure 11). Although Manchester's urban heat island is not as pronounced as other major cities such as London, scenarios show peak temperatures reaching 34ºC in the 2080s, with significant thermal discomfort likely from the 2050s onwards.

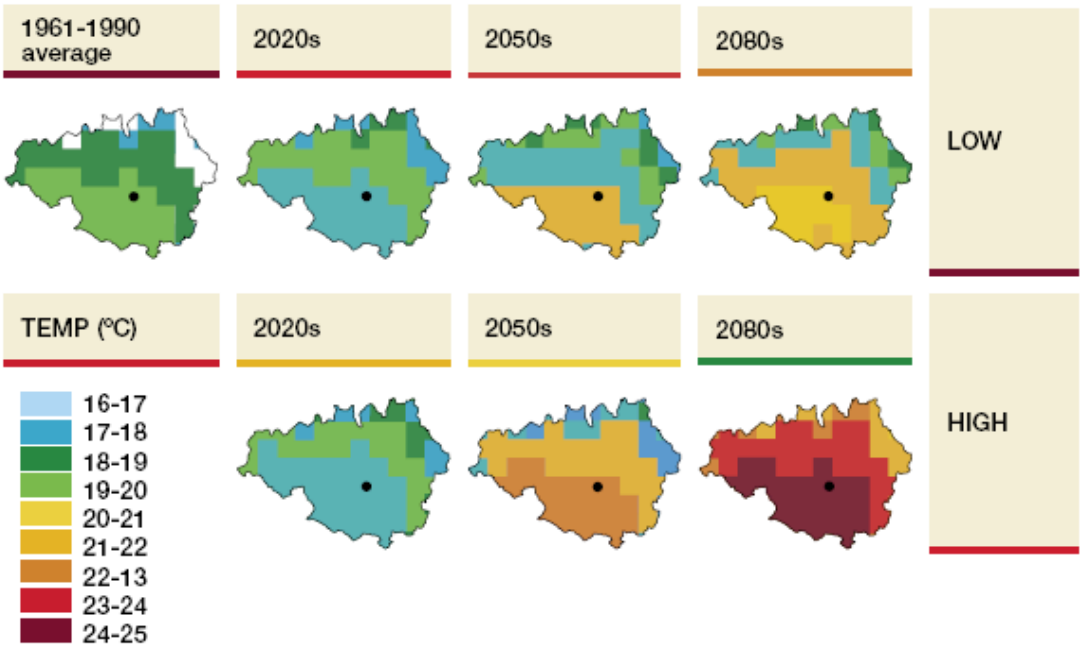


Figure 11 Climate scenarios for average summer maximum temperature for Greater Manchester (Produced using data supplied by UKCIP and the Met Office.

The Adaptation Strategies to Climate Change in the Urban Environment project (ASCCUE) focused on the urban environment of Greater Manchester with a view to assessing climate change impacts and developing and testing appropriate adaptation responses through spatial planning and urban design. This consortium project was completed in 2006 as part of the EPSRC/UKCIP Building Knowledge for a Changing Climate (BKCC) programme looking at how climate change will affect different aspects of the built environment (www.k4cc.org/bkcc). Key findings and recommendations of ASCCUE that are relevant to this study include:

- Greater Manchester is projected to be increasingly at risk of drought in the future. This was measured by considering the number of months that green cover is water stressed. This climate change impact is evident even under the low emissions scenario for the 2020s, indicating that change can be expected in the short term. This is significant as the cooling effect of evapotranspiration from trees and plants is reduced.
- Urbanisation accelerates surface run-off of rainwater, and this effect will be amplified by climate change. Under the 2080's high emission scenario, the 99$^{th}$ percentile winter precipitation event (i.e. the wettest day of the winter months) produces 56% more rain in comparison to the 1960-1990 baseline, and yet results in an 82% increase in runoff of rainwater across Greater Manchester when compared against the 1960-1990 baseline. This is due to the fact that soils will become

increasingly saturated during the winter months, reducing their capacity to absorb rainwater run-off.

- Greenspace moderates the effect of surface temperature, which is a key factor concerning human comfort in urban areas. ASCCUE demonstrated that adding 10% green cover (trees, grassed areas, green roofs etc) across Greater Manchester keeps maximum surface temperatures in high density residential areas and town centres at or below 1961-1990 levels under the 2080s high emission scenario. Greenspace also helps to reduce rainwater run-off through reducing the volume and speed of rainwater reaching water courses.
- There is a need to promote the multi-functional benefits of greenspace resources, which extend beyond their role in climate change adaptation. For example, Greenspace has positive impacts in terms of health, biodiversity and even economic development.
- There is a need to encourage the use of spatial planning, at the strategic, local and neighbourhood level, to design and implement climate change adaptation strategies based around greenspace resources. The research highlighted that conurbation level strategies are crucial for climate change adaptation via green infrastructure.

The next generation of climate change scenarios for the UK (UKCIP 09) are expected to be published in June 2009. They will extend the current UKCIP 02 scenarios by providing probabilistic weather scenarios (i.e. including extremes and the level of uncertainty) at a 25 km² grid scale which will be downscaled to 5 km² using a weather generator tool. Ringway (Woodford since 2006) is the only weather station in the Greater Manchester area with continuous weather data so the scenarios covering Greater Manchester will still be topographically modelled from data collected there. Unfortunately, given the prevalence of wind related damage as identified by the GM LCLIP, the UKCIP09 will not include scenarios covering wind because of the difficulty in modelling wind speed, direction and probability. However, the revised grid scale, further downscaling and probabilistic format of UKCIP09 should provide LAs with more refined and robust scenarios for the formation of adaptation strategies over those available from UKCIP02. To further reduce uncertainty, UKCIP generally advise that LAs determine time frames for consideration of impacts and adaptation strategies and they suggest 3 broad time zones:

- Short term 2009 – 2015: projected by slightly extending current trends.
- Mid term 2015 – 2045: the 2009 scenarios should be considered as being “certain” and based on a single set of projections.
- Long term 2045 – 2075: to be based on emission scenarios because carbon usage is still uncertain. (Metcalf, 2009)

Nevertheless, it is highly likely that the broad direction of change in the climate of the Northwest region, on which this report is based, will remain the same. Greater Manchester can therefore continue to expect warmer drier summers and warmer wetter winters. The UKCIP 09 scenarios will provide greater richness to existing knowledge, which will be of real benefit in developing adaptation strategies to respond to the impacts of climate change.

## 2.2 Other data/organisations useful in helping to understand and to monitor future weather and weather related impacts in Greater Manchester

Weather data is available through the British Atmospheric Data Centre, from the Met Office's weather stations in Greater Manchester such as those at Woodford Aerodrome (at Ringway until 2005), in Bolton and at Hulme Library. UKCIP 02 and also UKCIP09 scenarios for Greater Manchester are modelled on data from Ringway/Woodford because of the continuity of data sets. In addition the Environment Agency and Untied Utilities also operate a number of rain gauges around Manchester.

