

Appendix P Climate Change Adaptation Report

Bilston Leisure Centre

Sustainability Support




**Climate Change Impacts and
Adaptation**

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There is now widespread scientific consensus that accelerated climate change is happening and that human activities are the principle cause. Even if we make significant reductions to greenhouse gas emissions, the lag in the climate system means that emissions that we have already put in to the atmosphere will continue to affect the climate system for the next 30-40 years. Adapting to climate change is therefore an essential part of ensuring buildings remain fit for purpose.

Climate projections for the design life of the Bilston Leisure Centre development indicate that weather conditions are going to alter significantly and it is therefore no longer suitable to only design buildings to cope with historic trends. Climate observations from around the world and in the UK already show a strong warming trend over the past 50 years, with 10 of the 12 warmest years on record in England occurring since 1995.

This assessment has considered key elements of the building's design, primarily focusing on the building fabric rather than installation of services, as the design life for the former will need to be longer and the costs of leaving the implementation of adaptation measures until post-construction more costly. Whilst it is clear that not all climate impacts are sufficiently understood to justify a significant change in approach, there are areas like thermal modelling, water use and drainage where significant adaptations can and should be made to build long term resilience into the buildings.

2 Introduction

Recent extreme weather conditions have caused significant damage to buildings throughout the UK. Most evident have been rainfall and flooding events. In April 1998, severe flooding occurred in the Nene and Great Ouse valleys, directly affecting more than 10 000 people in Northamptonshire. The winter of 2000/2001 was one of the wettest on record and in 2007 extreme summer flooding hit Hull and Gloucester, which resulted in 13 deaths and damage to approximately 48,000 homes and 7,000 businesses.

These events are indicative of the sorts of factors that will affect the built environment on a more regular basis as our climate changes. It is therefore essential that future design assesses and manages the risks involved in this challenge to help ensure future resilience. A sentiment stressed by the recently published Pitt Review, commissioned by the government to review the UK response to the floods of 2007.

The importance of integrating climate change decision-making throughout the design process is a key element of the work completed for the wider Bilston Urban Village development to date and will form the basis for the approach used in this assessment. Engagement of the project team as the design develops will help to ensure the recommendations from this report are integrated throughout the Leisure Centre development.

The design brief for the development requires a 'Climate Change Adaptation Strategy' to be developed for the site, and to be submitted to the client. The aim of this assessment, which will inform the adaptation strategy, is to identify elements of the proposed development which are vulnerable to climate change over the development's design life (up to 2070). It will highlight key issues to the design team to help ensure the building is suitably adapted, increasing its resilience to potential impacts.

3 Targets and Requirements

3.1 National Planning Policy

Addressing climate change is a central part of sustainability. Central Government has expressed the view that Local Authorities should seek to address climate change across all service areas, but the focus to date has tended to be on climate change mitigation, especially through carbon management approaches and home energy / fuel poverty schemes. Planning Policy Statement 1 supplement – *Planning and Climate Change* (December 2007) – identifies the need for planning to help “shape sustainable communities that are resilient to and appropriate for the climate change now accepted as inevitable”.

3.2 Local Planning Policy

The regional Spatial Strategy for the West Midlands (January 2008) reflects aspirations of PPS 1, specifically in Policy CC1, which requires all new development to (i) minimise resource demand and encourage the efficient use of resources, especially water, energy and materials; and (ii) encourage the construction of climate-proofed developments and sustainable buildings to help ensure their long-term viability in adapting to climate change.

Wolverhampton City Council’s recognition of the importance of tackling climate change is reflected in the Bilston Urban Village Climate Change Adaptation Project conducted in 2005. Within the site wide risk register completed as part of this project the impacts from climate change were identified as the most significant risk for the development. It drew out the long term viability of the site in particular due to the areas topography and its particular susceptibility to flooding and identified that site design would need to take account of climate change, aiming for long term resilience.

3.3 Plot A Development Brief

This study has been completed in line with the requirements of the Plot A Development Brief, aiming to ensure consideration is given to the likely impacts of climate change and the need for the building to be resilient to them over its design life. The development’s target to achieve a BREEAM rating of ‘Very Good’ at a minimum will assist the integration of sustainable approaches and techniques throughout the building design, which will help to build resilience to future climate change.

