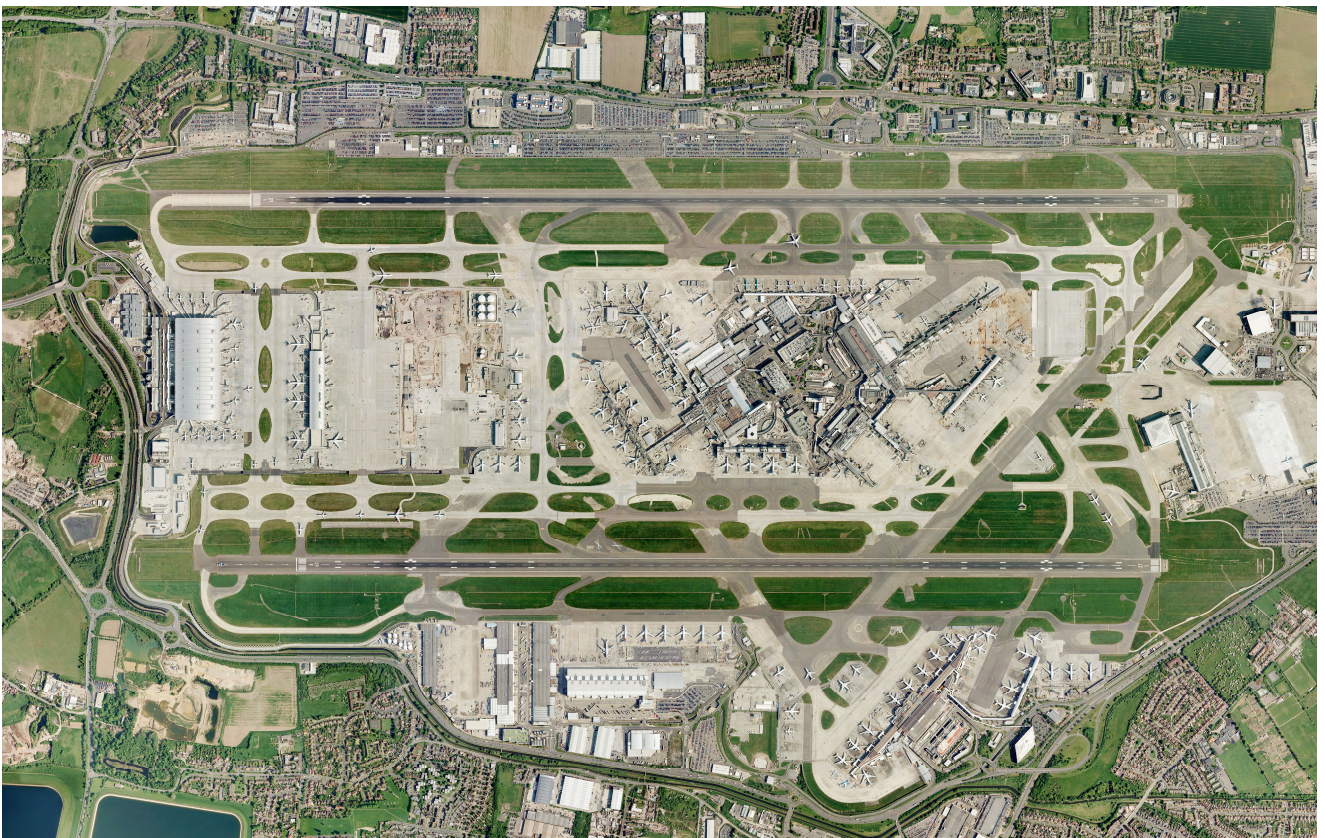


HEATHROW AIRPORT

CLIMATE CHANGE ADAPTATION REPORTING POWER REPORT



May 2011

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EXECUTIVE SUMMARY

I. INFORMATION ON HEATHROW AIRPORT LIMITED (HAL)

London Heathrow Airport is the largest airport in the United Kingdom and the world's busiest airport in terms of international passengers, and the busiest airport in Europe in terms of total passengers. The airport is owned and operated by BAA, who also own and operate five other UK airports. Heathrow is managed by Heathrow Airport Ltd (HAL).

The airport's vision is to "Become the UK's direct connection to the world and Europe's hub of choice by making every journey better" and relies on achievement of eight strategic objectives:

- Make Heathrow the preferred choice for passengers;
- Win support for our vision;
- Run our airport responsibly, safely and securely;
- Succeed through airline success;
- Transform the airport;
- Improve airport operations everyday;
- Focus people and teams on service and results;
- Deliver the business plan;

All facets of Heathrow's operation have the potential to be affected by future climate change.

II. BUSINESS PREPAREDNESS BEFORE DIRECTION TO REPORT WAS ISSUED

Heathrow's strategic corporate response to climate change has, to date, primarily focussed on the mitigation of GHG emissions arising from the airport's activities. Climate change risks relating to mitigation are already built into BAA's corporate risk registers.

In terms of adaptation, there are numerous weather related risks already considered and managed on BAA's risk registers, however these have not, to date, been specifically informed by the physical impacts of climate change but are based on current conditions and recent observed changes on the ground.

In addition there are numerous weather-related contingency plans and procedures already in place at the airport because of the weather-sensitivity of aviation. Day to day activities at the airport are guided by detailed meteorological forecasts which dictate corresponding changes to staffing levels, procurement of seasonal and contingency supplies, direction of work patterns and the implementation of contingency plans and procedures if needed.

Several changes to risk management systems are currently being implemented as a result of the findings of the Heathrow Winter Resilience Enquiry which are anticipated to significantly improve the airport's resilience to the future impacts of climate change.

III. SCOPE OF STUDY AND RESOURCES USED

This study considers assets owned by Heathrow Airport Limited and has involved a comprehensive risk assessment of climate related risks to the direct and indirect operations of Heathrow.

It was led by Heathrow's Corporate Responsibility and Environment Department with the expert support of ERM. The approach has been quantitative (where possible) incorporating climate modelling, a literature review, and concerted consultation with HAL/ external partners.

Climate modelling has been undertaken for two time periods: the short term (i.e. now to 2020) and the medium / longer term (i.e. 2020 to the 2050s) with high, medium and low scenarios that ensure a precautionary approach is taken.

IV. RISK ASSESSMENT APPROACH

To maximise the accessibility of the findings of this study to HAL staff; to put the risks into the context of day to day risk management activities; and to allow comparison of the risks associated with climate change to other risks on BAA's risk registers for the airport, the results of this assessment have been expressed in terms of the language, objectives and processes currently used at Heathrow for risk management where they are appropriate.

The prioritisation of risk is based on classic assessment that relies on judgements on likelihood and consequences of risk events and subsequent classification of risks into significant (red), moderate (amber) and low (green) risks taking into account HAL's control measures currently in place.

To address DEFRA's guidance BAA's risk assessment approach has been developed to address risks in the short (to 2020) and medium to long term (2040/50), alternative future scenarios of climate change, the implications of critical thresholds and uncertainty in core data used.

V. UNCERTAINTIES AND ASSUMPTIONS

Key uncertainties identified relate to the modelling of future climate change, future development of assets at Heathrow, indirect risks from 3rd parties, as well as critical threshold levels for specific assets. The assessment addresses uncertainties by adopting a precautionary approach and classifying the uncertainty of risks identified.

Key assumptions include;

- UKCP09 projections are an accurate representation of the climate change impacts which will occur;
- risks to the supply of key services upon which Heathrow relies, i.e. electricity, gas, water will be adequately managed by the authorities and organisations responsible for their supply;
- aviation infrastructure and technology continues to operate fundamentally in the same way as envisaged today; third party organisations, whose business affects HAL's activities and resilience continue to operate in the same manner and at the same performance standards that they do today;
- passenger and cargo requirements for air transportation will continue to develop in line with HAL and CAA forecasts, and that UK population levels develop in line with Government forecasting; and
- Heathrow's current business and development plans are assumed to be acceptable to the Regulators and Government.

VI. APPROACH

A summary of the prioritised climate change risks identified for the short and medium / longer term at Heathrow is summarised in the tables that follow broken down by business unit.

Each risk is prioritised based on the expert judgment made through the study team and stakeholders in terms of:

- the identified effects and its likelihood and consequences on airport operations,
- the likelihood critical thresholds are exceeded, and
- the robustness of existing control measures in place to manage the risk.

Risks have been classified into significant (red), moderate (amber) and low (green) risks in the short and longer term in line with Heathrow's risk management framework assuming no additional adaption response.

Each risk is additionally characterized in terms of the uncertainty that relates to the core climate modeling and the key climate variable resulting in the risk.

VII. KEY RISK OUTCOMES

The risk assessment has identified 34 risks in the short and medium to longer term.

Risks in the short term are generally low (green).

In the medium to longer term as climate change is predicted to accelerate, and assuming no changes to existing airport controls, risk levels are shown generally to rise in significance. This assessment is common to both the central and high climate scenarios.

In a low climate scenario risk levels in the medium to longer term would be essentially similar to those in the short term. The results as presented are therefore a worst case.


For Heathrow the most significant risks arise from climate change from projected longer term changes to temperature and precipitation extremes.

The biggest uncertainties surround future prevailing wind conditions. This is significant since Heathrow's two runways are parallel and the airport does not have a cross-wind runway.

(a) Airside Business Unit Climate Adaptation Risks

Risks and Control Measures							<table border="1"> <tr> <td>R</td> <td>Excessive</td> <td>E</td> <td>A</td> <td>Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now</td> </tr> <tr> <td>A</td> <td>Significant</td> <td>Optimal</td> <td>O</td> <td>P Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based</td> </tr> <tr> <td>G</td> <td>Moderate</td> <td>Adequate</td> <td>A</td> <td>W Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.</td> </tr> <tr> <td></td> <td>Low</td> <td>Inadequate</td> <td>I</td> <td></td> </tr> </table>		R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now	A	Significant	Optimal	O	P Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based	G	Moderate	Adequate	A	W Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.		Low	Inadequate	I	
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Risk ID	Risk	Climate Variable	Threshold	Confidence (climate projections and/or consequences)	Risk Grading (no adaptation)		Existing Control Measures		Adaptation Response Needed	Business Unit owners	Director/s Responsible																	
					Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy																				
AIRSIDE																												
1	Flashpoint of aviation fuel exceeded on hot days - potential fire hazard.	Temp	Aviation fuel flash point is 38°C. Temperatures during the summer of 2003 peaked at 37.5C	H	A	R	Spill reporting and defined clean up procedures.	A	P	Prepare: Research into spill clean up options currently used at airports in warmer climates to commence to develop policies robust to air temperatures exceeding 38°C.	Airside	Airside Director																
2	Increased incidence of fuel venting from aircraft in warm weather.	Temp	Aviation fuel flash point is 38°C.	H	A	A	Spill reporting, clean up procedures, airport pollution control system	O	P	Prepare: Research into options currently used at airports in warmer climates for spill reporting and clean up procedures.	Airside	Airside Director																
3	Increased fire risk due to hotter temperatures combined with increased lightning and drought potential.	Temp	Requires research	M	G	A	Onsite fire brigade, fire water supply and fire mains, regular drills, smoke and fire detection systems, vegetation management plans, PATS testing of electrical equipment.	O	P	Prepare: Ensure that the planned changes and development of the airport's fire main considers and addresses the potential for increased fire risk resulting from climate change.	Airside	Airside Director																
4	Change in distribution of pests and wildlife species. Potential changes to bird migration patterns and bird strike risk.	Temp	Requires research	L	G	G	PPE, first aid for outdoor workers. Veterinary service, bird management controls.	O	W	Watching Brief	Airside	Airside Director																
5	Reduced lift for departing aircraft due to 'thin air' and reduced engine efficiency in very hot weather.	Temp	Aircraft operate in multiple temp zones, unlikely to be breached	H	G	G	Potential to change load factors, ATM rates, if needed. Existing noise footprint monitoring and mitigation tools.	E	W	Watching Brief	Airside	Airside Director																
6	Torrential rain creates hazardous conditions for vehicles and planes i.e. airside and landside road vehicles, and taxiing and landing aircraft.	Precip.	Defined in Strategic Flood Risk Assessment (SFRA)	H	G	A	Grooved runway, drainage system, ATC procedures i.e. increased separation distances, runway safety zones, operational guidance for pilots/airside staff, warning signs on motorway network to announce hazardous conditions.	O	W	Watching Brief	Airside	Airside Director																
7	Seasonal changes to fog related disruption (increase in winter months, decrease for remainder of year).	Fog	Low Visibility Procedures when the Runway Visual Range (RVR) is < 600m and/or cloud ceiling is < 200 ft. Projections do not suggest any critical thresholds would be crossed	L	G	G	LVPs, operational guidance for pilots and airside vehicles, warning signs on nearby motorway network to alert drivers to hazardous conditions.	E	W	Watching Brief	Airside	Airside Director																
8	Increased risk of schedule interruption from stormy conditions.	Storms	High wind procedures and cross wind procedures enacted at defined criteria (dependent on aircraft type).	L	G	A	ATC procedures i.e. separation distances, contingency plans for disruption.	O	W	Watching Brief	Airside	Airside Director																
9	Increased longevity of wing tip vortex effect due to general becalming of surface wind speeds.	Wind	Wing tip vortex is particularly problematic for small planes taking off in quick succession after large aircraft.	L	G	G	Reparation programme to repair affected roofs, ATC procedures i.e. increased separation distances.	E	W	Watching Brief	Airside	Airside Director																
10	Change to prevailing wind direction affects runway utilisation and schedules.	Wind speed/direction	All commercial aircraft are tested to a "demonstrated" maximum crosswind as part of their certification. Large aircraft are better able to handle cross winds than light aircraft. Technology is improving all of the time.	L			Not able to be assessed due to lack of projection data.		W	Watching Brief	Airside	Airside Director																
11	Disruption to airfield operations from lightning i.e. refuelling suspension, changes to flight routing.	Lighting	All commercial aircraft are tested for resilience to lightning strike as part of their certification. Planes can withstand lightning strike in the air but during take off and landing instrument loss would be critical hence the diversion of routes and stacks.	L	G	A	Suspension of refuelling, changes to stack locations and departure routes, diversions.	O	W	Watching Brief	Airside	Airside Director																