Flood events are recorded by several agencies and AGMA has commissioned a Strategic Flood Risk Assessment (SFRA) for Greater Manchester. The EA is responsible for riverine flooding in designated main rivers and critical ordinary watercourses, i.e. rivers and high density streams and monitors all flood events from them. The utility industry is required to record those properties which have suffered from flooding other than by flood events caused by exceptional weather and properties deemed to be "at risk" of flooding (the DG 5 Register). Home Information Packs (HIPs) are now steadily becoming a requirement for all property transactions and there is considerable evidence that this document should be able to reliably inform on the risk of flooding and that it could also become part of the database of historical flooding. However, these records are not as yet of any value in providing preparedness for pluvial flooding and recording all flood events should become the responsibility of the Local Authority (Lawson et al., 2008). Also, LIDAR mapping of urban terrain would greatly assist in designating the topographic lows on the urban surface where flood waters tend to accumulate (Priestnall et al., 2000, Ashley et al., 2006). There are major constraints using GIS tools such as LIDAR in terms of the need to undertake extensive data collection to allow the generation of useful flood maps that are not dominated by modelling uncertainties and overcoming these concerns requires robust recording of historical flooding and ground-truthing to ensure flow paths are correctly represented (Hankin et al., 2008).

The Police are generally involved in all emergencies and other incidents involving the public and public safety, including those which are weather related and they could be a useful source of relevant data.

The Greater Manchester Fire and Rescue Service record all call-outs and these will include virtually all flood events. However, they do not at present record the cause of the event and this reduces the utility of a potentially very valuable source of data. Inclusion by the Fire Service of the causation could provide a most useful record of otherwise often unrecorded smaller scale pluvial flood events.

The insurance industry could also become a valuable source of data associated with extreme weather. The Association of British Insurers (ABI) at present only aggregates national figures and does not hold local/regional data. They are currently exploring the option of gathering more claims information but this is still work in progress.

Whilst the NHS does not as yet record the causation of death/illness and there is a great difficulty in linking causation to health outcomes as well as severe restrictions on this type of data due to confidentiality, they and the Health Protection Agency could in future be relevant sources of weather related impacts.

2.2.1 Recommendation:

Looking forward and beyond the scope of this project, it is clear that there are a range of potentially valuable sources of information that could become more important in assessing the impacts of climate change in the future. In several of these cases, the data on impacts of climate change is in effect being gathered, but not in the form that makes it useful to the task of researching climate change impacts. Data from the fire service, which record call outs to flood events, but not the causes of those events, is a good case in point.

Exploring the pattern of weather events which have triggered an impact in a certain locality and considering how these patterns might be affected by climate change can inform decisions on the development of longer term adaptation strategies and the implementation of adaptation responses. Historical weather and weather related events can thus form the basis for assumptions about future weather and future weather related events in a given locality and the impacts thereof on a particular LA service area. This will require a systematic and inclusive approach to data collection by all Greater Manchester Local Authorities in conjunction with the services mentioned above.

# 3. Vulnerability Assessment

## 3.1 Introduction

The outcomes and key findings of the GMLCLIP, review of UKCIP scenarios and related academic studies, and a multi-disciplinary workshop at University of Manchester are used in assessing vulnerability to climate change in a series of LA services identified as being potentially vulnerable to current weather and the impacts of future extreme weather events. These service areas are intended to provide an insight into how selected areas of the City Council might be affected by current and future weather events. Drawing on the findings of the vulnerability assessment, a series of broad conclusions and recommendations address issues relating to responding to the impact of current and future weather events on service provision within Manchester City Council.

Coupled with the data on future climate change impacts, the GM LCLIP offers a range of useful findings that are of benefit in assessing vulnerability of the Council's priority service areas to current and future weather and climate. The LCLIP indicates that flood is the principal cause of damage to property and infrastructure in Greater Manchester. Some 43% of severe weather related events which have impacted on human health/wellbeing and on infrastructure or have caused disruption to vital services resulted from precipitation causing flooding. The UKCIP scenarios demonstrate that flooding is likely to increase in the future as precipitation increases over the winter months and intense rainfall events become more frequent throughout the year. Further, across Greater Manchester, summer storm induced pluvial flooding is now more prevalent that riverine flooding. Spatially, the north of Greater Manchester is now more vulnerable to severe pluvial and riverine flooding whereas severe storm events would appear to affect most areas of Greater Manchester equally. The GM LCLIP demonstrates that the severity of the impact of intense storm related events has increased in the last 10-15 years. Significantly, UKCIP's work on recent changes to the region's climate and their scenarios for future climate change indicate a trend towards more frequent and intense storm events and more heavy rainfall events in the future.

The LCLIP also highlights that human health is most severely affected by wind and also by heat. Indeed, 28% severe weather related events were the result of damage due to storm induced wind, impacts that future climate change scenarios suggest will intensify. The UKCIP scenarios and the LCLIP have also shown that whilst prolonged cold events and heavy snow falls in Greater Manchester are receding, they still continue to cause severe disruption because whilst the risk of a 1:5 year event might well have diminished, as the experience of the 2008-9 winter demonstrates, the 1:25 year event remains a threat.

Based on the findings of the GM LCLIP and analysis of UKCIP's future climate change scenarios, it is apparent that all agencies dealing with flood risk, and particularly with pluvial (surface water) flooding, along with agencies concerned with health, safety and community welfare, should be undertaking an initial assessment of their vulnerability to current and future weather and climate. The vulnerability assessment reported below addresses some but not all of these services. Level 1 of NI188 requires only a selected range of service areas to be addressed by the vulnerability assessment. There follows an insight into the potential impacts of current and potential future weather and climate on six priority service areas, from which cross-cutting learning experiences can be drawn to other service areas within Manchester City Council.

## 3.2 Vulnerability assessment methods

UKCIP have developed a range of tools, methods and guidance that can be used to help organisations identify how they might be impacted by climate change and what they can do to minimise associated risks or exploit opportunities. Collectively these tools provide comprehensive guidance on relevant issues for an organisation seeking to develop an adaptation framework. For example, UKCIP's Adaptation Wizard includes reference to an easy to use vulnerability framework, their socio-economic scenarios provide excellent guidance on how vulnerability of people and urban areas may evolve in the future independently of climate change, and the methodology for calculating the costs of climate impacts demonstrates how large organisations can compare the cost of impacts to the costs of related adaptation measures. In addition, the Business Areas Climate Impacts Assessment Tool (BACLIAT) provides a simple checklist for business organisation to assess the potential impacts of climate change on their organisation or an entire business sector.