Climate change adaptation is identified as an important issue within the Plot A Development Brief Design Code, with a dedicated section covering the topic. The following specific design objectives are included:

- Incorporate safe access routes in event of flooding / extreme climate event
- Decrease run-off from the site
- Drainage systems should be designed to cope with more intense rainfall
- Consider role of planting to provide wind breaks / shelter from increases in wind
- Any cladding able to withstand possible increased wind speed

- Structure strong enough to cope with increased wind speeds and possible subsidence/heave
- Future proofing the building so that it can withstand warmer temperatures
- Selection of plant species to take account of warmer / dryer climate
- Maximise opportunities for outdoor activities
- Flexibility in design so uses can alter over the lifetime of the building

These objectives will be considered throughout the assessment and responses identified and summarised in the conclusion.

4.1 Climate scenarios

The following table summarises the projected changes to the climate of the West Midlands and this information will form the basis of this assessment. The data have been drawn from the climate scenarios produced for the UK in 2002 by the UK Climate Impacts Programme (UKCIP02). This summary was produced within a report by Entec UK entitled 'The Potential Impacts of Climate Change in the West Midlands', and was also listed within the Bilston Urban Village Climate Change Adaptation Project.

Table 1: Climate Impacts Summary for the West Midlands

Climate Indicators	Future predictions
Air Temperature	<p>The average mean temperature in Birmingham between 1961 and 1990 was 9.4°C. This is expected to increase by between 0.5°C and 1.5°C by the 2020s and between 1.0°C and 2.5°C by the 2050s</p> <p>Most of the warming is expected to take place in Summer, although Winters are also expected to be significantly warmer. Warwickshire and the South East of the Region are expected to warm more than Shropshire and the North West of the Region</p>
Rainfall	<p>The mean annual precipitation is expected to change by less than 10% by the 2050s. However this hides the dramatic change in seasonal precipitation. Winter precipitation might increase by between 0% and 10% by the 2020s and up to 20% by the 2050s. On the other hand, Summer precipitation might decrease by between 0% and 20% by the 2020s and up to 30% by the 2050s</p> <p>Cloud cover is expected to decline slightly overall (between 2% and 6% by the 2050s) with a small increase of up to 2% in Winter and a larger reduction of up to 10% in Summer by the 2050s</p>
Humidity	<p>Overall relative humidity (the amount of water vapour in the air in comparison to the maximum saturation) is likely to decline by a small amount in Winter (up to -2%) and decline much more in Summer (-2% to -4% by the 2020s and -2% to -8% by the 2050s) as the air temperature is expected to increase - see above. This may lead to a reduction in the number of days with fog.</p>
Wind Speeds	<p>Making accurate predictions on how the wind environment may change the future is very difficult. Predictions of the changes in the wind climate are among the least certain of the UKCIP02 scenarios, they do, however, indicate a slight increase in mean wind speed and a possible increase in the</p>

	<p>frequency of gales.</p> <p>The mean daily wind speed over the year is not expected to change very much (0% to +1%), but Winter mean wind speed is expected to increase by up to 4% in the South East of the region by the 2050s. Summer mean wind speed is likely to stay the same (+/- 1%).</p>
Soil Moisture	<p>The potential changes in soil moisture are quite dramatic. Soil moisture is a function of temperature, precipitation, humidity, sunshine and wind speed. Overall in Summer the Region would be drier and warmer and hence soil moisture could fall by between 5% in the North West of the Region and 35% in the South East of the Region by the 2050s. In Winter, however, the increased precipitation could lead to higher soil moisture levels and the increased probability of flooding.</p>

4.2 Extremes

As well as the changes in average climate conditions outlined above, the occurrence of extreme climate events is also expected to change. This could be in the daily extremes of temperature or precipitation for example, or in the occurrence of extreme years. UKCIP02 indicates that a 2003-type summer and the extreme temperatures experienced in August throughout Europe causing over 35,000 additional deaths will be an average summer climate in 2040 and a cool summer by 2060.

This section identifies the potential implications of climate change for the building and site design by applying the previously discussed climate scenario information available for the West Midlands. Once the potential impacts of climate change have been identified it will be important to consider the variety of adaptive options available to ensure the proposed response is suitable.