(b) Capital Business Unit Climate Adaptation Risks

Risks and Control Measures							<table border="1"> <tr> <td>R</td> <td>Excessive</td> <td>E</td> <td>A</td> <td>Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now</td> </tr> <tr> <td>A</td> <td>Optimal</td> <td>O</td> <td>P</td> <td>Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based</td> </tr> <tr> <td>G</td> <td>Inadequate</td> <td>I</td> <td>W</td> <td>Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.</td> </tr> </table>		R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now	A	Optimal	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based	G	Inadequate	I	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.
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Risk ID	Risk	Climate Variable	Threshold	Confidence (climate projections and or consequences)	Risk Grading (no adaptation)		Existing Control Measures		Adaptation Response Needed	Business Unit owners	Director/s Responsible												
					Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy															
CAPITAL																							
12(a)	Changes to groundwater levels affect asset integrity and could cause subsidence and water ingress damage to buildings and surfaces.	Precip.	See Strategic Flood Risk Assessment	M	G	A	Design standards and construction practices, emergency contingencies for areas affected by flooding / water ingress, Strategic Flood Risk Assessment (SFRA) on-going to identify risk and solutions.	A	A	Action: Ensure appropriate design standards are applied to new buildings to address risks from water ingress/flooding	Capital	Group Engineering Director											
13	Overheating of aircraft on stands. Increased cooling demand and rise in energy use.	Temp	Sustained temperatures above 25-30°C require use of APUs or fixed ground power for cooling aircraft.	H	G	A	Auxiliary Power Units (APUs), Fixed Ground Power at some stands, development of Preconditioned Air (PCA)	A	P	Prepare: Research robustness of PCA and FEGP (and any cooling alternatives) making sure that the design standards used are as robust as practicable against future temperature extremes.	Capital	Group Engineering Director											
14	Heat damage to road and apron surfaces caused by temperatures exceeding design standards i.e. melting, cracking.	Temp	UK tarmac standards (roads, aprons) begin to lose integrity once temperatures in the shade exceed 32°C. Tarmac itself is black, absorbs heat and can hit 80°C at such temperatures. Runway surfaces design standards withstand far higher temperatures to be able to cope with aircraft braking.	H	G	A	Regular inspections, rapid maintenance response, regular surface relaying, surfaces defined by detailed design standards based on current best practice.	O	P	Prepare: Review and ensure continued robustness of hard standing (road/apron/runway) assets design standards to future climate change.	Capital	Group Engineering Director											
15	Overheating of operationally-critical buildings which could impair performance of critical staff or equipment and breach regulated conditions	Temp	Problems rarely experienced today i.e. only in some areas after temperatures exceed 30-35°C for 2 weeks+. Temperature envelopes of some safety critical equipment not clear.	M	G	A	HVAC, temporary spot cooling (fans) if needed, onsite medical staff, monitoring of temperatures in buildings.	O	P	Prepare: Review and ensure continued robustness of building design standards to future temperature change. Prepare: Ensure design and development of Heathrow's long term masterplan manages risks from future climate change.	Capital	Group Engineering Director Masterplanning Director											


(c) Engineering Business Unit Climate Adaptation Risks

Risks and Control Measures							<table border="1"> <tr> <td>R</td> <td>Excessive</td> <td>E</td> <td>A</td> <td>Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now</td> </tr> <tr> <td>A</td> <td>Optimal</td> <td>O</td> <td>P</td> <td>Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based</td> </tr> <tr> <td>G</td> <td>Inadequate</td> <td>I</td> <td>W</td> <td>Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.</td> </tr> </table>		R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now	A	Optimal	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based	G	Inadequate	I	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.
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ENGINEERING																							
12b)	Changes to groundwater levels affect asset integrity and could cause subsidence and water ingress damage to buildings and surfaces.	Precip.	See Strategic Flood Risk Assessment	M	G	A	Design standards and construction practices, emergency contingencies for areas affected by flooding / water ingress, SFRA on-going to identify risk and solutions.	A	A	Action: Investigate and address risks of groundwater flooding to existing critical assets.	Engineering	Operations Director, Engineering & Baggage											
16	Pollution Control System (PCS) challenged during episodes of extreme weather. Increased severity of first flush effect, less seasonal distinction in PCS operation.	Precip.	Pollution Control System capacity limits	M	A	R	Water quality action plan, Pollution Control System (due to be upgraded), water quality monitoring, debris removal from surfaces, new permitting procedures with EA.	A	A	Action: Continue to liaise with the EA to develop and implement improvement options for the Pollution Control System (PCS), ensuring that the risks identified by this study are considered appropriately.	Engineering	Operations Director, Engineering & Baggage											
17	Localised flooding if older drainage overwhelmed by heavy rainfall events.	Precip.	Design standards for drainage	M	G	A	Design standards and construction practices, emergency contingencies for areas affected by flooding / water ingress, SFRA on-going to identify risk and solutions.	A	A	Action: Sensitivity test airport drainage infrastructure to ensure as robust as practicable to future climate extremes. Investigate and address risks of flooding to existing critical assets	Engineering	Operations Director, Engineering & Baggage											
18	Integrity of balancing ponds at risk of subsidence of earth walls and / or extreme rainfall events.	Precip.	See Strategic Flood Risk Assessment	M	G	A	Daily monitoring and evaluation, WQMS, evacuation contingency plans.	O	A	Action: Continue to liaise with the EA to develop and implement improvement options for the Pollution Control System (PCS), ensuring that the risks identified by this study are considered appropriately.	Engineering	Operations Director, Engineering & Baggage											
19	Increased energy demand for cooling in the summer, and for heating during winter extremes increases energy spend and emissions. High temperatures reduce performance of some plant.	Temp	Challenging only if temperatures exceed 30-35°C for 2 weeks+.	M	G	A	Dual fed supply, back up generation, move toward renewable energy centres.	O	P	Prepare: Ensure that future changes to the airport's heat, power and cooling generation and transmission assets are stress-tested to be as robust as practicable against future climate change projections. Research spare capacity and critical thresholds for plant and transmission infrastructure performance in hot weather and potential to accommodate increased demand.	Engineering	Operations Director, Engineering & Baggage											
20	Heat stress risk to staff, particularly those in highly physical roles. Additional cooling costs may result.	Temp	Sustained temperatures above 25-30°C require cooling or changes to working patterns.	H	G	A	Onsite medical facilities, PPE, temporary spot cooling (i.e. fans etc) if needed.	O	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage											
21	Drought conditions affect water availability and cause bore hole levels to drop. Restrictions may be posed to water intensive activities.	Precip.	Borehole capacity	M	G	G	Sustainable water strategy, conservation measures being retrofitted, design standards, WQMS, use of non-potable water where appropriate i.e. toilet flushing. Dual bore hole and mains supply, new permitting procedures with EA.	E	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage											
22	Freeze / thaw damage of surfaces as winter temperatures become more variable.	Snow/Winter	Requires research	M	G	A	Regular inspections, rapid maintenance response, regular surface relaying, surfaces defined by detailed design standards based on current best practice.	O	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage											
23	Increased risk of wind damage to assets, standing aircraft, vehicles and injuries to staff.	Wind/Storm	Various wind speed resilience thresholds	L	G	A	Design standards, regular inspections, maintenance as needed, operational guidance for airside staff in high winds, warning signs on nearby motorway network alerting drivers to hazardous conditions.	O	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage											
24	Impacts of lightning on control systems and electricity supply. Power cuts and voltage spikes to parts of the airport not on UPS during electrical storms.	Lighting	All modern control systems are sensitive to voltage spikes, risk of disruption and equipment failure or damage	L	G	A	UPS for safety critical systems, dual fed electricity supply.	O	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage											

(d) First and Last Risks

Risks and Control Measures													
					R		Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now			
					Significant		Optimal	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based			
					A		Moderate	Adequate	A	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.		
					G		Low	Inadequate	I				
Risk ID	Risk	Climate Variable	Threshold	Confidence (climate projections and or consequences)	Risk Grading (no adaptation)		Existing Control Measures		Adaptation Response Needed	Business Unit owners	Director/s Responsible		
					Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy					
FIRST & LAST IMPRESSIONS													
25	Wintry conditions pose health and safety risks for pax and staff.	Snow/Winter	Aircraft and surfaces treated with de-icer when temperatures fall below 3°C.	M	G	G	De-icing, gritting, PPE, additional heating, onsite medical facilities, warning signs on nearby motorway network alerting drivers to hazardous conditions.	O	W	Watching Brief	F&L	Campus Security Director	
26	Offsite impacts (snow, flooding, storms etc) could impede the flow of people (pax, crew and staff) if destination airports or the UK surface transport network is affected.	Offsite impacts	There are limits to the number of people who can be safely accommodated within HAL terminal buildings and min requirement for fire service cover.	L	G	A	Disruption contingency plans (marquees, refreshment vouchers, comfort facilities, flexible working patterns, communications plans), diversification of surface access toward public transport, motorway warning signs.	O	W	Watching Brief	F&L	Campus Security Director	
27	Remote impacts could restrict the flow of essential supplies to the airport.	Offsite impacts	Storage space	L	G	A	Contingency plans for disruption, (limited) storage of critical supplies, investigation of preferential partnership status / alternate supplies of key resources i.e. glycol.	O	W	Watching Brief	F&L	Campus Security Director	
28	Overheating on surface access transport from rising temperatures.	Offsite impacts	Temperatures over 30°C can be problematic for surface transport and underground.	M	G	A	Air conditioning, design standards, onsite medical facilities, coordination with HPA and TIL, public information campaigns, availability of refreshments in terminals.	O	W	Watching Brief	F&L	Campus Security Director	

(e) Cross Business Unit and Technical Standards and Assurance Climate Adaptation Risks

Risks and Control Measures												
					R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now			
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					Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy				
CROSS BUSINESS UNIT												
29	Fracture risk to underground infrastructure from increased winter temperature variability and freeze / thaw damage.	Snow/Winter	3rd party infrastructure thresholds not known	M	A	A	Regular inspections, rapid maintenance response and repairs as needed, back up links and spare capacity in utility supply.	A	P	Prepare: Investigate vulnerability of underground services to climate change risks from fracture /damage and ensure appropriate adaptation changes are incorporated into future development plans as appropriate.	Jointly: Airside Engineering	Airside/Ops Directors
30	Increasing variability of snowfall challenges winter contingency plans, de-icing supplies and staff experience.	Snow/Winter	Aircraft and surfaces treated with de-icer when temperatures fall below 3°C. Contingency plans in place today being updated to incorporate the findings of the Heathrow Winter Resilience Enquiry.	M	G	A	De-icing procedures, snow clearing vehicles, changes to staff working patterns, contingency plans, weather forecasts, findings of the Heathrow Winter Resilience Review implemented.	O	A	Action: Continue to implement the recommendations of the Heathrow Winter Resilience Enquiry and ensure that planned future contingencies consider future climate change.	Jointly: Airside Engineering Standards and Assurance	Airside/Ops/Risk Directors
TECHNICAL STANDARDS AND ASSURANCE												
31	Heat wave conditions result in negative impacts on air quality. More difficult to comply with air quality standards.	Temp	Standards are clearly demarcated and air quality is regularly monitored and reported.	M	G	A	Heathrow Airwatch, air quality monitoring, targeted landing fees, improved departure procedures, Clean Vehicles Programme, green travel initiatives, move toward PCA. GHG reduction targets for buildings and operations.	O	W	Watching Brief	TS&A	Sustainability Director
32	Changes to global distribution of disease could increase likelihood and frequency of epidemics and pandemics.	Offsite impacts	Requires research	L	G	A	Daily monitoring and evaluation, WQMS, evacuation contingency plans.	O	W	Watching Brief	TS&A	Sustainability Director
33	Sea Level Rise / storm surge risks loss of low lying destination airports i.e. Schiphol, Hong Kong (without adaptation).	Sea level rise	Elevation data for coastal airports and their design standards.	L	G	G	Contingency plans for changes to international schedules and airport closures.	O	W	Watching Brief	TS&A	Sustainability Director
34	Sea Level Rise / storm surge risks disruption to UK infrastructure i.e. utility supplies, surface transport routes (without adaptation).	Sea level rise	Not a direct risk for HAL. Infrastructure being managed and critical threshold being considered by others i.e. utilities, TfL etc	L	G	G	Contingency plans for loss of supplies, disruption to surface transport routes and utility supply problems.	O	W	Watching Brief	TS&A	Sustainability Director

VIII. HEATHROW'S ADAPTATION STRATEGY

The adaptation response to the risks identified by this study has been determined and prioritised through:

- a consideration of the scale and importance of the risk in terms of likelihood and consequence for HAL in the short and medium / longer term;
- an appraisal of the adequacy of the current control measures in place to deal with that risk;
- an understanding of any uncertainties and critical thresholds involved; and finally
- consideration of the timescales involved both in terms of when the risk may occur, and how long it may take to implement adaptation measures.

This has led to 3 classes of priority adaptation responses as follows:

Action: Action is required in the short term, either to manage short term risks (classified as high) or because the solution to longer term risks needs to begin in the short term because of long planning or implementation cycles;

Prepare: Identifies need for additional research and or development prior to confirming any risk management actions;

Watching Brief: Risks are longer term and require an ongoing watching brief to monitor science and effects of climate change.

The development and delivery of the adaptation strategy identified through this study will be a continuous and on going activity that responds and adapts to new and improved information on the science and understanding of critical thresholds. "Action" and "prepare" responses identified will be delivered within 3 years.

Delivery of the adaptation strategy will require detailed cost benefits of specific remedies as these are developed as well as an assessment of their wider sustainability implications in line with Heathrow's Sustainability policy.

The adaptation strategy will continue to be evolved based on the on going review and monitoring of climate change risks and detailed consideration of the barriers to adaptation identified and principles of good adaptation.

IX. RESIDUAL RISKS

The adaptation strategy has been designed to address key risks in the shorter term as well as to prepare Heathrow for risks that may occur in the longer term and which require early action due to long timescales for implementation.

Heathrow is committed to the delivery of this strategy and its on going development and evolution with the objective of ensuring that residual risks are managed to acceptable levels.

X. BARRIERS, STAKEHOLDERS AND INTERDEPENDANCIES

Key barriers to adaptation identified include:

- Scientific uncertainty;
- Financial uncertainties and resource constraints;
- Uncertainty regarding future aviation industry trends and developments;
- Onsite space constraints;
- Runway capacity constraints;
- Legacy infrastructure;
- Permitting constraints;
- Interdependencies;
- Stakeholder perception;
- Pace of regulatory change;
- Other regulatory requirements.

Key external partners and regulators consulted through this study included the Environment Agency, NATS, London Borough of Hillingdon, TfL, surface transport operators, and key Heathrow airlines.