These UKCIP tools, methods and guidance are useful aids in assisting those charged with the development of adaptation strategies. They help to establish the areas and issues within their organisation which are most vulnerable to climate change. Manchester City Council and University of Manchester, in conjunction with Red Rose Forest followed the general guidance provided by LRAP in their Guidance Notes for NI 188 (Local and Regional Partnership Board, 2008), which was heavily influenced by UKCIP, to formulate their own approach to assessing vulnerability to climate change. This methodology, which is described below, forms the basis for the following vulnerability assessment.

## 3.3 Exploring Manchester City Council's vulnerability

NI 188 requires that relevant managers/elected members are made aware of significant potential impacts associated with future weather and climate, and other potential impacts. NI 188 guidance from LRAP indicates that insights into current and future weather and climate events should be used to explore potential vulnerabilities within LAs and the threats and opportunities which these present. This assessment should identify priority areas for immediate

action, and those areas that need further investigation at level 2 of NI 188. The guidance also suggests undertaking a review of a few critical areas (at Level 1) to limit the scope of the task and to encourage the development of an approach which is transferable to other service areas in due course.

Following this guidance, 6 service areas and certain key functions of these services have been selected for this initial assessment at level 1 of NI 188. The following vulnerability assessment, undertaken by the University of Manchester, concentrates on the specific effects and impacts of current and future climate/weather on the selected key functions of the services. Tables 6-11 report the key findings of this vulnerability assessment.

| Service Area (Team/Dept.. Targeted) | Key functions of the service | Effects of current climate/weather on the service | Potential impacts of current climate/weather on service provision | Effects of future climate/weather on the service | Potential impacts of future climate/weather on service provision |
|---|---|---|---|---|---|
| ***Manchester Leisure Services (Parks operation and development)*** | • Strategic and operational management of indoor leisure (swimming pools, sports halls)<br>• Sports development<br>• Community activity (community officers)<br>• Sports events<br>• Parks and outdoor leisure facilities (e.g. parks, playing fields, play areas, river valleys, allotments) | • Impacts of heat on grass and trees.<br>• Wind damage to trees and to infrastructure.<br>• Importance of green areas and trees in outdoor facilities for flood control.<br>• *See synergy with Table 8.* | • Green space maintenance due to drier summers.<br>• Reduce the need to travel and ensure good accessibility to leisure facilities.<br>• Increased volume of tree works due to storm damage.<br>• Increased flooding and water logging in parks and gardens.<br>• Increased blue-green algae in river valleys.<br>• Heat effects on human comfort in indoor facilities.<br>• *See synergy with Table 8.* | • Increased potential of flood, heat and wind related impacts.<br>• Reduced summer rainfall will affect grass and tree health.<br>• Greater demand for swimming and other such leisure facilities during heat waves.<br>• Increased wind/storm and flood related effects on buildings and other infrastructure.<br>• *See synergy with Table 8.* | • Greater requirement for all outdoor leisure areas, community involvement and sports events.<br>• Need to reduce travel and ensure good accessibility to leisure facilities.<br>• Significantly increased flood risk in parks.<br>• Greatly increased use of parks and outdoor facilities such as rugby/soccer pitches as temporary flood storage basins and SUDS.<br>• Need to provide open air swimming/paddling facilities in parks with potential need for additional staff resources to maintain and supervise<br>• Potential heat stress during sports events. Provision of medical facilities for both competitors and spectators.<br>• Need to provide improved air conditioning/ventilation in indoor sports facilities.<br>• Need to wind/storm/flood proof all indoor facilities and outdoor infrastructure.<br>• Need for increased provision and maintenance of green/blue infrastructure (for example the installation of ponds to provide water to irrigate grassed areas).<br>• Potential need for more allotments for fruit growing and also for the provision of water to allotments.<br>• Consideration to less water dependent varieties of grass, shrubs, trees and bedding.<br>• Need to take a strategic view of the role of parks from a climate change adaptation perspective.<br>• Indirect effect of increased leisure and tourism.<br>• *See synergy with Table 8 Green.* |

Table 6 Weather related vulnerability assessment of Manchester City Council Leisure Services

| Service Area (Team/Dept.. Targeted) | Key functions of the service | Effects of current climate/weather on the service | Potential impacts of current climate/weather on service provision | Effects of future climate/weather on the service | Potential impacts of future climate/weather on service provision |
|---|---|---|---|---|---|
| ***Eastlands Homes (Registered social landlord with charitable status)*** | Public sector housing provision and maintenance in East Manchester, Gorton South, Longsight, Rusholme, Levenshulme and Ardwick. | • Cold, flood and wind effects on the housing stock.<br>• Heat impacts on tenants.<br>• Tenant mobility affected by snow and ice. | • A requirement for improved ventilation and insulation of the housing stock and increased maintenance due to storm/wind damage.<br>• Need to consider installing flood resilience measures to housing stock in vulnerable areas.<br>• Training needed for staff on assisting tenants in extreme weather situations.<br>• Advice / education for tenants on what to do in extreme weather situations.<br>• Potential increase in crime in vulnerable areas when windows are left open to improve ventilation on hot days/nights. | • Increased possibility of flood in areas with social housing and wind related impacts on building maintenance.<br>• Increased impacts of heat on human well-being. | • Installation and maintenance of flood resilience measures to housing stock in vulnerable areas.<br>• Increased maintenance due to storm/wind damage.<br>• Provision of alternative accommodation for flood victims.<br>• Need to provide better heat insulation and ventilation to housing stock and/or new build to an advanced specification to reduce heat stress and the impact of wind/storm on both the structure of buildings and on internal comfort.<br>• Need to increase greenspace surrounding housing stock as a cooling mechanism.<br>• Training for staff on how to deal with/ assist tenants to cope with climate change.<br>• Advice / education for tenants on what to do to cope with climate change scenarios. |