The UKCIP publication 'Risk, Uncertainty and Decision-making'¹ identifies 6 adaptation types which will frame our approach: share the loss (insurance); bear the loss (accept the risk); prevent the effects (structural/technological response); avoid the risk (change location); research; and behaviour change (increase public awareness). Within these 6 approaches we will also seek to identify 'no, or low, regret' options (cost effective approaches), 'win-win' solutions (deliver other benefits), and also seek to keep options open through incremental adaptive approaches.

This section follows the structure of the Developers Checklist produced by the Three Regions Climate Change Partnership in 2005, which has now also been adopted by the West Midlands Sustainability Partnership. It will therefore consider the following sections:

- Site layout/ materials/ structure
- Ventilation/ cooling
- SUDS
- Water use on site
- Outdoor space/ shading
- Landscaping / ecology

5.1 Site layout/ materials/ structure

Future flood risk

Flood risk for the site has been assessed through the flood risk assessment (FRA) conducted by Waterman Civils². The assessment identified that Plot A is on the boundary of the indicative flood plain for the Bilston Brook. The report modelled the 1 in 100 year flood event and found that Plot A was not at risk, partially due to the elevation of the site (maximum flood extent for the site was identified to be 135.5m Above Ordnance Datum (AOD) and the formation level for the lower ground floor is approximately 139m AOD), and also due to adequate capacity of the Bilston Brook culvert. However, it is not clear from the FRA whether the impacts of projected climate change on the peak river flow for the 1 in 100 year event has been taken into account.

Recommendation - The degree to which climate change has been incorporated within the FRA, specifically the consideration of PPS25 and the allowances for climate change should be checked with Waterman Civils.

For the site drainage strategy the FRA indicates that storage capacity for the 1 in 30 year storm event should be provided within oversized pipework for the site. The FRA

¹ Willows, R. & Connell, R. UKCIP. Climate adaptation: Risk, uncertainty and decision-making. 2003

² Waterman Civils Consulting Engineers. Flood Risk Assessment Bilston Urban Village Plot A and Site Wide Risk. January 2007.

recommends that to attenuate flooding beyond 1 in 30 year events, flood water should be diverted overland to the proposed balancing pond to the west of Bankfield Road. PPS25 requires a 30% increase in flow to be incorporated to allow for climate change over the lifetime of the development. This factor is included within the FRA and should therefore be incorporated into the design of the site ponds and swales

Recommendation – The PPS25 requirement to take account of a 30% increase in flow to allow for the impacts of climate change should also be considered within the design the surface water drainage capacity of the leisure centre, including the attenuation tanks positioned under the road outside of the boundary of leisure centre development.

Structural Stability

For the West Midlands UKCIP02 indicates that over the life span of this development wind speeds could increase in winter by up to 4% and reduce during the summer by up to 6%. However, compared to predictions of temperature changes there is significant uncertainty tied into wind speed predictions. The best approach in this situation is to develop 'win win' or 'no regret' responses that will deliver other benefits or have only very marginal additional costs.

For this project wind loads for the proposed building have been calculated in accordance with BS 6399: 2.1997 (Code of Practice for Wind Loads). This takes account of a variety of factors such as direction, season, altitude etc, but it does not consider the implications of climate change. Based on UKCIP02, BRE Digest 499³ provides national guidance on 'Designing roofs for climate change'. It recommends that for roof structures design wind speeds should be increased by 10% when calculating wind loads. However, the proposed roof design for this building appears to be very robust and therefore additional consideration for climate change is not required given the uncertainty involved. For the building structure wind loads will be applied to the building generally (overall stability) and to local structural elements in accordance with the wind loading code.

CIRIA C638⁵ recommends that for buildings of 2-10 stories, 'the increase in wind load should not require structural enhancement, but small increases in movement may occur.

Roof drainage

As rainfall intensity is projected to change as a result of climate change, roof drainage calculations will need to be amended to allow sufficient gutter capacity. Relatively standard external rainfall guttering and down pipes can be replaced at relatively little cost if an increase is required. However, internal and underground drainage pipes are less easily adapted. Buildings with flat roofs can be designed to store rainfall for short periods, lessening the impact of increased rainfall intensity. One of the benefits of implementing a green roof would be that it will help to attenuate intense rainfall events.