Interdependencies have been identified where others' actions are likely to impact on Heathrow's ability to manage its own climate change risks. These relate primarily to provision of key utilities, aircraft fuel infrastructure, surface access services and infrastructure and airline operations.

XI. MONITORING, REVIEW AND GOVERNANCE OF ADAPTATION RESPONSE

The adaptation "responses" identified by this study will be monitored through periodic review at existing senior Heathrow Health, Safety and Environment governance fora to track progress and where this is considered inadequate, escalate action.

Additionally it is proposed that the Corporate Responsibility team carries out a "comprehensive" review of the risks and climate science every 5 years to coincide with the development of Heathrow's Capital Infrastructure Plan (to respond to quinquennial regulatory settlements with the CAA) , with an "interim" review at each quinquennial midpoint.

This will manage HAL's climate change business risks, aligns with key decision points around HAL's capital plan and prepares HAL for any future response that may be required by Government.

The review cycle proposed will also ensure that Heathrow's adaptation strategy remains dynamic, responsive and appropriate by ensuring that it reflects latest scientific knowledge on climate change and critical thresholds.

XII. RECOGNISING OPPORTUNITIES

Not all of the impacts associated with climate change will be negative for Heathrow. Climate change could also present opportunities, although the net impacts of climate change are likely on balance for Heathrow (as for the UK in general) to be negative.

Key opportunities relate to potential for energy saving in winter as temperatures rise, potential for increased travel to the UK as its climate becomes relatively more attractive, reduced delays from fog, potential for competitive advantage relative to other more climate sensitive hub airports, and reduced risk from bird strike.

XIII. KEY CONCLUSIONS

This report has assessed the potential physical impacts of climate change upon Heathrow Airport Limited (HAL) and its statutory functions in line with statutory guidance from Defra.

Using best available information on future climatic effects and applying a comprehensive risk assessment approach that took a precautionary worst case approach to future climate change risks this study has concluded that:

- Heathrow has comprehensive control measures and contingency plans for managing climate related risks, and largely these are considered sufficient to manage climate change risks in the shorter term (eg to 2020).
- It is not feasible at this time to conduct a detailed assessment of climate predictions beyond the 2050s since this time scale falls outside typical airport planning cycles and the climate science becomes increasingly uncertain in the longer term.
- Climate risks in the short term are predominantly low, and where risks are more significant these are largely already being managed through existing mitigation and resilience programmes (eg plans to upgrade the airport pollution control system).
- Assuming no changes to existing control measures the risks associated with climate change impacts in the medium to longer term are predicted to worsen.
- Assuming the adaptation strategy identified by this study is implemented and continually evolved will ensure that residual risks are appropriately managed.
- Key adaptation responses identified in the short term generally build on existing actions planned by the business.
- Delivery of the adaptation strategy will be assured through clear ownership across Heathrow's business units together with a requirement for on going reporting of progress at senior HS&E performance management fora.
- Regular (5 yearly comprehensive and mid point reviews) of the climate risk assessment will ensure continuous updating of the adaptation strategy in line with best available information on climate science, risk thresholds and business and infrastructure planning cycles thereby allowing Heathrow to appropriately manage future risks from climate change.

1 INTRODUCTION

1.1 OVERVIEW

This report assesses the potential physical impacts of climate change upon Heathrow Airport Limited (HAL) and its statutory functions. The future climate for Heathrow has been defined by using modelling data from the UKCP09 climate change projections. The limitations of this data and caveats regarding its use have also been clarified. The evidence for the implications of climate change for Heathrow's future operations and resilience has been gathered through a literature review of airport related studies, a consideration of Heathrow's existing risk registers and contingency plans, and by interviewing key staff in HAL and its partner organisations.

Figure 1.1 Site Location



Source: Crown Copyright 2010, Image reproduced courtesy of the Ordnance Survey and Ordnance Survey of Northern Ireland

1.2 CONTEXT

Heathrow is the world's busiest international airport and a critical element of UK infrastructure. The airport also operates as a key node in the global aviation industry and so it is important that the impacts of climate change on Heathrow Airport and its infrastructure are understood and adaptation measures adopted on a timescale appropriate to the projected impacts of climate change.

Heathrow experiences a relatively benign climate today compared to other airports around the world, sheltered as it is from the worst of the extreme weather that can be brought to Britain by Atlantic storm tracks; but the weather can still challenge operations. Fog, high

winds, electrical storms, heavy rain, snow and high and low temperatures can all affect airport operations and assets to a certain extent.

Because of the paramount importance of safety and punctuality to the aviation industry, Heathrow already has well established plans and procedures in place to respond to extreme weather events. This study will determine if these will need to be revised to address the changes projected to result from climate change.

1.3 BACKGROUND TO THE REPORT

This report has been produced in response to the direction to report issued to Heathrow Airport Ltd (HAL) by the UK Department for Environment, Food and Rural Affairs (DEFRA) under the auspices of the Climate Change Act (2008).

The Climate Change Act (2008) created a legal framework for increasing the UK's ability to respond and adapt to the consequences of climate change. An essential component of the Act and the Adapting to Climate Change (ACC) cross-Government programme is to lay before Parliament risk assessments of the threats and opportunities posed to the UK by the physical impacts of climate change on a five-yearly basis, with the first national risk assessment to be presented in January 2012. Organisations whose assets and functions are felt to be of national importance have been directed by Government to assess their vulnerability to the consequences of climate change.

DEFRA identified the operators of Heathrow Airport as being of particular importance in adapting the UK to the changing climate, because of its importance to the national economy and to global transportation of people and cargo. Heathrow (amongst other UK strategically important airports i.e. Edinburgh, Glasgow International, Birmingham International, East Midlands, Cardiff International, Manchester International, London Stansted, London Luton and London Gatwick) is considered within the ACC strategy as a priority reporting authority and is part of the first tranche of organisations required to input into the National Climate Change Risk Assessment.

This report is HAL's response to the Climate Change Act (2008) and the direction to report under the Adaptation Reporting Power (ARP).

1.4 STRUCTURE OF THIS REPORT

This report is organised into eleven chapters and five technical annexes, as follows:

- *Chapter 1* introduces the purpose and structure of the report;
- *Chapter 2* presents the methodology used in this study;
- *Chapter 3* outlines the statutory functions of Heathrow and the assets, operations and functions of the organisation, the role of HAL and other stakeholders and relevant organisational objectives and development plans;
- *Chapter 4* outlines the baseline climatic conditions experienced at Heathrow, recent observed changes to the climate and a summary of existing controls and contingency plans in place;

- *Chapter 5* presents the methodology behind the climate change modelling undertaken and explains the rationale behind the selection of emissions scenarios and dates used within the modelling;
- *Chapter 6* details the assumptions made and the treatment of the uncertainty inherent to climate change projections;
- *Chapter 7* presents the results of the climate change projections for various meteorological variables for Heathrow;
- *Chapter 8* details the risk assessment process followed;
- *Chapter 9* presents the results of the risk assessment process;
- *Chapter 10* defines principles of good adaptation, identifies any constraints and barriers to adaptation at Heathrow and summarises the priority adaptation responses identified by this study;
- *Chapter 11* sets out how HAL will ensure adaptation will be embedded in business processes, monitored and reported through governance.

Additional information and supplementary technical details to the report are provided in a series of annexes:

- *Annex A* details the existing meteorological baseline at Heathrow;
- *Annex B* provides additional detail on the UKCP09 modelling results;
- *Annex C* illustrates the pro-forma of questions used in the interviews during the consultation process;
- *Annex D* lists the roles of the consultees, both internal and external who were interviewed, and those who attended the workshop;
- *Annex E* presents the results of the Heathrow Winter Resilience Enquiry (published March 2011) and its recommendations.

2 METHODOLOGY

2.1 INTRODUCTION

This Chapter describes the methodology followed by this study and which has been designed in accordance with the guidance from the UK Climate Impact Programme (UKCIP) and DEFRA, particularly DEFRA's Statutory Guidance, the Evaluation Framework developed by Cranfield University and UKCIP's Adaptation Wizard (1).

The approach has also been shaped by the experiences of the early responders to the ARP and the methodologies which worked well in assessing their risks; the recent sector wide risk assessments (2), and the latest advice on adaptation good practice from UKCIP (3).

2.2 HEATHROW'S CLIMATE ADAPTATION RISK METHODOLOGY

The methodology followed is based around eight steps as follows:

1. Organisational mapping;
2. Define current climatic baseline;
3. Model future climate change;
4. Literature review;
5. Consultation;
6. Risk identification and prioritisation;
7. Identification and prioritisation of adaptation response;
8. Reporting, Governance and Monitoring.

The approach is characterised by a combination of expert judgement; collation of the significant experience of HAL staff and partners; the use of best available climate change modelling data and peer reviewed scientific and risk management literature.

2.3 OUTLINING THE STEPS INVOLVED IN THE ASSESSMENT

Each element of the risk assessment process is considered in more detail in the following sections of this chapter. The findings from each of these steps are presented in subsequent chapters of this document as detailed below.

2.3.1 Step One: Organisational Mapping

The first step involved identifying the key stakeholder groups and business unit functions that needed to be involved in the assessment.

(1) UKCIP (2010). The UKCIP Adaptation Wizard v 3.0. UKCIP, Oxford available from: www.ukcip.org.uk/wizard

(2) Adapting Energy, Transport and Water Infrastructure to the Long Term Impacts of Climate Change. Ref No. RMP 5456. January 2010, prepared by URS Corporation Limited (URS) for the UK Government's cross-departmental Infrastructure and Adaptation project.

(3) Managing Adaptation: Linking Theory and Practice. Alistair Brown, Megan Gawith, Kate Lonsdale and Patrick Pringle, January 2011, UKCIP.

The findings of the organisational mapping exercise are summarised in *Chapter 3* of this document.

The risk assessment is also informed through consultation with external stakeholders. For these risks it is likely that partnership working will be needed to secure mutually satisfactory and holistic adaptation solutions.

2.3.2 Step Two: Establishment of the Current Climatic Baseline

To understand the impacts of climate change it is vital to understand the baseline climate, complete with the extremes experienced in the recent meteorological record. Therefore, the first stage of the risk assessment was to understand and define the current climate experienced at the airport and to establish how resilient operations are to the extremes currently observed. A summary of the climatic baseline is presented in *Chapter 4* together with an overview of HAL's existing control and contingency measures. More detailed baseline meteorological data is presented in *Annex A* of this document.

2.3.3 Step Three: Climate Change Modelling

Once the current climate was understood, extraction of projections of future climate change for Heathrow were then undertaken using the best available evidence and data sources as recommended by UKCIP and DEFRA. The methodology used in the climate modelling is described in *Chapter 5* of this document.

The data sources used and known limitations of climate change projections with regard to some of these variables are also discussed in *Chapter 6*. The results of the modelling are summarised in *Chapter 7* and a full technical annex detailing climate projection data for Heathrow is presented in *Annex B* of this report.

2.3.4 Step Four: Literature Review

A literature review was undertaken by the study team to assess the present understanding of the risks posed to airport operations around the world by current weather extremes and those postulated to arise as a result of climate change. An understanding of the current implications of weather for the aviation industry and particularly flights operating out of Heathrow was also essential ⁽¹⁾.

Heathrow's existing risk management system was examined to ensure that any risks identified as a result of the climate change risk assessment are able to be managed in a robust manner and integrated into existing risk management systems at the airport. An understanding of past incidents of climatic disruption at the airport was essential and the findings of the recent *Heathrow Winter Resilience Enquiry* have been used.

(1) Pejovic, T., V. Williams, R. Noland and R. Toumi, 2009, Factors affecting the frequency and severity of airport weather delays and the implications of climate change for future delays, TRB

Guidance from academia, the IPCC (1), Regulators and the Government for the transport sector was also considered. The literature review also included a high level assessment of the emergency planning / contingency processes, climate change adaptation plans, and risk assessments of key stakeholders upon whose services Heathrow relies, and with whom Heathrow works in partnership. Notable studies considered in this category include research undertaken by Transport for London (2), the Mayor of London (3) and utilities suppliers (4). Heathrow is also keen to understand the findings of the Foresight study on the *International Dimensions of Climate Change* project to improve the airport's understanding of how climate change impacts overseas will affect the UK. However the results of this study had not been produced at the time of this report going to press and unfortunately have not been able to be included in this present study (5).

2.3.5 Step Five: Consultation

An essential element of the risk assessment process has been an in depth and wide-ranging consultation with key HAL stakeholders and also with external partner organisations. Consultation has been an essential part of the reporting process from the information gathering stage to the production of the final report.

To assist with information gathering and to engender buy-in to the reporting process, a series of interviews were held from December 2010 to March 2011 with a range of key people who work at the airport, or who have some responsibility for its operation and / or regulation. At these interviews the study team presented the likely modelled future climate and sought the opinion of the interviewees as to how they thought the airport would be able to respond to the new climatic parameters. The consultation enabled the study team to:

- understand how the airport responds to the current climate by clarifying the existing contingencies in place to deal with weather-related issues, and identifying any activities or assets considered to be of high vulnerability to weather-related impacts today;
- establish the reality of how operations occur on the ground, the business 'criticality' of assets and operations, and current limitations and risks;
- clarify the financial values of assets, the costs incurred by interruption and the financial impacts of past disruption / weather damage;

(1) Wilbanks, T.J., P. Romero Lankao, M. Bao, F. Berkhout, S. Cairncross, J.-P. Ceron, M. Kapshe, R. Muir-Wood and R. Zapata-Marti, 2007: Industry, settlement and society. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 357-390

(2) Climate Change Adaptation for London's Transport System available from: http://www.sd-research.org.uk/wp-content/uploads/cc_adaptation.pdf

(3) Mayor of London's Draft Climate Change Adaptation Strategy, February 2010, available from http://legacy.london.gov.uk/mayor/priorities/docs/Climate_change_adaptation_080210.pdf

(4) Acclimatise (2009). 'Building Business Resilience to Inevitable Climate Change'. Carbon Disclosure Project Report. Global Electric Utilities. Oxford available from: <http://www.acclimatise.uk.com/resources/reports>

(5) <http://www.bis.gov.uk/foresight/our-work/projects/current-projects/international-dimensions-of-climate-change>

- understand the lifespan of existing assets, the design standards being used and the development plans which are likely to be implemented in the short and medium / longer term;
- clarify known weather-related critical thresholds where they exist and where quantitative values are understood, and identify areas where critical thresholds are a source of uncertainty;
- understand any spare capacity or capacity constraints affecting assets and operations today;
- gain a more detailed understanding of interdependencies, partnerships and ownership of the activities that happen at Heathrow;
- understand the volume of materials, passenger flows and/or other throughputs handled by the airport through different terminals and surface access routes; to identify any 'pinch points' or concentrations of flows including assets which have limited spare capacity / duplicability, and any seasonality in flows of passengers and cargo;
- supplement the academic quantification and characterisation of risks from the academic literature, with on-the-ground experience; and
- help prioritise key risks by melding the study team's knowledge of climate change with HAL's expertise and experience of the Heathrow site and their business.