Table 7. Weather related vulnerability assessment of Eastland Homes

| Service Area (Team/Dept.. Targeted) | Key functions of the service | Effects of current climate/weather on the service | Potential impacts of current climate/weather on service provision | Effects of future climate/weather on the service | Potential impacts of future climate/weather on service provision |
|---|---|---|---|---|---|
| ***Environmental Services (Green Spaces division)*** | • Woodlands (not under control of Manchester Leisure).<br>• Highways trees and other trees on Council owned land (not land under control of Willow Park Housing Trust)<br>• Grass verges and other green space (not parks) owned by MCC.<br>• Street trees planting and replacement of dead/dying trees.<br>• Dealing with trees on private land in emergency situations. | • Wind damaging/ dropping trees.<br>• Heat/water stress to trees and grass verges.<br>• *See synergy with Table 6* | • Water pipe renewal to reduce leaks affects the water supply to urban trees which are important for climate change adaptation.<br>• Need for improved tree management.<br>• Need to provide more green space for flood control and human comfort in areas most at risk.<br>• Consider the use of grass verges and other green spaces as SUDS.<br>• Increase in "Poplar Scab", and other fungal disease affecting trees which might be weather related.<br>• *See synergy with Table 6.* | • Decrease in summer and autumn soil moisture content.<br>• Serious potential of increase in storm/wind and precipitation related events.<br>• Increased potential for water stress to trees and grass verges during the summer.<br>• Threat from invasive species (plants, insects etc) as the climate changes.<br>• Increasing winter rainfall and summer temperatures will affect water bodies.<br>• *See synergy with Table 6.* | • Need for increased provision and maintenance of green/blue infrastructure through installation of ponds and other sources of water for urban green space.<br>• Increased need for tree care services due to storm and heat impacts.<br>• Increase need to provide and maintain trees/green spaces to reduce impacts of flooding and heat.<br>• Need to use grass verges and other green spaces as SUDS.<br>• Need to consider which trees and plants are most appropriate for the projected changes in climate.<br>• Greater potential for weather related fungal diseases to trees.<br>• Longer growing season in parks could lead to year-round grass growth and is a potential contributory factor to increased tree disease, thus necessitating increased maintenance cost.<br>• Need to adapt tree pit design to maximise soil volume and irrigation / drainage.<br>• Water bodies will require more management. Water surplus may result in overtopping of lakes and falling levels in summer may necessitate a pumped water supply and oxygenation.<br>• *See synergy with Table 6.* |

Table 8. Weather related vulnerability assessment of Manchester City Council Environmental Services (Green Spaces Division)

| *Service Area (Team/Dept.. Targeted)* | *Key functions of the service* | *Effects of current climate/weather on the service* | *Potential impacts of current climate/weather on service provision* | *Effects of future climate/weather on the service* | *Potential impacts of future climate/weather on service provision* |
|---|---|---|---|---|---|
| ***Adult Social Care (Part of Social Services)*** | Health and well-being of adults in the following categories:<br>• Vulnerable older people.<br>• Individuals with physical disabilities.<br>• Individuals with HIV/AIDS.<br>• Individuals with drug / alcohol dependencies.<br>• Individuals suffering from mental health problems.<br>• Individuals with learning difficulties.<br>The management of residential homes and day centres providing services to these groups. | • Heat and cold related illnesses to older people and people with disabilities.<br>• Mobility constraints due to extreme weather.<br>• Heat effects on ventilation of care homes.<br>• Ability of staff to attend work may be compromised by weather events.<br>• Potentially vulnerable to power failure due to extreme weather. | • Need to provide better ventilated premises or gardens for elderly/disabled people in residential care.<br>• Need to take people in receipt of day care outside.<br>• Need to provide mobility or home care services during extreme weather.<br>• Training needed for staff on how to deal with / assist vulnerable adults in extreme weather situations.<br>• Advice / education for vulnerable adults on what to do in extreme weather situations. | • Increased potential for heat stress and heat related illnesses for all vulnerable adults especially the elderly and disabled.<br>• Potential extra protection of people with mental disabilities during storm events and to the physically disabled during flood events.<br>• Potential impacts of storm/wind and flood on infrastructure.<br>• Increased problems of mobility due to extreme weather.<br>• Potentially vulnerable to power failure due to extreme weather. | • Same as the impact on service provision now but increasingly critical impacts of heat leading to the requirement of re-designed care facilities and infrastructure to manage human comfort.<br>• Increased levels of flood and storm events will require the provision of alternative services when both carer and client mobility is compromised.<br>• Training for staff on how to deal with / assist vulnerable adults to cope with climate change.<br>• Advice / education for vulnerable adults on what to do to cope with climate change scenarios. |

Table 9. Weather related vulnerability assessment of Manchester City Council's Adult Social Care

| Service Area (Team/Dept.. Targeted) | Key functions of the service | Effects of current climate/weather on the service | Potential impacts of current climate/weather on service provision | Effects of future climate/weather on the service | Potential impacts of future climate/weather on service provision |
|---|---|---|---|---|---|
| ***Corporate Services (ICT-Technology and infrastructure section)*** | Provision and maintenance of Information and Communication Technology for MCC and Local Strategic Partners (by MCC and service providers) | • Potentially vulnerable to power failure from extreme weather.<br>• Diesel back up is for only 6 hours, if roads are blocked by snow / storm damage this will inhibit the delivery of diesel for emergency generator. Town Hall Data Centre has currently no back up energy supply.<br>• Wind damage to roof of ICT building could leave Data Centre vulnerable to ingress of rainwater.<br>• The failure of ICT would have massive implications for all MCC Departments and some LSPs with respect to service delivery. | • Need to provide backup power source for Town Hall Data Centre – this has already been identified as a short term priority.<br>• Protective screen has already been installed directly above the Data Centre to protect from rain / leakage.<br>• Need to look at strengthening of Daisy Mill roof.<br>• Key staff is currently able to work remotely so extreme weather will not prevent service from being delivered through mobility restrictions. However, weather related damage to ICT infrastructure cannot be addressed remotely so there is vulnerability here. | Prolonged periods of extreme heat could potentially be a problem as temperature of the Data Centre needs to be maintained. If threshold temperature is breached this could cause a failure of the system. | • Possible delays to service/maintenance personnel and staff absenteeism due to weather related impacts on mobility or illness.<br>• Sustained high temperatures may necessitate the need for more efficient cooling options or technology advances to reduce heat levels generated by IT infrastructure.<br>• ICT is already investing in Thin Technology which is reducing heat emissions.<br>• Continuing research is being undertaken to identify technological advances to reduce power requirements and consequently heat emissions which will reduce cooling needs. |

Table 10. Weather related vulnerability assessment of Manchester City Council's Corporate Services (ICT Technology and infrastructure section)

| Service Area (Team/Dept.. Targeted) | Key functions of the service | Effects of current climate/weather on the service | Potential impacts of current climate/weather on service provision | Effects of future climate/weather on the service | Potential impacts of future climate/weather on service provision |
|---|---|---|---|---|---|
| ***Transport Services Unit in Chief Executive's Department (Highway Services and Transport Policy Unit)*** | • Highways network and traffic management.<br>• Highways maintenance/ improvements<br>• Bridges maintenance/ improvement<br>• Street Lighting (through a PFI supplier)<br>• Environmental/ Landscape Design services<br>• Road safety and school crossing patrol<br>• Maintenance of drainage systems<br>• Transport Policy Unit (delivers MCC transport policy) | • Disruption due to cold/snow.<br>• Disruption due to wind/storm and to tree falls.<br>• Potentially vulnerable to disruption to the power supply due to extreme weather. | • Increased need for provision and maintenance of road drainage systems.<br>• Need to provide road gritting and snow clearing services.<br>• Requirement of highways maintenance due to frost and heat related damage.<br>• Landscape design services to consider the need for increased green/blue space to increase SUDS capacity. | • Increased asphalt melting and rail buckling due to heat.<br>• Potential for storm/wind and flood to affect infrastructure.<br>• Drainage issues due to increased flooding.<br>• Potentially vulnerable to disruption to power supply due to extreme weather.<br>• Greater potential damage/disruption due to tree falls. | • Need to install and maintain improved road drainage systems and possible higher curb heights to reduce the impacts of flooding in vulnerable areas where kerb heights are exceptionally low.<br>• Need to install and maintain heat resistant road surfaces.<br>• Need to protect maintenance staff and equipment against impacts of increased wind/storm.<br>• Need to ensure that all infrastructures are flood and wind/storm proof.<br>• Need for increased maintenance to ensure that all infrastructure remains wind/storm and flood proof. |