Current rainfall intensity is specified within BS EN 12056-3. BRE Digest 499 indicates that there is insufficient experience within industry of applying this standard to formally recommend a modification for climate change. However, the digest does suggest that one adaptive response would be to increase gutter capacity by 10%.

³ Designing roofs for climate change. Modifications to good practice guidance. Digest 499. May 2006
- 5-4 -

Recommendation – The costs of increasing gutter capacity by 10% should be assessed to determine whether such a measure could be incorporated as a no/low regret option (i.e. little additional cost).

Site Foundations

Climate change is anticipated to reduce soil moisture content by up to 35% by 2050 in the region, which could have significant implications for the site particularly if it is underlain by clay. The geological records indicate that the site base is up to 6.3m of made ground, which typically comprises colliery spoil with varying thickness of granular demolition and foundry waste. This material is underlain by middle coal measures with a weathered upper layer recovered as stiff slightly sandy slightly gravelly clay. The bedrock of the middle coal measures consists of mudstone, sandstone, siltstone and coal⁴. Within the Foundation Design Report (June 2008) it is recommended that due to the unstable nature of the made ground the proposed development is founded on either improved made ground or natural competent strata. The proposed design is for the structure to be founded on a reinforced concrete raft due to the presence of shallow mine workings and mine entries in order to mitigate possible structural instability. This approach will also reduce any potential risk as a result of soil shrinkage due to declining soil moisture.

Building Materials

It is important to consider the climate impacts on materials used for the shell of the building which will need to have a design life of 60 years. Issues such as thermal mass, solar gain, wind exposure and water penetration can be managed through building design and suitable material use.

Our understanding is that solar gain within the atrium will be managed using solar shading in the form of louvre panels across the entire elevation. It is also understood that all glass being used for the project is laminated low-e glass with high insulating properties. The aspect of this elevation (NE) will also reduce concerns relating to overheating.

An increase in intense rainfall could make rain penetration a significant issue for the building. Consideration should be given to the avoidance of penetrating damp issues, such as mould growth. The building fabric and attachments such as louvres should be designed to prevent ingress of driving rain⁵.

Recommendation - For this development the angle and fabric of the louvers to be installed on the north east elevation should incorporate the guidance provided within CIRIA C638, ensuring that the design prevents the ingress of driving rain.

5.2 Ventilation / cooling

Thermal Comfort

Thermal comfort within buildings is an important element of any design. To ensure that the modelling conducted for this development suitably represents the climate over its entire life, it is essential that we move beyond using the standard Design Summer Year (DSY) and Test Reference Year (TRY). Although the data has recently been updated and draws on a baseline from 1985-2005, it is still using

⁴ Bilston Leisure Centre Foundation Design Report. Jacobs. May 2008

⁵ Climate change risks in building – an introduction. CIRIA C638. 2005

observations which do not reflect current climate let alone the climate in 2050's. To tackle this issue it is recommended that we use the approach developed by CIBSE in TM36⁶, which is currently recognised to be the best approach available. This essentially adapts the DSY and TRY data using the UKCIP02 climate scenarios.

TM36 considered three of the 14 weather regions for the UK; London, Manchester and Edinburgh. As demonstrated in Figure 1 a large proportion of the DSY for the 2050's moves into 'hot' or even 'heat stressed' conditions, a significant consideration for building modelling. The guidance suggests that for Manchester overheating in the 2050s and 2080's will be similar to London during the 1980s and 2020s. By applying this approach to the weather file for the Birmingham area we will be able to ascertain whether this is a significant issue for this project and the wider Bilston Urban Village development.