For consistency, a standardised pro-forma of key questions was used as the basis for all interviews. This combined generic questions that were of relevance to all consultees, with tailored questions for specific functions and bodies. The pro-forma of questions used during the consultation phase is presented in *Annex C* of this document. Formal interviews in the first phase of information gathering were held in person where possible, and otherwise on the telephone, with 30 consultees from HAL and sister airports, and key external partners such as Heathrow Express, the National Air Traffic Service (NATS), British Airways, Hillingdon Local Authority, the Environment Agency and Transport for London. A list of interviewees and the organisations they represent is included in *Annex D* of this document.

2.3.6 Step Six: Risk Identification and Prioritisation

Risks were identified using the knowledge and experience shared by consultees, the technical knowledge of the study team, the findings of the literature review, interviews with stakeholders and lessons learned from past interruption events at Heathrow and other airports. Risk prioritisation was informed by judgements on the likelihood of a given event and its likely consequences and a consideration of the control measures in place to address the risk today and was facilitated through a workshop with stakeholders. This methodology, derived from HAL's own risk management processes is described in more detail in *Chapter 8*.

The risk evaluation and prioritisation exercise outcomes are presented in *Chapter 9*.

2.3.7 Step Seven: Identification and prioritisation of adaptation response

This step identifies adaptation actions to address risks identified in the previous step. Adaptation response actions have been classified into 3 basic categories to reflect the severity of the risk, the uncertainty in what is required and the urgency of action

Action: Action is required in the short term, either to manage short term risks (classified as high) or because the solution to longer term risks needs to begin in the short term because of long planning or implementation cycles.

Prepare: Identifies need for additional research and or development prior to confirming any risk management actions

Watching Brief: Risks are longer term and require on going watching brief to monitor science and effects of climate change

The adaptation response is summarised in *Chapter 10*. Again stakeholders were consulted individually and through a workshop to determine the appropriate classification and response.

2.3.8 Step Eight: Reporting, Monitoring and Governance

Finally the results of each stage of the assessment were written up and presented within this report. The findings were circulated to the key consultees involved in the generation of the document and their comments and suggestions were incorporated into the final draft. The monitoring and governance of risks identified is described further in *Chapter 11*.

2.4 EXPERTISE AND INVESTMENT LEVEL

Heathrow takes the issue of climate change seriously and because of this has made significant investment in examining the likely risks and consequences to the airport that may result from the physical impacts of climate change. This present study was led by Heathrow's Corporate Responsibility and Environment Department with the expert support of ERM, and has entailed in depth consultation (approximately 250 person hours) with approximately 30 HAL and partner stakeholders in addition to the research effort of the study team which is calculated to be in the region of 330 person hours.

3 OVERVIEW OF HEATHROW AIRPORT

3.1 INTRODUCTION

London Heathrow Airport is the largest airport in the United Kingdom. The airport is owned and operated by BAA, who also own and operate five other UK airports (London Stansted, Southampton, Edinburgh, Glasgow International and Aberdeen). Heathrow is managed by Heathrow Airport Ltd (HAL).

Key facts about Heathrow include:

- Opened in 1946, Heathrow is located 24km west of Central London and is the world's busiest airport in terms of international passengers, and the busiest airport in Europe in terms of total passengers;
- Heathrow is the UK's only hub airport used almost wholly by network airlines and has a significant proportion of transfer traffic;
- Heathrow handles approximately 70% of all the UK's long haul air traffic and 51% of all air traffic in the Greater London area;
- Heathrow is served by two parallel runways which operate in 'segregated mode', with arriving aircraft allocated to one runway and departing aircraft to the other at the same time;
- Heathrow is permitted to schedule up to 480,000 air transport movements (ATMs) per year and currently operates at approximately 95% of its permitted capacity;
- Heathrow has five terminals (including T2 which is currently under construction) which handled 65.7 million passengers in 2010;
- The airport site covers 1,227 hectares (4.69 square miles);

This chapter describes in more detail Heathrow's:

- Strategic objectives
- Organisation and business unit structure
- Assets and responsibilities
- Key stakeholders and their responsibilities

3.2 STRATEGIC OBJECTIVES

Heathrow's strategy is informed through its vision and a series of strategic intents (see *Figure 3.1*).

Figure 3.1 Heathrow's Strategic Intents



Source: HAL, 2010

3.3 ORGANISATION AND BUSINESS UNITS

HAL is organised across a number of business units (see *Table 3.1*) which can principally be classified into those involved with the day to day operations of the airport and those necessary to provide wider supporting functions, as detailed below. The risks and adaptation response identified through this study have in each case been assigned to the appropriate business unit.

Table 3.1 Heathrow Business Units

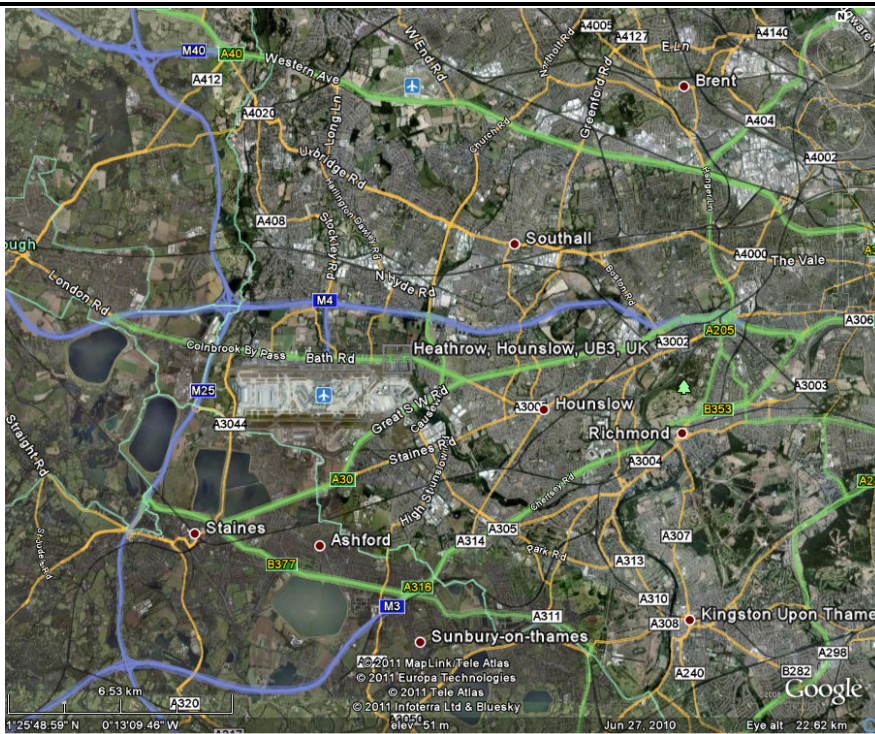
Function	Business Unit
Operations	Airside Fire Service Engineering Terminals First and Last Security HEX (Heathrow Express)
Non Operations	Finance IT Capital Projects Technical Standards & Assurance Commercial Regulation Communications HR

3.4 ASSETS

3.4.1 Location

Heathrow is located 24km west of central London, in the south of the London Borough of Hillingdon. The location of the airport is illustrated in *Figure 3.2*.

Figure 3.2 The Location of Heathrow Airport



Source: © 2010 Google Map data © Tele Atlas (Google Earth Professional)

To the north, the airport is surrounded by the Greater London suburbs of Harlington, Harmondsworth, Longford and Cranford. To the east lie Hounslow and Hatton, and to the south are East Bedfont, Staines, Egham, Ashford and Stanwell. To the west, the M25 motorway separates the airport from Colnbrook in Berkshire.

The airport site is delineated by a perimeter fence and the area within this covers 1,227 hectares (4.69 square miles).

3.4.2 Existing Onsite Assets

The existing onsite assets at the airport are illustrated in *Figure 3.3, Table 3.2 and Table 3.3.*

Table 3.2 Airside Infrastructure

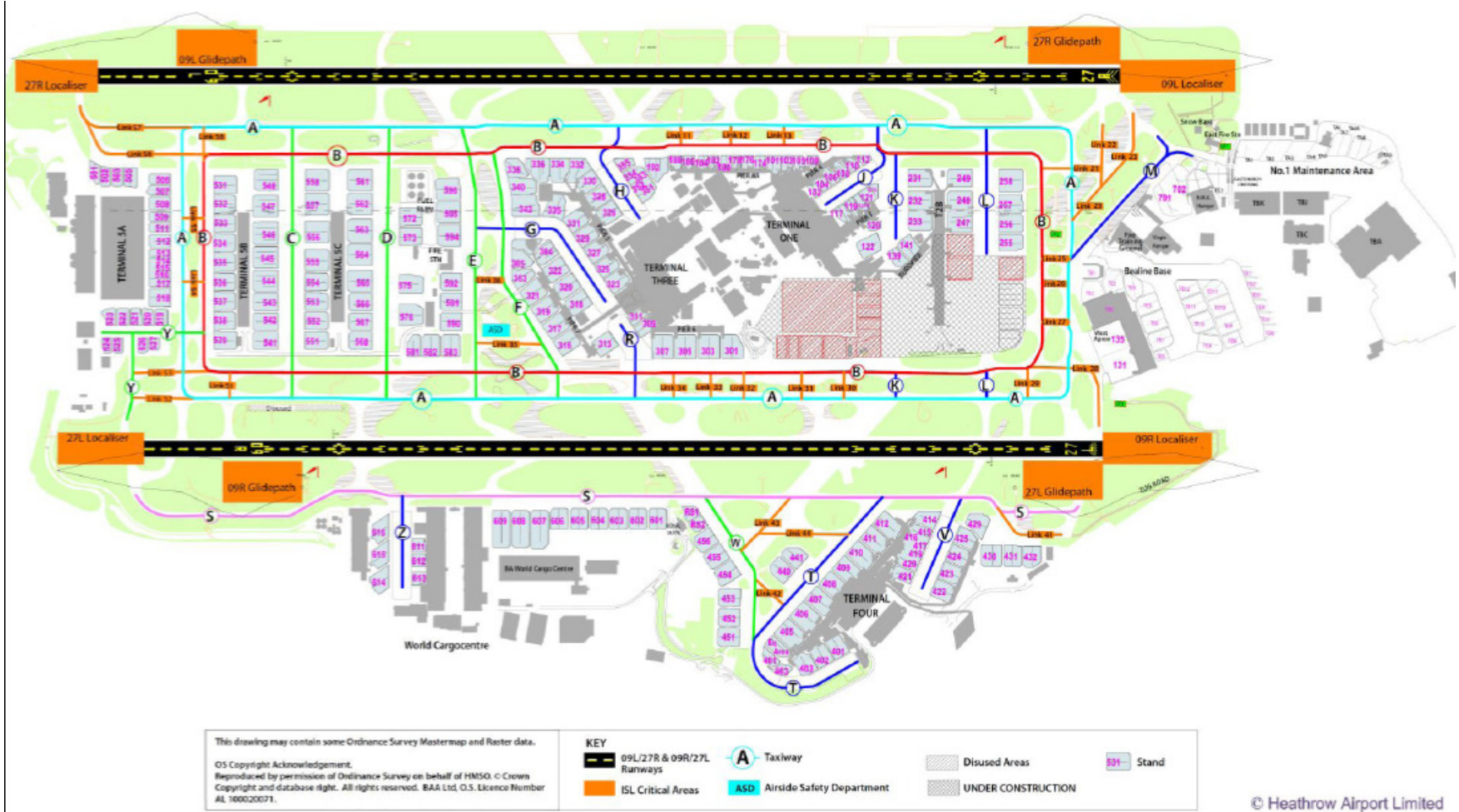
Runways	Northern: 3902m long Southern: 3658m long
Aircraft stands served by airbridge	118
Number of remote stands	80

Table 3.3 Terminal Infrastructure

	T1	T2	T3	T4	T5
Opening	1968	2014	1961	1986	2008
Surface (m ²)	74,601	185,000	98,962	105,481	353,020
Passengers (million)	13.6	0	20.4	8.3	23.4
Airlines	20	0	38	36	1

Heathrow has two parallel main runways spanning east-to-west which are aligned to the prevailing wind direction. In addition to the parts of the airport visible to the travelling public there are a considerable number of ancillary buildings and large airside areas, including onsite energy centres for the generation of heat and power (and associated distribution systems), deep basement baggage halls, and underground services i.e. baggage tunnels; which are restricted to security cleared staff only. Other ancillary buildings onsite include cargo warehousing, maintenance hangers, staff welfare centres for airline crews and other shift workers, and the Animal Reception Centre (where livestock and incoming animals are quarantined, which handles over 650,000 animals each year). To ensure passenger wellbeing there are numerous medical facilities distributed across the Heathrow campus; including emergency phones throughout the terminals, health centres with nurses on hand in each terminal, plus a number of pharmacies and the official Port Health facilities.

Figure 3.3 Onsite Assets



Development Plans

HAL's development plans for Heathrow are presented in the airport's current Capital Investment Plan - CIP 2010 which covers the ten-year period commencing April 2010, spanning three regulatory periods (quinquennia), which are:

- Q5: 2010/11 – 2012/13
- Q6: 2013/14 – 2017/18
- Q7: 2018/19 – 2019/20

Heathrow's significant capital investment programme means that whilst by day Heathrow is the world's busiest airport, by night it is Europe's busiest construction project. £4.8 billion is currently being invested in upgrading the existing terminal buildings and constructing new facilities. A third Terminal 5 building - satellite C – is currently under construction to enable more aircraft to park at the terminal so that passengers do not need to take a bus from the aircraft. Terminals 1 and 3 are also being redeveloped with improved facilities and services. Terminal 4 is benefiting from an extensive construction programme and has been transformed with a £100 million new check-in area and forecourt, creating an additional 6,000 square metres of space. The current Terminal 2 has been demolished to make way for a brand new terminal – Terminal 2A and satellite buildings. The new T2 will match the main T5 building in terms of scale and functionality. Construction of the new Terminal 2 complex to replace the terminal building and adjacent Queen's Building began in 2009; the first phase is expected to open in 2014.