Table 11. Weather related vulnerability assessment of the Transport Services Unit in Manchester City Council's Chief Executive Departmen

## 3.4 Additional information regarding the potential impacts of climate change discussed in Tables 6 – 11

This section expands on some of the most relevant issues relating to the impacts of climate change raised in Tables 6-11.

The impact of flooding: Although significant advances have been made increasing the linkages between planning and flood risk management in recent years, there is evidence that all the relevant information is not yet influencing actual land use decisions. There is a tendency for flood risk to be assessed and mitigated on a site by site basis thus inhibiting the potential for strategic solutions. Many planning departments no longer have drainage engineers and have to rely on the EA and the utility company for information. The lack of robust data adversely affects flood risk management and LAs should be encouraged to become more proactive in managing data on flood events. Strategic Flood Risk Assessments (SFRAs) inform local development decisions but to be more effective, SFRAs must include pluvial flood risk and address strategic storage issues and options (Lawson et al., 2008). Building regulations should consider flood resilience as a requirement for all new buildings (Adult Social Services, Eastland Homes and Leisure Services). Sustainable Urban Drainage Systems (SUDS) should be promoted in public open spaces, along roads or in parking areas (Leisure Services, Environmental Services and Transport Services).

The impact of climate change on human well-being in the built environment: Climate change will increasingly impinge on human well-being in the built environment and this will impact on service providers and users in five of the service areas selected for this initial vulnerability assessment. The Met Office Heat Health Watch (http://www.metoffice.gov.uk/weather/uk/heathealth/) suggests that day time temperature in excess of 30ºC and night temperatures of minimum 15 ºC could have a significant effect on health in the North West of England if reached on at least two consecutive days and the intervening night. Maintaining comfortable internal temperatures is essential. Comfort in the working environment is important for productivity (Corporate Services), temperature impacts on human health (Adult Social Services and Eastland Homes), on indoor sport (Leisure Services) and in trams and busses (Transport Services). The Chartered Institution of Building Services Engineers (CIBSE) recommends comfort criteria and temperature ranges for specific applications and building uses. The recommendations cover winter and summer operative temperature ranges for various public and private buildings and specific activities within these buildings (CIBSE, 2006). Maintaining these standards will require increased levels of natural ventilation, air conditioning and the maintenance/provision of Manchester City Council's buildings and facilities.

The impact of climate change on urban greenspace and trees: The impact of climate change on gardens (and thus, by implication, on urban greenspaces managed by Manchester City Council) has been assessed by Bisgove and Hadley (2002). Soil changes brought about by climate change will have a very profound influence on plant growth. Higher air temperatures will increase evapotranspiration by plants, thus reducing soil moisture content. Higher

temperatures will also increase the rate of loss of soil carbon by oxidation. This will lead to loss of soil structure and loss of permeability so intense rain rainfalls may lead to run-off (and therefore erosion and flooding) rather than the recharge of soil moisture reserves. Decreased rainfall will slow conversion of soil to $CO_2$. Usually plants will cease to take up water (and therefore nitrates) from the soil before the soil has dried to the extent that organic matter breakdown stops. Nitrates will therefore accumulate in the soil and leach out in heavy rains. Thus, any action which increases soil organic matter will help to reduce these problems.

The impact of climate change on woodland has been assessed by Broadmeadow et al. (2003). They conclude that it is clear that climate change has the potential to dramatically affect forestry in the UK. Whilst rising concentrations of $CO_2$ in the atmosphere will be beneficial to tree growth, moisture availability is likely to have serious consequences and species suitability will change over wide areas of England. The increasing complexity of dealing with climate change impacts in urban greenspace and to trees will require sensitive management and training for staff (Environmental Services and Leisure Services).

### 3.5 Indirect impacts of current and future climate/weather on service provision.

This section considers some indirect impacts of current and future climate/weather on the 6 service areas addressed by the vulnerability assessment, and makes some preliminary recommendations on how Manchester City Council should address these issues.

Tourism and recreation: Tourism and recreation in Northwest England, and thus in Greater Manchester, will potentially benefit from climate change (McEvoy et al. 2006). This will increase the requirement for outdoor leisure facilities, urban green spaces and associated infrastructure (e.g. toilets, car parking). Manchester Leisure Services, Environmental Services and Transport Services need to be aware of this potential increased demand on their services.

Housing density and vulnerable sectors of the population: Social housing is invariably the home of the more vulnerable sections of society (the poor and the elderly). The impacts of climate change on this housing (particularly flood, wind and heat) must be addressed. Furthermore social housing is invariably higher density, but it is precisely these areas which will require greater access to green space as a response to the impacts of climate change on health and human comfort.

Walking and cycling: As weather patterns change there is considerable potential for an increase in cycling as a form of transport. Demand for pedestrian friendly areas of the city will also increase. This will impinge on the provision of transport services and on the use of green spaces and green corridors. Old railway lines and pathways are already being developed as cycle and pedestrian routes but much more is needed. Cycling needs to be integrated into strategic road and transport planning to enable Greater

Manchester to maximise this form of sustainable travel and to match other cities in the UK and in Europe in promoting sustainable transport in the light of climate change.

Population growth and increased mobility: All service areas will need to take account of the potential strain on their ability to deliver key functions because of increased population and demand for personal mobility. Manchester City Council predicts that the population of the city will increase from 452,000 in 2006 to 599,100 in 2031 (Manchester City Council on line, 2009). The Regional Economic Strategy identifies the wider Manchester City Region as having the potential to make the most significant contribution to the future economic growth of the North of England. The current reference estimate for the increase in gross value added (GVA) in Greater Manchester between 2007 and 2022 is 2.8% per annum, with a potential for this to be up to 3.2% per annum if Greater Manchester realises the unique opportunities and assets afforded to it. The scale of new employment projected for Greater Manchester will significantly increase the demand for an effective transport system, not only serving the Regional Centre but the whole of Greater Manchester and the wider City Region. These increases will have a particular effect on the delivery of Transport Services but will also impinge on the provision of key functions for all of the six selected service areas (Greater Manchester Passenger Transport Authority and Association of Greater Manchester Authorities, 2008). Issues of managing increases in population growth and housing demand must be seen in the context of a changing climate.