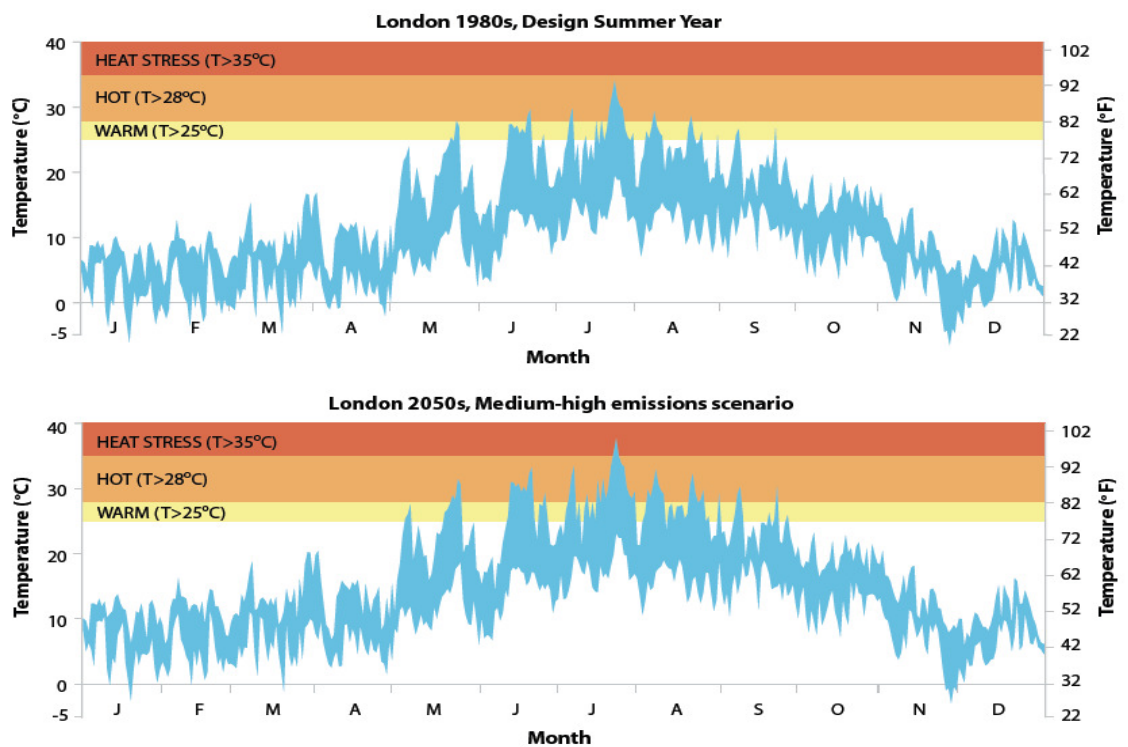


Figure 1: Daily temperature ranges in the CIBSE London Summer Design Year for the 1980's and 'morphed' ranges for the 2050's under UKCIP02 scenarios (Med-High scenario)⁷

Recommendation – Use adapted DSY and TRY data that incorporates UKCIP02 climate scenarios into the weather file for Birmingham when conducting the thermal comfort modelling for the building.

To reduce solar gain within the atrium the glass will be shaded using louver panels across the entire elevation. The aspect of this elevation (NE) will also reduce concerns relating to overheating. All glass being used for the project is also laminated low-e glass with high insulating properties.

⁶ Climate Change and the indoor environment: impacts and adaptation. CIBSE TM36:2005.

⁷ Beating the Heat UKCIP/ARUP 2005

Insulation

Part of the thermal modelling exercise will consider the insulation installed within the building which will act to reduce the need for both heating and cooling. Insulation is a crucial element of adapting to future climate change as well as being key to reducing the operational energy demands relating to heating and cooling the building. This exercise is driven by Part L, as well as the project's drive to achieve a minimum BREEAM rating of 'Very Good', so will not be covered in any detail within this assessment as suitable consideration will already have been made elsewhere. An example of the approach being taken on site to ensure best practice is the ETFE roof, which will be used above the atrium. It will ensure high insulation against solar gain (relative to a glass roof). A standard three layer cushion has a U value of 1.96 $\text{w/m}^2\text{K}$, which is better than triple glazing when used horizontally.

5.3 SUDS (link with drainage work)

Surface Water Storage

Due to site contamination and the composition of the made ground at the site it has been deemed unsuitable to have any form of soakaway or permeable drainage on site. Therefore all surface water needs to be used or attenuated to reduce the maximum discharge from Plot A breaching the 72l/s stipulated by Severn Trent Water².