In addition to the highly visible changes to the airport's layout as demonstrated by the new improved terminal facilities, significant changes are ongoing 'behind the scenes' at Heathrow. A major upgrade of Heathrow's onsite drainage systems and pollution control system (PCS) which handles runoff from the airport's surfaces is underway. Furthermore, a further £1 billion has also been set aside to upgrade Heathrow's baggage systems.

Work has already begun to bore a new £300 million baggage tunnel to connect Heathrow's five terminals and significantly improve baggage-handling performance.

The Heathrow Post T5 Transfer Baggage System project is a major infrastructure project which comprises the construction of a 2.1 km tunnel containing an automated baggage transfer system between Terminal 5C and 1 and 3 with a link to the future Terminal 2A. By 2012, in time for the London Olympics, Heathrow will have the world's largest integrated baggage system capable of handling 110 million bags a year.

All HAL owned and leased assets on the site are built in accordance with HAL's design standards which confirm to UK Building Regulations and other technical design standards such as those issued by the CAA and the Highways Agency. The new Terminal 2 building currently being built on the site considerably out-performs Part L of the UK Building Regulations in terms of its energy efficiency and reduced carbon intensity. This forms an integral delivery mechanism for HAL's current target of reducing CO₂ emissions from its energy use in fixed assets by 34% below 1990 levels by 2020 .

3.4.3 Third Party Assets

Many of the buildings and infrastructure at Heathrow are not occupied or operated by HAL, but are leased to external organisations such as the Port Health Authority, airlines, ground handling companies, and catering and other service companies. Leased buildings are managed in partnership with tenants to ensure that the needs of the occupiers are met, and direct control of these assets is not in the hands of HAL. Any adaptation solutions required in these buildings would have to be developed in partnership with the long term tenants.

The large (4 million litre capacity) fuel farms currently located on the southern Perimeter of the Heathrow site (close to Terminal 4), and in the centre of the site (close to the control tower), supply aviation fuel (also known as Jet A-1 fuel) to the airlines. These fuel farms and the fuel supply pipe work (hydrants) linking the fuel farms with the aircraft stands is not owned by HAL but are owned and operated by Heathrow Airport Fuelling Company (HAFCO) which itself is owned by a consortia of oil companies, and Heathrow Hydrant Operating Company Ltd (HHOpCo) respectively.

Furthermore the supply of Jet A-1 fuel to the airport depends on long supply lines and assets owned by numerous external organisations outwith the remit of HAL. Heathrow, along with other major UK airports is connected to the UKOP (UK Oil Pipeline) system. This pumps aviation fuel and other products produced from refineries including Esso Fawley, Texaco Pembroke, Total/Fina/Elf Milford Haven, Shell Stanlow, Lindsey & Conoco Immingham, Phillips Billingham, and BP Grangemouth, and that imported to the UK by sea into the terminals at the Isle of Grain, Hamble, Immingham and Avonmouth.

3.4.4 Offsite Assets

Whilst the majority of HAL's existing assets are located within the perimeter fence, other important assets are external to this – most notably the airport's balancing ponds such as the Clockhouse Lane Pit, North Western Balancing Reservoir, and the Eastern Balancing Reservoir. These ponds store and treat run-off from the airport before returning treated water to local watercourses. As described above, important third-party assets are also located offsite and can involve long supply chains and associated infrastructure that is located outwith HAL's direct control.

3.4.5 Surface Access

Heathrow is well connected to London and other parts of the country, by a number of surface access routes including train, tube, taxi, and bus etc. The airport is also well connected to the UK trunk road and motorway network.

Rail

The main rail access routes to the airport are:

- The Heathrow Express (HEX) is an electrified non-stop train service directly linking stations at Terminal 5, and Heathrow Central station (serving Terminals 1 and 3 and with a transfer service to Terminal 4) with London Paddington mainline station. Approximately 5 million (7%) passengers a year use the HEX service to get to and from Heathrow Airport. HEX is owned and operated by HAL;

- Heathrow Connect is an electrified stopping train service to Paddington calling at up to five stations between the airport and central London. Heathrow Connect services terminate at Heathrow Central station (Terminals 1 & 3).
- London Underground Piccadilly line serves the airport via four tube stations: three of which, those at Terminals 1 / 3; Terminal 4; and Terminal 5 serve the passenger terminals, and one at Hatton Cross which serves the maintenance areas and commercial warehousing and light industrial premises on the airport's periphery. Approximately 2.7 million passengers a year use the Hatton Cross station (not all of which should be considered airport traffic), 8.3 million use Heathrow Terminals 1 and 3 Station, 1.8 million use the Terminal 4 Station, and 3 million use the Terminal 5 Underground Station ⁽¹⁾. In total up to 15.8 million journeys to and from Heathrow are made by passengers and crew (representing approximately 20% of HAL passengers surface access journeys) on the Tube. The Piccadilly line is owned and operated by Transport for London (TfL);

Buses and Coaches

Many buses and coaches operate from the large Heathrow Airport central bus station serving Terminals 1, 2 and 3, and also from bus stations at Terminals 4 and 5. Bus and coach transport to and from the airport serves both local communities, and also links more distant parts of the UK with Heathrow.

Car

To limit congestion on the nearby road network and to reduce the environmental impact of travel to and from the airport, HAL actively encourages crew and passengers to use public transport to access the airport. HAL has invested in a wide range of initiatives including a free fare zone on public transport around the airport. However many passengers continue to prefer to travel to the airport by private transport and approximately 50,000 cars per day enter the Central Terminal Area. Heathrow is accessible via the nearby M4 motorway and A4 road (Terminals 1–3), the M25 motorway (Terminals 4 and 5), and the A30 road (Terminal 4). There are drop off and pick up areas at all terminals and short and long stay multi-storey car parks. Additionally, there are car parks (not run by HAL) just outside the airport; these are connected to the terminals by shuttle buses.

The road network on the site is well developed and well used. Given the limited space on the airport site many road routes travel underground. Four parallel tunnels under the northern runway connect the M4 motorway and the A4 road to Terminals 1–3.

(1) *Customer metrics: entries and exits*. London Underground performance update. Transport for London. 2003-2009.
<http://www.tfl.gov.uk/tfl/corporate/modesoftransport/tube/performance/default.asp?onload=entryexit>.

Taxis

Taxis are available at all terminals.

Inter-terminal Transport

Terminals 1 and 3 are within walking distance of each other. Transfers from the Central Terminal area to Terminal 4 are by Heathrow Express trains or bus and to Terminal 5 by Heathrow Express trains or bus. All terminals can be accessed via London Underground. On Heathrow Express and local buses (but not on the London Underground) transfers between Heathrow Central, Terminal 4 and Terminal 5 are free of charge.

3.5 CAPACITY AND OPERATIONS

Table 3.4 Summary

Annual air transport movements	449,220
Daily average air transport movements	1,247
Vehicles per day / week passing through the main tunnel	Approximately 50,000 per day (entering the Central Terminal Area), 350,000 per week
Mode of runway operation	Segregated mode
Operational hours	365 days per year, with night time restrictions

Operations at the airport may be subject to temporary alteration and suspension during periods of heightened security, extreme weather events, and other unpredictable events outwith HAL's control such as the recent Eyjafjallajökull volcanic eruption. There are contingency plans in place to manage these risks so as to minimise the impacts on the users of the airport and to maintain their safety at all times.

3.6 KEY STAKEHOLDERS

As detailed in *Section 2.2* there are a large number of stakeholders who have an interest in operations at Heathrow and it was important to consult with a wide range of these organisations as possible as part of this study. The most significant stakeholder groups with an interest in Heathrow are detailed in the following paragraphs.

3.6.1 Passengers

Table 3.5 Passenger Numbers (2010)

Number of passengers arriving and departing per day	Average 182,631 (split 50/50 between arrivals and departures)
Number of passengers arriving and departing in 2010	65.7 million
Percentage of international passengers	92.6% (60.6 million)
Percentage of domestic passengers	7.4% (4.9 million)
Percentage of transfer passengers	37% (24.3 million)

3.6.2 Employees

Those who work at Heathrow represent another important stakeholder group. Heathrow is the UK's largest single-site employer with over 77,000 people working directly at the airport. Of the 77,000 employees whose place of work is Heathrow Airport only a relatively small fraction (4,385) are in the direct employ of HAL or BAA.

Hundreds of different businesses and Government agencies work at Heathrow, from the largest airline alliances to independent business operators such as taxi drivers.

3.6.3 Suppliers

Alongside those directly employed onsite, Heathrow has long supply chains and it is estimated that across the UK there are another 100,000 more people engaged in supplying and supporting the airport. Key suppliers for Heathrow range from those involved in providing aviation fuel to the airport's fuel farms, to the suppliers of de-icing fluid, caterers, retail suppliers, ICT providers, utility companies and engineering and manufacturing companies supplying equipment and parts for use in the airport's assets and vehicles.

3.6.4 Airlines

Table 3.6 Destinations and Airlines

Number of airlines	95 (Heathrow based airlines are: British Airways, Virgin Atlantic and BMI)
Number of destinations served	180

3.6.5 Retailers

The 84 retail stores and 43 restaurants located within Heathrow's terminal buildings form an essential part of the passenger experience. Rental income from retailers is also an important element within HAL's income stream.

3.6.6 Freight

Half of the UK's air freight, nearly 1.3 million tonnes a day, passes through Heathrow. Air freight accounts for a significant share of UK cargo in terms of value. Almost 40% of UK trade with non-EU countries by value is transported by air ⁽¹⁾. Heathrow alone accounts for a quarter of the UK's non-EU trade by value, (by contrast, Felixstowe, our largest container port, accounts for 12%) therefore the airport's cargo facilities are of vital importance to the broader UK economy by ensuring the smooth flow of imports and exports. In contrast, domestic flights only account for 5% of all UK air freight (107,227 tonnes in 2008) since narrow-bodied aircraft with minimal belly-hold capacity are used for these flights, and road transport around the UK is more cost effective ⁽²⁾.

3.6.7 Surface Transport Operators

As discussed in *Section 3.4.5* of this Chapter, there are numerous surface access transport routes serving Heathrow and the operators of these transport modes are another important stakeholder with which the airport operator regularly liaises.

3.6.8 Air Traffic Control

Air traffic control at Heathrow Airport is provided by National Air Traffic Services (NATS) from facilities at Swanwick in Hampshire, and from the Air Traffic Control (ATC) Tower at Heathrow Airport. Aircraft destined for Heathrow usually enter its airspace via one of four main reporting points: Bovingdon (BNN) over Hertfordshire, Lambourne (LAM) over Essex, Biggin Hill (BIG) over Bromley and Ockham (OCK) over Surrey. When the airport is busy, aircraft will orbit in defined holding patterns or 'stacks' which lie respectively to the north-west, north-east, south-east and south-west of the London conurbation.

3.6.9 Regulators

The activities at Heathrow Airport are highly regulated both by the UK authorities and the EU. The chief regulatory bodies that oversee Heathrow Airport and influence HAL's operations are the Civil Aviation Authority (CAA), the local planning authority (the London Borough of Hillingdon), the Department for Transport, and the Environment Agency. Utility supply arrangements are overseen by the usual suite of regulators i.e. Ofgem, Ofwat etc.

3.6.10 The Local Community

Approximately 980,000 people live in the five boroughs which surround Heathrow Airport. Maintaining good relationships with the local community is very important to HAL. BAA has its own grant-making charity, The BAA Communities Trust. Funded by an annual donation from the company, the independently run Trust makes grants to support education, environmental and regeneration projects in the communities closest to BAA's airports including Heathrow. The Trust has made grants worth a total of more than £6 million since it was first set up in 1996.

(1) Analysis of the End to End Journey of UK Air Freight, Department for Transport 12th May 2009

(2) (ibid)

3.7 RESPONSIBILITIES AND INTERDEPENDENCIES

3.7.1 HAL Responsibilities

HAL owns and manages the airport infrastructure that enables airlines to operate their schedule and passengers to arrive and depart. A nominated HAL senior manager is also the airport licence holder under CAA regulation and is responsible for ensuring that all safety requirements are met. HAL's specific responsibilities and accountabilities at Heathrow include:

- Airbridges – HAL owns and maintain the airbridges linking planes to the terminal buildings. Airlines are responsible for manoeuvring airbridges to the planes;
- Airfield maintenance – HAL is responsible for safe runway operations and runway lighting;
- Airport utilities – HAL manages the provision of electricity, heating, water, lighting, fire alarms, etc;
- Baggage – HAL is responsible for providing and maintaining baggage systems. Airlines handle baggage and manage hold baggage screening;
- Fire service – HAL has responsibility for all fire service activities at the airport. 110 people work in the Fire Service at Heathrow;
- Flight information – HAL operates the flight information display screens in the terminals and online;
- Heathrow Express (HEX) – HAL owns and operates the Heathrow Express train services from London Paddington to Heathrow and between Heathrow terminals;
- Property – HAL's portfolio is diverse, including offices, airline lounges, business centres, warehouses, fuel facilities, crew reporting centres and aircraft hangars;
- Retail – HAL develops, lets and manages retail units, including car parks, shops, catering outlets, currency exchanges and car hire;
- Roads – HAL engineers maintain the road network in and around the airport which consists of over 50km of road carrying over 100,000 vehicles every day;
- Safety and security – HAL's number one priority is the security of passengers. Over half of HAL staff work in security and are responsible for passenger and staff screening as well as general security around the airport.

3.7.2 External Stakeholders' Responsibilities

Airlines

Airlines are responsible for checking-in passengers, delivering hold luggage to its final destination, cargo, providing and fuelling aircraft, boarding passengers, passenger safety and on-board catering. Some airlines employ their own ground-handling agents to carry out this work; others subcontract this work to dedicated ground-handling companies.

Airport Coordination Limited (ACL)

Owned by the airlines, ACL is responsible for slot allocation, schedules facilitation and schedule data collection at the airport. Slot allocation is a technique to balance the supply and demand for scarce airport capacity, in order to minimise congestion and delays through the issue of permissions for aircraft to land and take off at particular times. The cost of landing at Heathrow is determined by the CAA and BAA.

Airline Operators Committee (AOC)

AOC supports the airline community at Heathrow Airport and consults and collaborates with HAL in the common cause of providing a high standard of passenger service.

Civil Aviation Authority (CAA)

The CAA controls all flight paths and aircraft routes at UK airports, regulates airlines, airports and NATS. The CAA also sets airport charges at London airports.