# 4 Discussion

This section draws on the key findings of the Greater Manchester Local Climate Impacts profile (GMLCLIP) to consider future vulnerability to climate change in Greater Manchester, to assess of how this vulnerability will affect some of Manchester City Council's key service areas, to discuss ways of reducing vulnerability to climate change in Greater Manchester and to explore opportunities associated with climate change.

### 4.1 The Greater Manchester Local Climate impacts Profile

The Greater Manchester (GM) LCLIP demonstrates that of all severe weather related events which have impacted on human health/wellbeing and on infrastructure or have caused disruption to vital services, 43% resulted from precipitation causing flooding and 28% were the result of damage due to storm induced wind. Those LA services most at risk to flooding are therefore particularly vulnerable to climate change. Likewise agencies dealing with flood risk and Civilian Welfare should be undertaking an initial assessment of their vulnerability to climate change. The LCLIP also indicates that whilst flood is the principal cause of damage to property and infrastructure, human health is most severely affected by wind and heat. Also, summer storm induced pluvial flooding is now more prevalent that riverine flooding. A trend towards more frequent and intense storm events and more heavy rainfall events is also apparent, and vulnerability to these risks has increased in the last 10-15 years. The GM LCLIP indicates that whilst prolonged cold events and heavy snow falls are receding, they still continue to cause severe disruption.

### 4.2 Future vulnerability

UKCIP scenarios and studies undertaken at University of Manchester demonstrate that weather patterns in Greater Manchester are projected to change significantly, and that this change is set to accelerate from the mid-21$^{st}$ century. Winter and summer temperatures will increase. Winters will be wetter whereas summers will be drier. Storm events will become more frequent and more severe. Growing seasons will be longer and the need for green space will become more prevalent, with requirements for the maintenance of this green space also increasing. Whilst riverine flooding in Greater Manchester has largely been contained by levees and temporary flood storage basins in recent years, flood risk will increase as winters become wetter. The increase in storm events is already being felt by more frequent and more severe instances of pluvial flooding, and climate change scenarios suggest that this trend is likely to continue. More frequent and severe winds will affect the arboreal and the built environment. Heat will compromise human comfort and will potentially affect health and well-being although in some cases increasing temperatures will bring opportunities such as for outdoor recreation and tourism.

### 4.3 Vulnerability assessment

To meet the requirements of Level 1 of NI 188, Tables 6-11 and sections 3.4 and 3.5 reflect in detail on both current and potential future vulnerability to weather impacts of six of Manchester City Council's service areas. They clearly demonstrate that climate change will necessitate action by LA

departments in adapting LA buildings to increased heat levels, protecting vulnerable sectors of the community, providing and maintaining more urban green spaces and outdoor leisure facilities, managing water supplies and protecting infrastructure in vulnerable areas of the city and vital services against increased threats of storm and wind events.

However, the GM LCLIP demonstrates the need for Manchester City Council to take a holistic view of how these impacts affect vulnerability to both other service providers in general, and on the wider range of the Council's services in particular. Levels 2 and 3 of NI 188 require the identification of priority areas for action to ensure that impacts of current and future weather and climate are dealt with in a proportionate way, the development of a comprehensive adaptation action plan, and the implementation of appropriate adaptation responses whilst ensuring that consideration of changing climate impacts and risks is embedded in all authority decision making (Local and Regional Partnership Board, 2008). The range of service areas identified in Tables 6-11 for this current exercise will need to be extended in line with NI 188 guidance to include other vital services such as education and civil contingencies (emergency planning). Moreover an internal vulnerability assessment by the different service departments could usefully be undertaken to aid the consideration of the impacts of current and future weather and climate. Furthermore whilst planning is not as yet in itself vulnerable to the impacts of climate change in providing its services, it has a crucial role to play in facilitating vital adaptation strategies such as the provision of green spaces, SUDS, and in ensuring that new build meets suitable standards.

### 4.4 Vulnerability reduction

An analysis of the GMLCIP and of current and future vulnerability and risks leads to the proposal of a number of broad cross-cutting observations towards reducing Greater Manchester's vulnerability to the principal climate/weather induced risks:

*Reducing vulnerability to flooding:* To reduce vulnerability to flooding agencies concerned with urban drainage (the Environment Agency, LA highways and drainage departments, the utility company) flood forecasting and mapping (the Met Office and the Environment Agency), emergency services (civil contingency departments, the Fire Service, the Police), the development and use of land (planning departments) and Building Control, need to act in a cohesive and coordinated manner. Specific recommendations include the need for the police to close flooded roads quickly to ensure that splash from heavy vehicles does not enter houses. The increased vulnerability to pluvial flooding highlights the need for LAs to consider how best to improve the drainage system. This will include increasing natural infiltration rates and providing for Sustainable Urban Drainage Systems (SUDS) to reduce runoff which will require action by all departments concerned with urban planning. Flood victims suffer considerable disruption and stress and this will require action by all social and public health services.

All levees and dams can fail. Dams are vulnerable to climate change induced failure because extreme drought, prolonged very heavy rain or storm induced wave action could subject a dam to stresses for which it was not designed. Old earth filled structures are the most vulnerable and the earth dams containing the Audenshaw reservoirs were constructed by Manchester Corporation between 1877 and 1882. Even a minor earthquake could be the final trigger for an old dam weakened by climate change (Chartered Insurance Institute, 2009) and the Manchester quake of 2002 measured 3.9 on the Richter scale and that of August 2007 was 2.5 on the same scale. Whilst the utility company is responsible for maintaining reservoirs such as Audenshaw and the EA is responsible for the enforcement of the Reservoirs Act 1975 which covers all large raised reservoirs in England and Wales, it is Manchester's population and infrastructure at risk.

*Reducing vulnerability to the impacts of wind/storm:* To reduce vulnerability to wind damage LAs should assess the health of urban trees (and here caution is required because urban trees are important in adapting to climate change through in reducing runoff and in mitigating the effects of heat on human comfort) and the state of the built environment such as roof tiles and other vulnerable parts of buildings (building control).

*Reducing vulnerability to cold/snow:* To reduce the still prevalent vulnerability to cold/snow will require a reassessment of those agencies charged with dealing with the effects of snow and ice on the transport infrastructure (highways departments) and of cold on vulnerable sections of the population (education, health and social services).