To manage this issue Wolverhampton City Council have installed large attenuation tanks beneath the access road to receive all of the site drainage. The specification for these tanks should have incorporated allowances for the increased levels of rainfall caused as a result of climate change to ensure sufficient capacity is provided. However, no information has been provided by the client to allow an assessment of whether this allowance was included.

Rainwater harvesting (if implemented)

To determine the size of the collection tank required for a rainwater harvesting system it is routine to use the methodology developed by Fewkes & Warm (2000) and their ratio of storage vs water saving efficiency for a site (see figure 2 – from CIRIA C539). This ratio will almost certainly be affected by climate change through altered rainfall patterns and intensity, as well as annual demand.

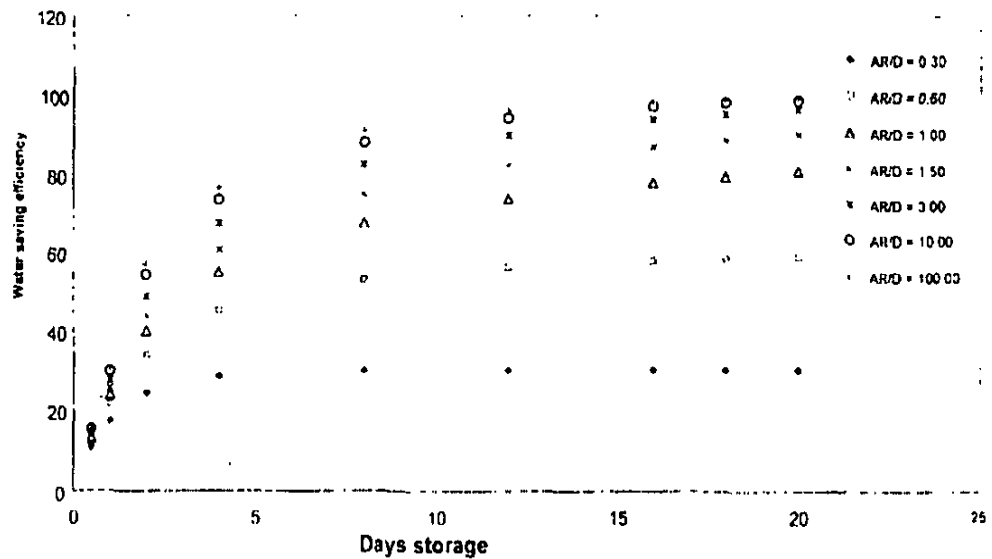


Figure 2. Average percentage of water conserved versus storage ratio (AND = 0.3 - 100)

As can be seen from section 3 the climate for the region is predicted to be significantly wetter in winter and the summers significantly drier with the overall annual rainfall still very similar to the present volume. However, if average monthly rainfall is used to calculate storage capacity for the rainwater harvesting system the alteration to the seasonality of rainfall and the knock on implications for the potential efficiency of the system, is not captured.

Calculations completed within Appendix B of the Water Efficiency assessment⁸ indicate that for summer periods in 2050 the current approach using the CIRIA guidance, which is based on current climate, would fail to supply sufficient capacity to meet demand for the centre. The way in which this rain will fall is also expected to change, with predictions indicating more intense storm events. It will therefore be crucial to have additional capacity to ensure that when the rain falls as much as possible is captured.

Recommendation – If CIRIA C539 guidance (figure 2) is used to calculate the storage capacity for a site rainwater harvesting system, additional storage should be incorporated. This will ensure that during the longer drier summers predicted as a result of climate change sufficient water is available to deliver the planned efficiency. Rainfall is predicted to fall in shorter more intense events and less frequently. Therefore storage capacity will have to be greater to capture such events and sustain the building for longer during the dry periods. Given the information above and the fact that the development will continue to operate beyond 2050, with increasing pressure on water resources in the summer, it is recommended that storage capacity aims for a minimum of 3 weeks storage. Therefore tank capacity should be 60,000 litres with actual capacity of 51,000 litres as described in section 3, Appendix B of the Water Efficiency Report.