Commercial Services

Hundreds of other private sector companies operate at Heathrow in a diverse range of roles. Individual businesses and franchises provide catering, shopping facilities, car hire, car parking and banking services. Other private sector businesses include the large ground handling organisations such as Aviance and Menzies, ICT provision, public transport companies, hauliers and logistics companies, maintenance engineers, health professionals and veterinary staff, cleaners, and those companies responsible for the airport's fuel supply and distribution including HAFCO and HHOpcO. The Met Office and numerous other meteorological data provision companies are responsible for supplying HAL and the individual airlines with up to date weather projections. In terms of utilities suppliers, supplies are managed in a central fashion by HAL with chief suppliers being Thames Water for water supply and wastewater treatment and EdF for electricity supply.

Metropolitan Police

The Heathrow Division provides an armed response to terrorist incidents in addition to its general law and order policing role. The Met operates out of buildings owned and managed by HAL.

National Air Traffic Services (NATS)

NATS is responsible for air traffic control (ATC) and management, including managing arrivals and departures and ensuring aircraft flying in UK airspace and over the eastern part of the North Atlantic are safely separated. NATS activities at the airport operate out of Heathrow ATC tower, which is a building owned and managed by HAL.

Public Sector Bodies and Regulators

The chief regulatory bodies that oversee Heathrow Airport are the Civil Aviation Authority (CAA) which deals with airside operations and liaises on issues of capital investment planning; the local planning authority (the London Borough of Hillingdon) for planning matters and development plans; the Department for Transport for strategic issues, and for environmental issues, permitting and compliance – the Environment Agency. Numerous other Government agencies have an interest in, and in some cases operate directly from Heathrow Airport including Port Health and Hillingdon Borough's Imported Food Inspection and Law Enforcement Service. These regulatory bodies are responsible for dealing with issues such as food safety relating to air freight, animal welfare for livestock and pets using the HARC and passenger health.

Whilst HAL does not have direct control of the operations of these bodies, as a landlord it provides the facilities from which they work and / or regulate and ensures that the facilities provided are fit for purpose.

UK Border Agency (UKBA)

UKBA is responsible for securing the UK border and controlling migration. It manages border controls, enforces immigration and customs regulations and considers applications for permission to enter or stay in the UK, including for citizenship and asylum. UKBA operates out of buildings owned and managed by HAL.

4 BASELINE CLIMATE AND RISK MANAGEMENT

4.1 INTRODUCTION

This chapter summarises information on the climate currently experienced at Heathrow and observations of how the climate has changed in recent times.

It also summarises how climate risks are presently managed through business preparedness and contingency planning and crisis management.

Annex A contains further details of the baseline meteorological conditions.

4.2 METEOROLOGICAL DATA

Because of the importance of accurate weather data for the aviation industry, there is a Met Office observing station at Heathrow Airport which records local meteorological conditions and maintains climatic records. Many functions at the airport rely on regular intra-daily updates on weather conditions from the Met Office and other meteorological data providers.

Meteorological conditions have been recorded at Heathrow in a systematic manner since 1948. Data was provided to this study directly from the Met Office observing station at Heathrow and supplemented by historic records published on the Met Office website for the Heathrow weather station ⁽¹⁾.

Table 4.1 Heathrow Historic Meteorological Data (30 Year Mean)

	Average rainfall (mm)	Mean dry bulb temp (°C)	Mean wind direction (deg true)	Mean wind speed (kt)
January	54.5	5.2	194.4	7.7
February	38.3	5.3	193.5	7.3
March	42.7	7.6	200.7	7.4
April	43.6	9.8	183.9	6.9
May	49.6	13.3	176.5	6.8
June	48.1	16.3	204.6	6.5
July	45.9	18.6	211.0	6.6
August	48.3	18.5	213.1	6.1
September	48.8	15.7	200.0	6.0
October	69.2	11.9	191.2	6.5
November	58.8	8.0	205.5	6.6
December	55.6	5.7	193.3	7.0
ANNUAL	603.2	11.4	192.4	6.8

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(1) Online data sourced from: <http://www.metoffice.gov.uk/climate/uk/stationdata/heathrowdata.txt>

30 year mean data for a range of climatic variables, as provided by the Heathrow observing station, are illustrated above in *Table 4.1*; and long term averages and maxima and minima for a range of variables are given in *Table 4.2*.

Table 4.2 Heathrow Historic Meteorological Data (Long Term Averages, Minima and Maxima 1948 - 2010)

	Max Monthly Temperature C	Min Monthly Temperature C	Airfrost Days per Month	Monthly Rainfall mm	Monthly Sunshine Hours
Average	14.78	6.97	3.09	50.35	130.55
Max	28.20	16.70	28.00	174.80	310.10
Min	0.80	-4.60	0.00	0.30	18.50

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<http://www.metoffice.gov.uk/climate/uk/stationdata/heathrowdata.txt>

4.3 BASELINE CONDITIONS

4.3.1 Climate Baseline Summary

Lying at a latitude of approximately 51° North, and approximately 50 miles from the coast, Heathrow has a temperate marine climate ⁽¹⁾, with mild damp winters, and warm, drier, sunnier summers like much of the southern British Isles. Heathrow is located in the part of the UK closest to continental Europe and as such can be subject to continental weather influences that bring cold spells in winter and hot, humid weather in summer. It is also furthest from the paths of most Atlantic depressions, with their associated cloud, wind and rain.

Summers are generally warm, with daytime temperatures above 20 °C (68 °F) on over 90% of days. Warm weather can usually be expected from May to September. In recent years, 30 °C (86 °F) has been recorded in early May on several occasions and as late as mid September. On average, Heathrow receives 28 days above 25 °C (77 °F) per year, and 4 days above 30 °C (86 °F). Because of the Urban Heat Island effect (UHI), Heathrow's location within the Greater London conurbation means that temperatures can be up to 5°C higher than that experienced in the surrounding countryside. Rainfall is relatively low in the summer months, but when rain does fall it often falls in heavy convective events.

Winters are chilly, but for the most part temperatures remain at or above freezing, with daytime highs around 6 °C (43 °F) to 8 °C (46 °F). Winter temperatures can reach as high as 16 °C (61 °F) occasionally, and also below 0 °C (32 °F) even during daytime. The winters of 2009-10 and 2010-11 have been considerably colder than the long term average and stand in contrast to the mild winters experienced over the last decade and a half at Heathrow.

Because of the UHI and potentially because of the impacts of climate change, snowfall at Heathrow has not been commonplace in recent years, although the last two winters represent a departure from this trend. Most precipitation during winter months falls as rain rather than snow.

(1) Köppen climate classification Cfb

Spring is characterised by mild days and cool evenings in March and April, and generally warm days and mild nights during May. Spring weather can be changeable and cold weather is possible until late April. Conversely 29 °C (84 °F) has been recorded in London in April. Spring is normally the driest time of year in the South East of England.

Autumn is usually mild but often unsettled as colder air from the Arctic and warmer air from the tropics meet. Temperatures usually remain warm, above 18 °C (64 °F) until late September, and increasingly, in recent years until early to mid October.

London is a relatively dry city with regular but generally light precipitation throughout the year, with an average of 583.6 mm (22.98 inches) every year. This is around the same as Jerusalem. The Heathrow site receives slightly more precipitation than central London, but at 603.2 mm per year rainfall is still very low compared to the rest of the UK and Northern Europe generally. Precipitation is generally fairly evenly distributed throughout the year with a spring minimum and late autumn maximum.

4.3.2 Locational Factors

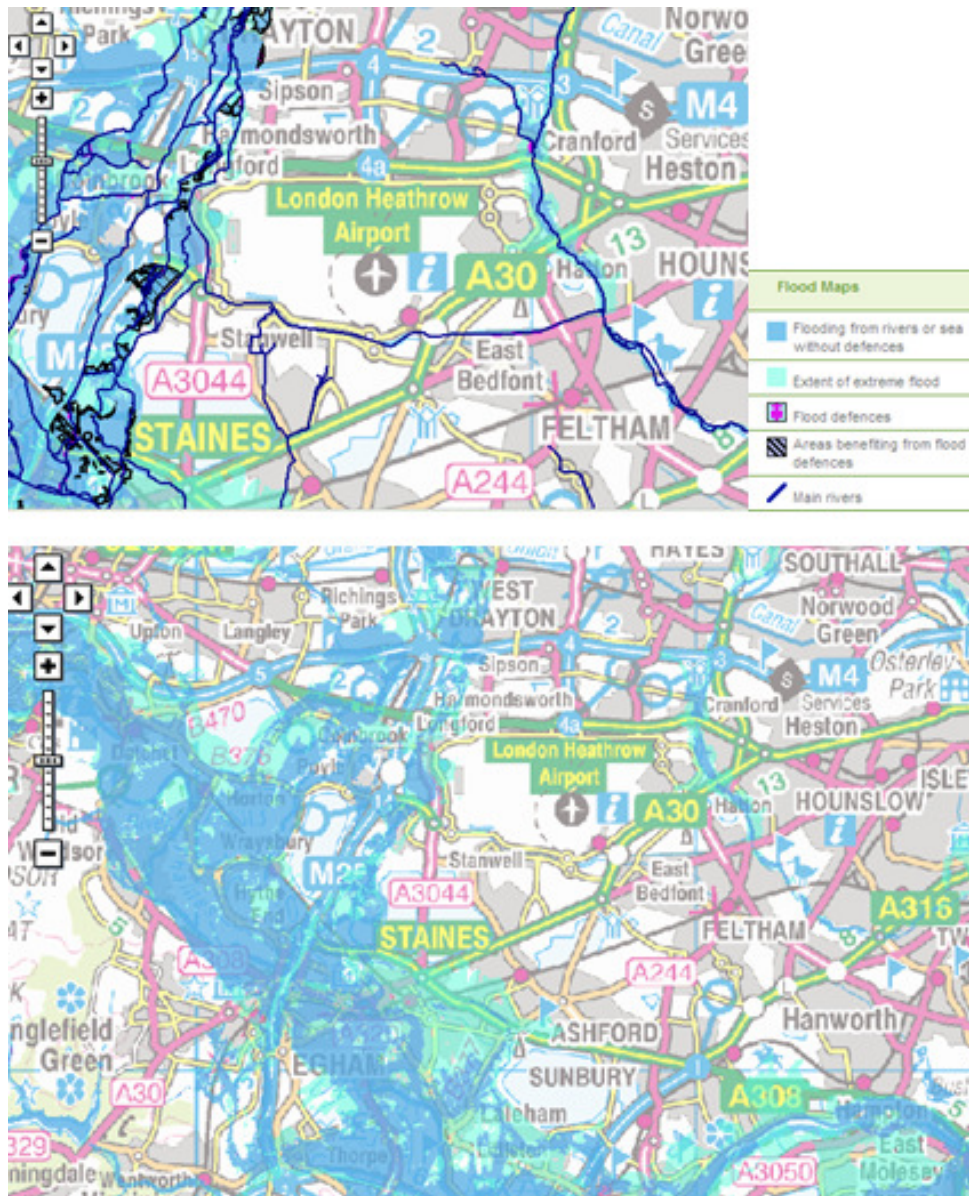
Heathrow's climate, and the airport's potential vulnerability to future climate hazards, is to a large degree dictated by its physical location. The site is relatively low-lying, at 25 metres above sea level. This low elevation, combined with its relative proximity to the River Thames (the river passes approximately 3.5 miles to the south), means that Heathrow can be prone to fog, and particularly freezing fog, during the autumn and winter months.

The site's low altitude and proximity to various watercourses including the River Thames, the Duke of Northumberland's River, the River Crane and the River Colne, means that the wider area around Heathrow is classified by the Environment Agency as having a low to moderate vulnerability to flooding, and has been designated to lie within Flood Zone 1 and 2 accordingly.

The Heathrow site itself is in an area that is unlikely to flood (from river flooding) except in extreme conditions. The chance of flooding estimated by the Environment Agency for Heathrow, each year is 0.5% (1 in 200) or less. The location of Heathrow in the context of local flood zones is illustrated in *Figure 4.1*. It should be noted that flooding from overland flow (pluvial flooding) and flooding resulting from drainage system inundation is not able to be included in the Environment Agency's flood mapping at this time.

The low lying nature of the site, and the large expanse of hard-standing associated with the terminals and runways has resulted in occasional historic flooding episodes at the airport.

Figure 4.1 Environment Agency Flood Map



Source: © Environment Agency copyright and database rights 2010.

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Detailed work is being undertaken by HAL and external stakeholders to establish the degree of flood risk across the site in greater detail so as to be able to reduce flood risk in the future through improvements planned for the short and medium term to drainage infrastructure.

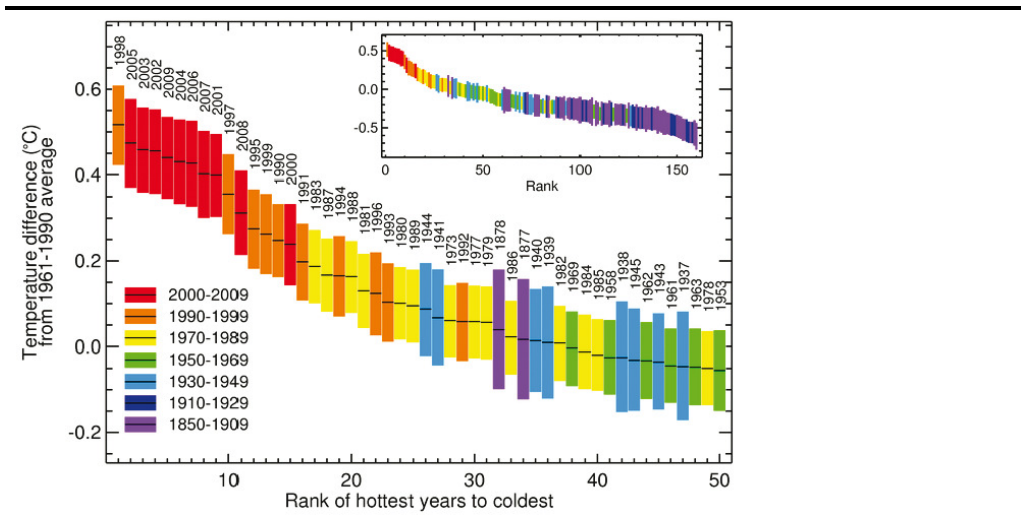
4.4 OBSERVED CHANGES TO THE CLIMATE BASELINE

Climate change should not be thought of as a risk that will occur only in the medium to long term future. The UK's climate is already changing. Whilst it is not possible to attribute any individual weather event or meteorological change as categorical evidence of anthropogenic climate change, observations demonstrate that temperatures are 1 °C

higher on average than they were in the 1970s. The UK Sub Committee on Climate Change Adaptation notes that this warming has been accompanied by more frequent heat waves, more intense rainfall events and rising sea levels.