*Reducing vulnerability to heat:* To reduce vulnerability to the impacts of heat will require improved levels of natural ventilation (and/or air conditioning when natural ventilation is impossible or inadequate) in all public buildings, educational premises and LA owned/maintained public housing and homes for vulnerable sections of the population such as the elderly, the disabled and the very young. The provision of additional urban green space with trees (or alternative shaded areas) and of water based leisure facilities is likely to be increasingly important in maintaining human comfort. Also, crime prevention agencies will need to take account of a greater propensity for people to leave windows open and housing unattended on hot days, as well as the possibility of increases in public disorder due to more outdoor activity in cities.

*Reducing the risk of drought*: Whilst drought has not been a serious phenomenon in the Northwest of England and in Manchester in the past, climate change scenarios suggest a decline in average summer rainfall. The provision of clean water and the disposal of soiled water is primarily the responsibility of the local utility company but the appropriate LA departments will need to assess, and be prepared for, possible water shortages in the future. Drought also has a potential impact on the health of green space areas and of trees, which are crucial for adapting to the impacts of climate change in cities. Furthermore, in steep areas green cover and healthy trees act to reduce the risk of landslip. Thus, the need to provision for the watering of green space and trees, particularly in built up areas, is likely to increase in the

future. To adapt to these impacts the water utility will need to work closely with the LAs in providing storage and distribution facilities able to meet the predictable increases in the demand for water at crucial times of the year.

*Reducing the risk of wild fires*: There are large areas of moorland within Greater Manchester. Outside of the Peak District National Park, where wild fire is a constant threat, LAs are responsible for the protection of these areas. More and more people use these areas for recreation. Longer dryer summers are likely to increase recreation pressure and reduce soil moisture content. These factors will ultimately increased fire risk, as fires are often caused by humans. McEvoy et al. (2006) consider various mitigation methods such as gully blocking to raise the water table and reseeding vulnerable areas and they particularly highlight the importance of careful management practice.

*Reducing the risk of subsidence:* All voids under a city face some degree of risk from climate induced subsidence due to increased levels of precipitation and higher temperatures reducing soil moisture content. The quaternary tills (boulder clay) deposits which form a large part of Manchester's drift geology contain a high proportion of quartz and rock-flour from the glacial erosion of the bedrock and are not generally considered to be particularly susceptible to shrink-swell. However, much of Manchester is covered with lodgement till overlain by supraglacial tills and fluvio-glacial deposits which are inherently unstable and intrusion can induce changes in their hydro-geological regime which could trigger increased instability. Manchester has not only been excavated to make way for coal mines, sewers and services but also has a series of other lesser known underground voids such as The Guardian Underground Telephone Exchange, cold war bunkers and underground canals (Lawson and Lindley, 2008). Thus, those agencies dealing with transport, underground services and the state of infrastructure should be aware of potential increased risk of ground subsidence.

**4.5 Exploiting opportunities associated with a changing climate:**

Many of the most significant challenges associated with climate change relate to developing adaptive response to climate risks such as flooding or heat stress. However, from a regional perspective, there are a range of potential opportunities relating to climate change. These centre on the warming trend projected for Greater Manchester. Possible opportunities, linking to warmer summers in particular, include enhancing outdoor recreation and leisure, providing a more attractive tourism offer, and securing health benefits linked to outdoor lifestyles. Warmer temperatures and an extended growing season may also enhance local food production. The City Council should look to develop strategies to exploit beneficial climate change effects for its population.

# Project conclusions and overriding recommendations

In this final section we integrate the conclusions from the study undertaken by University of Manchester with those of the study undertaken by Red Rose Forest. The University of Manchester study identifies current and future vulnerability to climate change in Greater Manchester and considers the effects and the potential impacts of current and future climate/weather on key service areas within Manchester City Council and the way forward for the Council. Red Rose Forest's study covers the awareness of staff and service departments and the organizational priorities required for Manchester City Council to adapt to climate change.

**Current vulnerability to climate/weather in Greater Manchester**
The GM LCLIP demonstrated that flood and storm are the principal cause of damage to property and infrastructure, but that human health is most severely affected by wind and heat. The GM LCLIP also highlighted that summer storm induced pluvial flooding is now more prevalent that riverine flooding, and that whilst prolonged cold events and heavy snow falls in Greater Manchester are receding, they continue to cause severe disruption when they do occur. Trends in current climate, identified by the LCLIP, are set to intensify in the future as the climate changes. Strategies to address vulnerability to current weather and climate have a clear role to play in adapting to a future where climate change accelerates.

**Future vulnerability to climate/weather in Greater Manchester**
The GMLCLIP demonstrates that LA services which are already most at risk of flooding, wind/storm and heat are particularly vulnerable to the direct impacts of climate change as projected by the UKCIP scenarios. Climate change projections indicate that peak summer temperatures in Central Manchester could reach 34ºC in the 2080s, with significant impacts on human comfort likely from the 2050s onwards. Projections also demonstrate that summers are likely to be drier, but winters become significantly wetter and storm events will become more frequent and intense. The effect of current and future vulnerability is further addressed in the University of Manchester's study into Adaptation Strategies to Climate Change in the Urban Environment (ASCCUE) which highlights the importance of urban greenspace in moderating the effect of surface temperature, protecting biodiversity and in decreasing runoff.

Climate change projections indicate the potential for significant increases in Manchester's vulnerability to heat, storm and precipitation related impacts, issues that are already generating current issues for Manchester City Council to address. The Council needs to take a holistic view of how climate change affects vulnerability to the wider range of the Council's services and on other service providers working with the LA. Related issues are explored within the vulnerability assessment conducted as part of this project. For example, reducing vulnerability to urban flooding requires close liaison with the Environment Agency, the local utility company, the police and the fire services

as well as LA departments dealing with drainage, green infrastructure, planning and civil contingencies. Reducing vulnerability to wind and storm involves planning and building control. Reducing vulnerability to heat requires the intervention of planning departments and of the Health Protection Agency. Reducing vulnerability to drought requires close liaison between the LA and the water utility company. Strategic, coordinated and in many cases conurbation wide adaptation responses are ultimately necessary.

**The effects and potential impacts of current and future climate/weather on key service areas within Manchester City Council**

The GMLCLIP and the study of the requirements to meet Level 1 of NI 188 highlight that Local Authorities need to be committed to the principal of adapting their service areas to climate change. The weather related impacts outlined in this report, and in particular those resulting from increased levels of precipitation, storm/wind events and heat, show that all of Manchester City Council's departments and individual sections need to undertake an early, holistic, and comprehensive assessment of their current and future vulnerability to climate change. Moving towards meeting the requirements of NI188 will assist considerably in this task.