Green roof

⁸ Jacobs (2008), Sustainability Support, Drainage & rainwater harvesting/ greywater recycling review DRAFT - 5-8 -

A green roof, established as grassland with a range of ephemeral and short perennial forb species, has been recommended for the Leisure Centre⁹. To support this habitat the substrate should be nutrient-poor, such as crushed aggregate. The installation of such a feature would bring multiple climate adaptation benefits to the development. It would act to attenuate storm water runoff, delaying/ reducing runoff from the roof. The feature would improve the thermal insulation of the building, helping to keep heat out in warm weather and thereby reducing the demand for air conditioning. In winter the extra insulation that a brown roof would provide would help to keep warmth in, thereby reducing heating demands. It would also provide additional habitat for local species helping to strengthen local populations and by doing so increase their resilience to future changes in climate.

Recommendation – Install maximum area of green roof available, using drought resistant low maintenance species. Consideration should be given to the functionality of the rainwater harvesting system when selecting the substrate and species for the roof as they will affect the quality and quantity of water available.

5.4 Water use on site

Due to climate change the availability of water resources at the national, regional and local level will become more restricted, while the demand increases due to hotter summers and increasing consumer demand¹⁰. Water use and the need to take account of water availability is a key component of the region's new Regional Spatial Strategy and within policy CC1 has specific requirements for ensuring water efficiency.

This development should seek to exploit the synergies between water resource management, flood risk and energy conservation. The water demand for this development will be significant so the potential for rainwater harvesting and grey water capture and reuse should be maximised to minimise the impact of the development. This should be tackled, as appropriate, through three techniques: water efficient fittings, rainwater harvesting (see section 5.3) and grey-water recycling.

Water efficiency

If this development is going to champion sustainability and climate change adaptation then water efficiency should be central to the buildings specification. In order to gain the targeted BREEAM rating, water efficient products will have to be used throughout the development. These products and approaches should be highly visible and where possible engage the public. A good example of this has been employed at Redhill Primary School where resource metering is electronically displayed in the foyer, with a programme of engagement and targets set around it. A similar initiative could be organised for the Leisure Centre, which would both help to drive water efficiency and act to raise the public profile of the issue.

Grey-water recycling & rainwater harvesting

Both grey-water and rainwater harvesting have multiple benefits in relation to climate change. They reduce water demand for the site and the associated carbon emissions relating to water supply and treatment. Rainwater harvesting is a form of sustainable urban drainage, which helps to reduce potential flood risk for properties down stream from the development by reducing surface water runoff. Both systems

⁹ Jacobs (2008), Sustainability Support, Ecology report

¹⁰ Climate Change and Demand for Water. Downing et al. 2003

also have the potential to reduce costs in the long term by reducing water rate charges. The feasibility and benefits of both systems are considered within the separate water efficiency report.

5.5 Outdoor space/ shading

Due to the increase in ambient external temperatures expected over the life time of this development, particularly related to the frequency and severity of more extreme summer heat wave events, the outdoor space design should include the provision of green space and tree cover to help ameliorate future conditions. This is particularly pertinent in densely built environments which are affected by the urban heat island¹¹.

Recommendation – the outdoor space design should include the provision of green space and tree cover to help ameliorate future conditions.

The landscaping design will play an important role in ensuring the provision of shade and access to green space. In addition to this, where the site design seeks to utilise external areas the use of shades etc should be considered.

5.6 Landscaping / Ecology

Climate change could affect the longevity of selected species and should therefore be considered within the landscaping design. During the recent two year drought in southern England (2004-2006) beech trees (*Fagus sylvatica*) have already experienced limited dieback across East Anglia and the southern counties. Species such as Corsican Pine (*Pinus nigra maritima*) are predicted to benefit most from climate change in the UK¹².

If a green roof is implemented, the planting scheme should consider the increased risk of summer drought, intense heat and potentially higher wind speeds that are anticipated as a result of climate change. The recommendations made by the Ecology report for the development have taken this issue into account and has recommended low growing resilient alpine species.

Recommendation - For the landscaping features around the car parking area the most important consideration will be the selection of tree species (and shrubs with an anticipated lifetime of over 10 years) and their location. Selected varieties should be drought tolerant and those located near the building should be deciduous to maximise solar gain in the winter and minimise it during the summer

¹¹ Due to the radiative properties of the urban environment observed temperatures within our towns and cities are significantly higher than the surrounding countryside. Current estimates are that this can increase average temperatures by 1.4-1.9 C.