2010 was the warmest year since measurements began 130 years ago. According to the Global reinsurer Munich Re 'The first nine months of the year (2010) have seen the highest number of weather-related events since Munich Re started keeping records'. Munich Re believes 'that a clear pattern of continuing global warming is contributing to natural disasters (1).'

Figure 4.2 Global Annual Average Temperatures Ranked Hottest to Coldest



(2) Source: Met Office, Hadley Centre

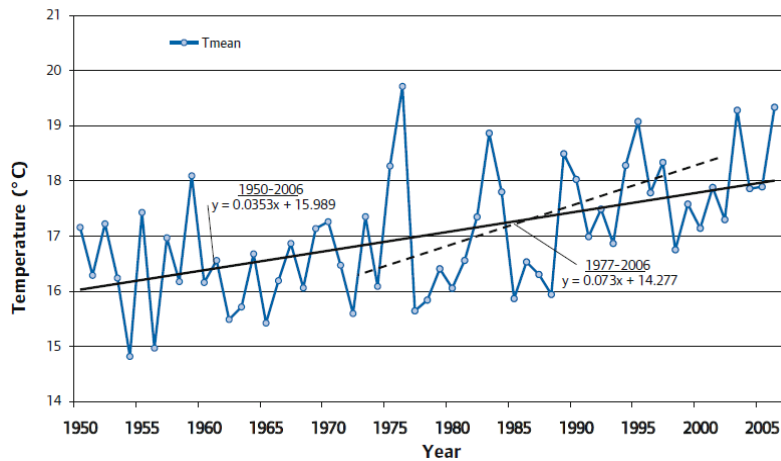
The Mayor of London's adaptation plan (1) notes that an analysis of global annual average temperatures shows that global temperatures have been progressively rising for over a century and that this change has accelerated in the last thirty years. Figure 4.2 ranks global annual average temperatures, with different colours used to highlight different decades. It can be seen that every year from the last decade falls within the 15 hottest years on record.

At a more local level all regions of the UK have experienced an increase in average temperatures between 1961 and 2006 annually and for all seasons, with increases greatest (1.7°C) in the South East of England. Average summer temperatures in London have warmed by over 2°C over the period 1977 - 2006.

(1) Dr. Peter Hoeppe, Head of the Geo Risks Research Department at Munich Re cited by: AFP, October 28th 2010 and available at: <http://www.google.com/hostednews/afp/article/ALeqM5iL1VhIWN2XDKI3APiITxnv8oNU9Q?docId=CNG.c8806b0465005156c3ed4b83c649cb5d.3d1>

(2) http://legacy.london.gov.uk/mayor/priorities/docs/Climate_change_adaptation_080210.pdf

Figure 4.3 Average Summer Temperatures in London (1950-2006)



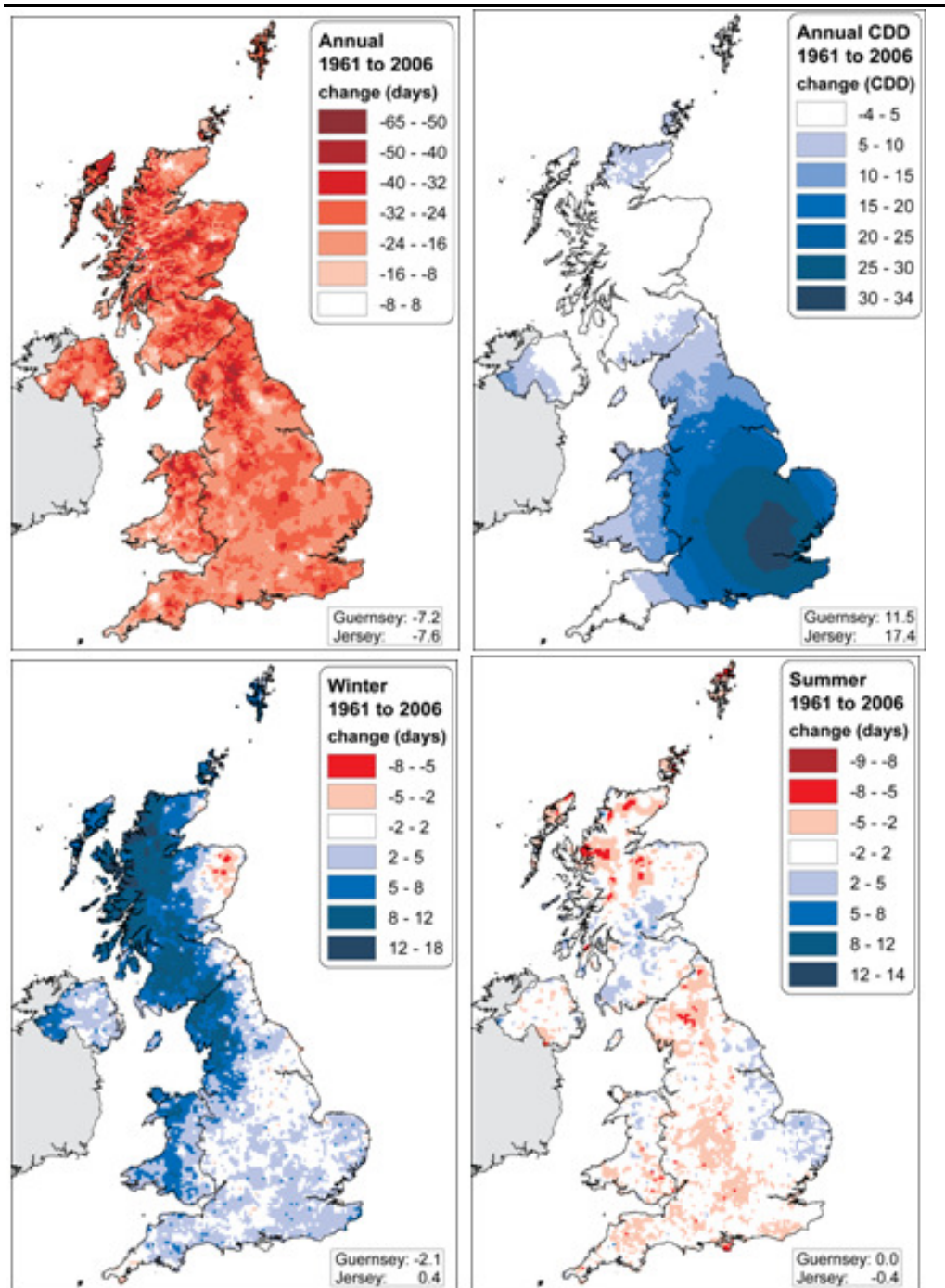
Source⁽¹⁾ © Crown Copyright Met Office 2010

Figure 4.3 is taken from the Mayor of London's Adaptation Report and plots the average summer temperatures (June, July and August) observed in London for the period 1950 - 2006. It can be seen that despite considerable variation from year to year, summers have got progressively warmer and that this rate of warming has increased over the past 30 years (as indicated by the dotted line), compared to the last 50 years (as depicted by the solid line).

Observed changes in a number of other climate variables over the period from 1961 - 2006 have been collated and presented by UKCIP from the historical Met Office records, including a reduction in the number of days with air frost and an increase in the number of days when artificial cooling is needed; these are summarised in the following figures:

(1) http://legacy.london.gov.uk/mayor/priorities/docs/Climate_change_adaptation_080210.pdf

Figure 4.4 Some Observed Changes in the UK Climate from 1961-2006



Clockwise from top left: Changes in air frost days; Change in cooling degree days; Change to summer precipitation and Change to winter precipitation;

Generally in the UK over the last forty years the climate has become warmer, with a reduction in air frost and days of snow fall, which has led to a reduction in the length of the heating season and a greater need for artificial cooling. Annual trends of precipitation show little change; seasonally, however, it can be seen that winters are getting wetter and summers and the springtime in particular are getting drier. In the decade since 2000, rain more typically fell in concentrated downpour events than was observed in 1961.

4.5 HOW AIRPORT OPERATIONS ARE AFFECTED BY THE CLIMATE

The aviation industry is weather-sensitive, and without mitigation adverse weather conditions have the potential to affect the safety of aircraft both in the air and during take-off, landing and taxiing. However the industry's international nature has facilitated the development of good practice operational and technological mitigations gained from experience in extreme conditions around the world, to minimise the impact from most climatic phenomena on aircraft operation and scheduling.

Safety is the paramount concern of airlines and airport operators and this is enforced by the Civil Aviation Authority (CAA) which is the public corporation which oversees and regulates all aspects of aviation in the United Kingdom. The CAA, airport operators such as HAL, and the aviation industry have developed comprehensive precautionary measures to ensure flight safety during the full range of adverse weather conditions experienced.

Generally the most significant consequences of weather extremes such as strong or cross-winds, heavy rain, fog, high temperatures or wintry conditions are impacts on air traffic movements (ATMs) due to the increased separation distances required between aircraft, and on rare occasions the diversion of incoming aircraft to alternate airports. Due to the high capacity factor that Heathrow operates at - any decrease in ATMs per hour has the potential to result in delays and cancellations.

Extreme weather events at destination airports, even those located many thousands of miles away also have the potential to affect ATMs at Heathrow. Where scheduling impacts from poor weather are prolonged or affect a wide geographic area, it can take airlines many weeks to return their timetables to punctuality due to problems from aircraft and crew being in the wrong locations. Furthermore large scale disruption in a destination region may mean that outbound flights from Heathrow have to specify different alternate airports (designated airports to which planes would be rerouted in the eventuality that it is not possible for the flight to land at its original destination i.e. due to weather conditions, security concerns etc) to those they regularly assume as part of their flightplans, which can affect the amount of fuel that they need to carry.

Other indirect impacts of the weather and climate govern destination choice and passenger demand. In good summers outbound passengers tend to fall, and incoming visitors to the UK increase in number. Disruption at popular leisure or business destinations (such as the Greek wild fires in 2008, or the Japanese earthquake and tsunami of 2011) can reduce their desirability as a destination and ensuing passenger demand. A perception of health risks may also lead to a reduced number of passengers choosing to fly to a given destination, and in some cases may reduce customer demand generally (i.e. SARS).

The weather can pose health and safety risks to passengers, HAL employees and other Heathrow workers. Slips, trips and falls are more common during wintry conditions. Hot weather can cause health problems (particularly cardio-respiratory conditions) for vulnerable passengers. Both high and low temperatures impact on staff productivity and are managed by personal protective equipment (PPE) and changes to working conditions for outdoor staff. Temperature extremes also affect operating costs at Heathrow as heating and cooling demand responds to cope with an associated impact on energy costs.

The effects of snow are described later in this chapter.

The climate and extreme weather events also influence the maintenance schedules and asset integrity at the airport. Extreme conditions have the potential to damage HAL infrastructure i.e. wind damage to lighting columns and signage, localised flooding of low lying assets, subsidence and cracking of surfaces.

The weather and climate also determine the design standards used in the masterplanning process at Heathrow to ensure that assets constructed are resilient to the conditions they are likely to encounter during their operating life.

4.6 BUSINESS PREPAREDNESS BEFORE DIRECTION TO REPORT WAS ISSUED

Heathrow's strategic corporate response to climate change has, to date, primarily focussed on the mitigation of GHG emissions arising from the airport's activities. This has involved concerted action to reduce the airport's direct emissions and influencing users of the airport such as airlines and passengers to encourage them to mitigate their emissions. HAL has a climate change strategy, led by the airport's Corporate Responsibility Department, which advises all business units on reducing emissions and sustainable resource use. Climate change risks relating to mitigation are already built into BAA's corporate risk registers.

In terms of adaptation, there are numerous weather related risks already considered and managed on BAA's risk registers, however these have not, to date, been specifically informed by the physical impacts of climate change but are based on current conditions and recent observed changes on the ground.

Because aviation is weather-sensitive, Heathrow is unlike many office based businesses in that it has a good understanding of how the weather and climate impacts on its operations, and has numerous contingency plans and procedures in place already to deal with weather related risks. Weather is however of considerable importance to the airport and it is regularly monitored and forecasts are used to inform a number of activities at the airport. Meteorological information is provided to airport staff in the form of a half hourly weather report or METAR which describes current conditions, and by a Terminal Aerodrome (or Area) Forecast (TAF) which describes forecast conditions.

There are numerous weather-related contingency plans and procedures already in place at the airport because of the weather-sensitivity of aviation. Day to day activities at the airport are guided by detailed meteorological forecasts which dictate corresponding changes to staffing levels, procurement of seasonal and contingency supplies, direction of work patterns and the implementation of contingency plans and procedures if needed.

Other existing contingency plans which could be used to respond to climate change, are more generic in nature and deal with the likely consequences of a range of events likely to result in common impacts for the airport i.e. delays, disruptions, runway closure. These plans focus on managing consequences to some degree regardless of the specific nature of the input trigger, which could be anything from heavy snow to volcanic eruptions.

For HAL if an external threat, outwith HAL's direct control causes disruption at the airport the first priority is to manage the disruption, and the specific cause of the disruption is to some degree irrelevant. Hence the development of generic consequence-based rather than causal contingency plans to ensure that even if events occur which it would not be possible to foresee, the consequences can be managed in a systematic and well-practiced manner.

More information on Heathrow's risk management and contingency planning is detailed in the following sections of this chapter.

4.6.1 Existing Risk Management Framework

Up until March 2010, Heathrow's risk management framework defined five levels of incident ranging from Level 0, which is considered as business as usual through to Level 4 (which is a major cross-terminal crisis). Levels 1 and 2 fell within the incident management category; and levels 3 and 4 trigger crisis management responses. This crisis management framework is currently being revised in the light of the findings of the Heathrow Winter Resilience Enquiry which recommended numerous improvements to existing systems in March 2011.

Crises and contingency plans are managed via a tactical response defined as Gold and Silver Command crisis management teams. Whether a Gold or Silver crisis command response is required is determined by a number of 'trigger' criteria, and the crisis management response being used can be up or down graded depending on how the situation on the ground changes.

4.6.2 Contingency Plans and Control Measures

Heathrow has a comprehensive approach to risk management given the diverse threats and challenges facing the aviation industry. BAA's risk registers cover topics as diverse as industrial unrest, fossil fuel depletion / price shocks, terrorism and the threat of global pandemic. Dealing with meteorological risks is an important part of this process.