A range of potential adaptation responses are available to planners and decision makers tasked with addressing this challenge. Services need to take a strategic view of the role of all urban green spaces from a climate change adaptation perspective; consider the impacts of significantly increased use of parks and outdoor facilities; consider the potential use of these areas in flood mitigation; be aware of the need to provide human comfort in a warmer climate and the potential impacts of heat, wind and water on their infrastructure and their outdoor facilities. Services will also need to take account of the increased potential for heat stress and heat related illnesses for all vulnerable sections of the population. Some services are particularly vulnerable to climate related power failures and extreme heat breaching threshold temperatures. Population growth, increased mobility and tourism and increases in urban density will have an indirect impact over and above the direct effects of climate change.

**Awareness of Manchester City Council staff and services to climate change adaptation**

An appraisal of Manchester City Council's business plans and interviews with senior officers in the key areas selected for this study concludes that there is overall a good understanding of future climate change scenarios and extreme weather. However, there were instances where the lines of differentiation became blurred. Business Plans made very few references to dealing with extreme weather and planning for future climate change scenarios with respect to service delivery. Nevertheless, several interviewees stressed that emergency planning procedures (Emergency Plans / Business Contingency Plans) would cover emergency events like extreme weather even though this was not directly referenced.

Some consideration has been given to planning for climate change in particular by Highways, Leisure and Green Spaces, and it was acknowledged

by all of the interviewees that there would be resourcing implications for dealing with the expected changes. Further, all interviewees had some comprehension of the negative aspects of climate change to service delivery but there were very few instances where positive outcomes or opportunities were cited.

The LCLIP and analysis of future climate change scenarios demonstrate that extreme weather, both in the present day and concerning future climate projections, has a varying actual and potential degree of impact on the different services, with those services relating to the external environment bearing the brunt of additional cost and staffing requirements. It was apparent from the interviews undertaken that these services are already struggling to resource the cost of extreme weather and that an escalation in these events would likely exceed their capacity to respond in an effective way without compromising service provision elsewhere.

Wind, extreme cold and floods were perceived as the most damaging events in terms of service disruption and associated costs. Extreme / prolonged heat did not incur the same degree of perceived significance. This is potentially because extended periods of extreme summer heat / drought have not been experienced in Manchester, and thus the potential consequences are less easily visualised.

**Organisational Priorities**

Manchester City Council needs to engage with all departmental managers to ensure that a range of officers are actively involved in the assessment of vulnerability to climate change and the generation of strategic responses to related impacts within their respective departments. It will also be important to raise awareness of resourcing issues at the strategic level. Specific training for all levels of Council staff to raise their awareness and understanding of extreme weather / climate change will be required.

Awareness raising with the general public to instil and understanding of why change in service provision is needed to adapt to climate change and what is they can do to make themselves less vulnerable to these changes will also be important. This awareness raising can be undertaken directly with individual beneficiaries as would be the case with Adult Social Care or on a group basis with Friends of or Park Groups via Leisure Services or the Green Spaces Division.

The forecast increase in flooding events, both pluvial and riverine, highlights that immediate work on this topic is essential. From an organisational perspective, an inter-departmental strategic approach is needed, taking account of all service delivery areas utilising council land for drainage and/or water storage where possible. Likewise the potential increase in extreme wind events should stimulate a review of Local Authority and LSP building stock to assess current vulnerability. From a future development perspective a piece of work identifying minimum standards for resilience to wind damage is suggested in the form of supplementary planning guidance / design guides.

Of the departments interviewed in this Level 1 NI 188 work, Highways Maintenance have the largest shortfall in resources, technical expertise, and IT systems to deal with drainage and flooding. This clearly has serious implications for business continuity across all of Manchester as well as public safety, and should be considered in greater detail by Council staff. Highways Maintenance and Green Spaces Division have monitoring systems in place for extreme weather. It is suggested that all service providers adopt a similar system so the resource implications of these events can be scrutinised so that this can be built in to the annual budget planning process.

The snow fall and extreme cold this year demonstrated that although these events are now less prevalent, they can still nevertheless be very disruptive. Weather warnings issued by a source such as the Meteorological Office, combined with set procedures for dealing with these events, may help to reduce associated impacts and prepare staff and beneficiaries alike for dealing more effectively with these eventualities. Careful consideration needs to be given to the impact of how future episodes of extreme heat will affect service provision and potential beneficiaries. There is at present insufficient understanding and contemplation of what the implications for more frequent weather of this nature will mean in practice in Greater Manchester.

**The way forward**

The findings of this study into the effects and the potential impacts of current and future climate/weather on key service areas within Manchester City Council emphasises the need to address the core requirements of NI 188. The Council must communicate potential vulnerabilities and opportunities to department/service heads and other local partners, and they must begin to set out the next steps in addressing them. This report provides these department/service heads and other local partners with relevant guidance into these topics. Many of the key lessons learnt are generic and applicable across a wide range of services within the council and their Local Strategic Partnership.

This report also indicates that department/service heads are best placed to act on the requirement of NI 188. Local managers need to ensure that a range of officers within their units are actively involved in the development of adaptation responses in their own, and in other cross-cutting service areas.

Climate change has the potential to impact on virtually all of the Authority's key functions. The generation of strategic responses to weather and climate related impacts within individual LA departments, and the wider services of both Manchester City Council and other local partners/external service providers within Greater Manchester, is imperative.

# Glossary of terms

**Climate**: The general weather conditions prevailing in an area/region and over a long period of time (years).
***Drift**:* material that is deposited directly by ice
**Evapotranspiration:** the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.
**Events (Weather related):** Extreme weather conditions which have impacted on human health/well-being and/or infrastructure and/or have caused severe disruption to services.
**Fluvio-glacial deposits:** glacial sediments sorted and stratified by the action of melt water.
**GIS:** Geographic Information Systems
**Impacts (of weather related events):** The consequences of a weather related event.
**Infill:** Covering urban greenspaces with infrastructure. For example, the practice of converting previously infiltrating and evapotranspiring urban spaces such as gardens and open spaces with impervious car parks and buildings.
**LIDAR (Light Detection and Ranging):** High accuracy, high resolution elevation data derived from airborne sources
**Peri-urban:** Areas immediately outside, but adjoining, the urban conurbation- the urban fringe.
**Pluvial flooding:** surface water flooding which occurs when the runoff from high rainfall events (typically summer thunderstorms) exceeds the hydraulic capacity of the drainage system.
**Quaternary:** The Quaternary period is the youngest of three periods of the Cenozoic era in the geologic time scale, spanning 2.588 +/- 0.005 million years ago to the present.
**Shrink-swell:** the extent to which clay soil shrinks as it dries out or swells when it gets wet.
**Vulnerability:** the degree to which a system is susceptible to, and unable to cope with, adverse effects.
**Weather:** the state of the atmosphere at a particular place and at a particular shorter time (hours, days, seasons).

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