¹² Adapting to climate change: a checklist for development. GLA 2005

6 Recommendations

Within the Development Brief for Plot A specific climate change adaptation objectives were identified (see section 3.3). Table considers identifies the development brief objectives and potential impacts of climate change and summarises this reports recommendations to address each issue.

Table 2: Summary of the project design response to climate change

Issue	Development Brief Objective	Climate Change Impact	Recommended response
Increased Flood Risk	Incorporate safe access routes in event of flooding / extreme climate event	Damage to ground floor infrastructure, temporary closer of site, dangerous for occupants	The degree to which climate change has been incorporated within the FRA, specifically the consideration PPS25 and the allowances for climate change should be checked with Waterman Civils.
			The PPS25 requirement to take account of a 30% increase in flow to allow for the impacts of climate change should be considered within the design of the surface water drainage capacity of the leisure centre, including the attenuation tanks positioned under the road outside of the boundary of the leisure centre development.
Structural Stability	Structure strong enough to cope with increased wind speeds and possible subsidence/heave	Potential for increased wind speeds as a result of climate change (up to 4%)	CIRIA C638 ⁵ (p64) recommends that for buildings of 2-10 stories, 'the increase in wind load should not require structural enhancement, but small increases in movement may occur.
Site Drainage	Drainage systems should be designed to cope with more intense rainfall	Roof and site drainage potentially have insufficient capacity to cope with changing nature of rainfall patterns – short duration high intensity events.	BRE Digest suggests that one adaptive response would be to increase gutter capacity by 10%. This option should be costed to determine whether such a measure could be incorporated despite the uncertainty (no/low regret option).
	Decrease run-off from the site		A green roof would help to attenuate flow from the roof of the site. This would also help provide valuable habitat for insect and bird species. The habitat this is created will be low maintenance and

			be tolerant to extreme weather conditions, ensuring resilience to future climate change.
		Prolonged summer droughts	Rainwater water harvesting would help to reduce run-off from the site. To ensure sufficient water saving efficiency the ratio of water saving capacity should be increased to take into account reduction in summer rainfall.
Site Foundations	Future proofing the building so that it can withstand warmer temperatures	Due to decreases in soil moisture (up to 35% by 2050) clay based soils at risk of subsidence.	The structural report recommends that the proposed structure be founded on a reinforced concrete raft due to the presence of shallow mine workings and mine entries in order to mitigate against possible structural instability. This approach should also mitigate any potential risk as a result of soil shrinkage due to declining soil moisture.
Building Materials	Any cladding able to withstand possible increased wind speed	Materials and their performance will be affected by climate change, particularly as a result of more extreme conditions.	For this development the angle and fabric of the louvres to be installed on the north east elevation should incorporate the guidance provided within CIRIA C638, ensuring that driving rain is considered within the design.
Thermal comfort	Future proofing the building so that it can withstand warmer temperatures	Average temperatures for the region are expected to rise by as much as 2.5C by 2050 with more significant summer daily extreme temperatures causing prolonged periods above 28C.	Use adapted DSY and TRY data that incorporates UKCIP02 climate scenarios into the weather file for Birmingham when conducting the thermal comfort modelling for the building.
Water Efficiency	Future proofing the building so that it can withstand warmer temperatures	Hotter, drier summers combined with increased consumer demand will mean that water efficiency will become increasingly important.	Water efficient appliances, rainwater harvesting, and grey water recycling would all help to ensure that the buildings water use is as efficient as possible.
Landscape design / Ecology	Consider role of planting to provide wind breaks / shelter from increases in wind Selection of plant species to take account of warmer / dryer climate	Changing climatic conditions will affect the ability of species at their southerly climate limits to survive.	For the landscaping features around the car parking area the most important consideration will be the selection of tree species (and shrubs with an anticipated lifetime of over 10 years) and their location. Selected varieties should be drought tolerant and those located near the building should be deciduous to maximise solar gain in the winter and minimise it during the summer.

	Maximise opportunities for outdoor activities		
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