Risks at Heathrow are managed by a suite of control measures which include extant risk management equipment, design standards, operations, procurement, policies and procedures. Many of these control measures are able to be adjusted as the conditions dictate (i.e. changes to the heating and cooling regime in terminal buildings, increased staffing for snow clearance during periods of wintry conditions).

Alongside standard control measures, to cope with existing extremes Heathrow has comprehensive contingency plans in place which are regularly reviewed and tested and an integral element of HAL's risk management function. This suite of contingency plans cover a wide range of meteorological events and other natural 'disasters' including snowfall, flooding, high winds, fog, offsite problems at destination airports (for example the Boxing Day Tsunami in 2004), disruption to surface access (including contingencies for the closure of the Central Access Tunnel) and extended flight bans such as that resulting from the Eyjafjallajökull volcano.

Weather-related Contingencies and Controls

Weather-related disruption is something that Heathrow has had to face historically, and will not be a new challenge for the airport resulting from climate change. It is acknowledged however, that the severity and frequency of weather-related disruption and the type of challenges encountered are likely to change as a result of the changing climate; both around Heathrow itself and in the vicinity of its destination airports.

Some periods when a contingency plan is likely to be enacted can be discerned in advance and the contingency planning process is forward-looking and informed by the best available evidence. In the case of weather events this process is informed on a weekly planning basis. Heathrow Airport Ltd sources its weather forecasts from the *Met Office* and *WSI Hubcast*. Both forecasts provide comprehensive, quantitative assessments of weather conditions for the next five days. This data is supplemented by observations from ATC observers at Heathrow Tower. Most pre-prepared contingency plans are enacted when conditions on the ground or meteorological forecasts meet certain predefined trigger thresholds. Weather forecasts are used by HAL management to determine shift patterns and staffing levels, prioritise activities scheduled for the week and are also used for the procurement of essential supplies to help deal with a given forecast weather event. In periods of poor weather, forecasts are communicated to those involved in weather-sensitive activities and planning, on at least an hourly basis throughout each day to ensure that the latest conditions and projections are considered.

Forecasts are also communicated with members of the travelling public and partner organisations such as the airlines. The airlines receive their own weather briefings and knowledge is passed from them to HAL and vice-versa to ensure that relevant knowledge and forewarning is shared across the Heathrow campus. It is quite normal for flights to be disrupted by weather as aviation is very weather-sensitive. Some airlines will proactively cancel parts of their schedule in response to severe conditions.

Other Contingencies and Controls

Other information sources which are used to inform contingency planning at the airport include the weekly liaison between the port medical officers and the Health Protection Agency (HPA), from which any relevant information is shared with key stakeholders such as Heathrow Animal Reception Centre, waste disposal contractors dealing with food waste, cleaners and flight crews.

Other events such as the occurrence of SARS and the flight ban arising from the 2010 Icelandic volcano cannot be predicted with any certainty in advance and require a proactive and rapidly evolving response. These events rely on generic rather than causal contingency plans and the stores of emergency supplies already in place at the airport and may necessitate rapid changes to staffing levels, operation patterns, information communication and supply procurement. Heathrow, like most airports, has a plan in place for example, to respond to mass congestion at the airport. This has been agreed informally with the Airline Operators Committee (AOC) and the CAA and requires HAL to provide information and certain emergency welfare items (e.g. water, chairs, ponchos, blankets etc) to passengers, and additional shelter via marquees when disruption is expected to exceed six to eight hours.

4.6.3 Development of Crisis Management Processes

Contingency plans are constantly evolving and are learning documents which incorporate new knowledge as it arises. Each time a contingency plan or Gold or Silver command is enacted the lessons learned from its implementation, and nuances from the specific incidence of disruption, are evaluated and incorporated into contingency plans to improve resilience in the future. It is possible that as a result of climate change Gold and Silver crisis command teams could be enacted with increasing frequency.

Heathrow learns not just from events that occur at Heathrow, but from the experiences of the aviation industry worldwide. In the unlikely event that an incident occurs either at Heathrow or any airport around the world that has not been possible to foresee in advance and which is not covered by existing contingency plans and control measures then new contingency plans are put in place based upon the lessons learned. For example the 2002 'shoe bomber' incident at Charles de Gaulle Airport in Paris, which led to the instigation of new control measures including an upgraded screening process for passengers footwear during security.

4.6.4 Heathrow Winter Resilience Enquiry Recommendations

Heathrow has recently conducted a thorough review of the snow related disruption which the airport experienced as a result of the abnormally heavy snow witnessed in December 2010. This review, known as the Heathrow Winter Resilience Enquiry reported its findings at the end of March 2011 and the lessons to be learned from this episode of disruption are currently being incorporated into HAL's contingency planning to improve resilience in the future.

In response to the Enquiry's conclusions, the airport plans to develop a £50 million 'Heathrow resilience investment plan', which will allow it to implement all the recommendations contained in the report.

The proposed improvements include new investment in equipment to deal with heavy snow, increased staffing resources and better training, new crisis management processes, better communication systems and improvements to passenger care and support. A new and enhanced snow plan will be produced and agreed by HAL and partner organisations i.e. airlines, ground handling agents etc and others to ensure that Heathrow remains open at all times, other than for safety reasons.

The panel also recommended that steps be taken by HAL and the airlines to ensure that every crisis response team has sufficient on-call dedicated resources rostered to enable it to function 24-7 for a sustained period, and the process to implement this is ongoing. Such staff will be trained, experienced and have the necessary leadership skills to undertake what can be a challenging role in a crisis.

HAL is also strengthening its emergency planning, response and recovery. In the future a single control centre will be established to manage major incidents, so that all parties can meet to make more informed decisions. A real-time incident management system available to all stakeholders is being established which will provide information to all stakeholders and track and support decision making. In addition HAL, airlines and retailers will regularly test a sustainable welfare plan, to be triggered immediately to look after passengers and provide accurate information.

HAL is also simplifying and streamlining its crisis management framework to the standard three tier process used by central, regional and local government and the emergency services across the UK. Staff at the airport will be trained in the new structure to understand the different roles they play in it.

The recommendations from the Heathrow Winter Resilience Enquiry (see <http://www.heathrowenquiry.com/>), and are currently being undertaken by HAL are summarised in *Annex E*.

5 CLIMATE CHANGE MODELLING

5.1 INTRODUCTION

This chapter introduces the approach used for the climate change weather modelling. The timeframe for the climate projections, location, emissions scenarios used and the meteorological variables modelled are presented. Sources of information are reported in this section and the UKCP09 (UK Climate Projections 2009) are introduced.

The methodology used in the climate change modelling is in accordance with national guidance from DEFRA, UKCIP (the UK Climate Impact Programme), the Environment Agency and Cranfield University, international guidance and emerging best practice where no formal guidance exists. The approach makes use of the precautionary principle, particularly when considering issues with a high degree of potential future uncertainty or where rapid advances in the science are possible. The modelling used in this assessment makes use of the best available climate modelling datasets and projections.

5.2 EVIDENCE

The key evidence sources used in the production of this report are primarily:

- the climate change projections produced by the UKCIP;
- in depth consultation with HAL staff and external partners on the airport's present resilience and risk management practices;
- peer reviewed science, published since the UKCP09 projections were released, for variables where greater clarity was sought; and
- guidance produced by the Environment Agency and DEFRA.

5.3 TIMEFRAME

Because of the long lifespan of the assets already existing, and planned for construction at the airport, climate change data has been examined for a number of reference decades to establish likely short and medium / longer term impacts at Heathrow. The periods considered for this study were:

- Short term: 2020s (UKCP09 defines the decade of the 2020s for modelling purposes as a thirty year time slice from 2010 – 2039 by UKCP09);
- Medium / longer term: 2040 /50s (defined by UKCP09 as the thirty year timeslice from 2030 – 2059);

Whilst dates as distant as the 2050s are unlikely to reflect the planning horizons regularly considered today by HAL, it is important to include this time period to understand the magnitude of change likely to be experienced in the UK climate by the middle of the 21st century, which may not readily be apparent should only short term projections be considered.

It was considered that assessing dates beyond this time period would not be meaningful at this juncture given the uncertainty in the science, emission scenarios and future airport development plans for such a long time horizon.

5.4 LOCATION

The direct physical impacts attributed to climate change on the Heathrow site itself have been modelled in detail using the UKCP09 suite of climate change projections. UKCP09 projections have a 25 km grid square granularity. For the UKCP09 projections a grid has been imposed on a map of the British Isles and data produced for all grid cells where the cell includes 50% or more land area (i.e. grid squares that include mostly coastal waters have not been modelled). Grid cell ID 1627 which encompasses the Heathrow Airport site has been used for this assessment. Grid cell ID 1627 has the following coordinates: Latitude 51.47°, Longitude -0.46° and is illustrated in *Figure 5.1*.

Given the global reach and interconnectedness of the aviation industry, impacts from climate change events around the world have the potential to affect operations at Heathrow. To attempt to quantify global climate change impacts and the indirect consequences for Heathrow is beyond the scope of this study, however the international dimension of the potential challenge is considered qualitatively using the best available evidence. As the science progresses this may be an important area for further research by HAL and its aviation partners.

Figure 5.1 Reference Location for Climate Modelling

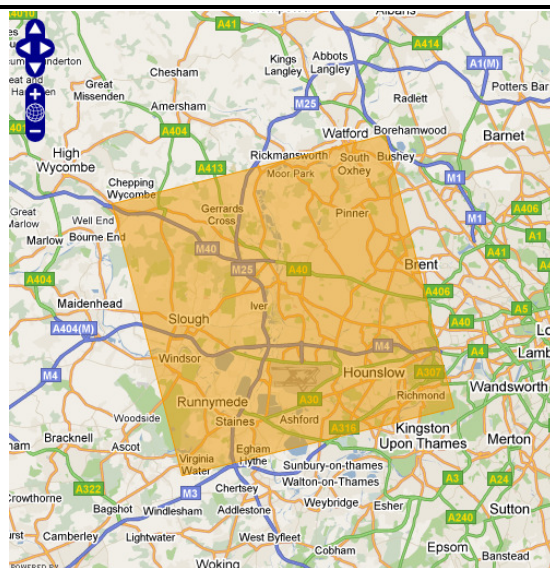


Image courtesy of UKCP09 and Google Maps 2010 ©

5.5 CLIMATE CHANGE MODELS

Projections of the potential impacts of climate change are made through the construction and use of global climate models / general circulation models (GCMs) which distill key physical and dynamical processes of the climate system into equations and algorithms.

GCMs attempt to describe the complex interrelationships of the atmosphere, biosphere (living things), geosphere (geology), oceans, cryosphere (ice caps) and human society.

Climate models are extremely complex and can never be 100% accurate due to limitations in our understanding of atmospheric chemistry and physical processes and due to limitations in computing power. The sophistication of GCMs is improving with time. There are, however, numerous physical processes which have so far been unable to be modelled due to the complexity of the natural systems involved.

This report uses the UKCP09 (UK Climate Projections 2009) suite of climate models to assess the potential impacts of climate change on the Heathrow site. Details of the UKCP09 projections are given in the following section.

5.6 UKCP09 PROJECTIONS

The UKCP09 projections are the first generation of probabilistic climate change projections and are considered to be the most advanced climate change modelling projections available in the world today. The projections were developed specifically for the British Isles by the UK Climate Impact Programme (UKCIP).

In April 2009, UKCIP released a suite of probabilistic impacts scenarios (UKCP09) to update the UKCIP02 scenarios it produced in 2002 with the latest science. UKCIP02 provided little transparency over the uncertainty attached to these projections. Therefore, rather than producing a limited number of climate change scenarios (i.e. high, medium and low emissions) as in previous projections, the probabilistic UKCP09 projections produce a range of results to allow a number of outcomes to be considered and the uncertainty associated with climate change projections to be better understood.

It is important to clarify the treatment of probability within the UKCP09 projections used for this study. The probabilities used in UKCP09 are subjective probabilities (similar to horse racing odds) based on scientific judgement rather than objective probabilities based on a known fixed number of outcomes (like flipping a coin). The UKCP09 projections make use of percentiles / probability levels to express the likelihood of changes being greater than or less than a certain amount.

The 90th percentile of a given UKCP09 projection illustrates that 90% of the model runs fall at or below that level, and 10% of the model runs returned values higher than that level, and is an indication of a level that is unlikely to be exceeded. A 90% probability level is not indicating that there is a 90% chance of a given projection occurring in the future. In fact, UKCP09 gives no probability of any individual projection actually occurring in the future.

5.7 EMISSIONS SCENARIOS

GHGs can have a long term affect on the climate and current emissions will impact upon the climate for many years after they have been released, due to time lags in the atmospheric and ocean system.

For short term projections, GCMs can be used to assess the impacts of climate change based upon recorded past GHG emissions. When considering the time period from the 2030 - 40s onwards, however, models must be run with assumptions about future emission levels as these will be the most significant determinant of climate change from this date. Future climate change will be impacted by emissions of GHGs which have yet to be emitted (the evolution of which is uncertain) and so GCMs are used in conjunction with speculative pathways of potential future development commonly termed *emissions scenarios*.

To ensure standardisation and consistency, the IPCC published a Special Report on Emissions Scenarios ⁽¹⁾ (SRES), which provides standardised emissions scenarios for use with GCMs to describe the range of possible future emissions of greenhouse gases (GHGs) that different socio-economic development pathways could produce over the coming century. Each emissions scenario is associated with different degrees of climate change, dependent on the assumptions made in the emissions scenario about population growth, energy use and the future fuel and technology mix. These alternative scenarios are known as A1, A2, B1 and B2, and within A1, there are a further three sub-scenarios A1FI, A1T and A1B, making a total of six emissions scenarios.

The SRES Emissions Scenarios are summarised in *Table 5.1*.

Table 5.1 SRES Emissions Storylines

A1 (A1FI, A1T and A1B)
Rapid economic growth and adoption of efficient technologies, low population growth. Per capita income regional differences converge. 3 alternative energy use storylines: fossil fuel A1FI, the non-fossil fuel (nuclear and renewable) A1T, and A1B which is a mixture of the two.
A2
A very heterogeneous world, fertility patterns across regions converge very slowly, which results in high population growth. Economic development is primarily regionally oriented and per capita economic growth and technological change is more fragmented and slower.
B1
A convergent world with low population growth. Rapid changes toward a service / information economy. Reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to sustainability.
B2
Emphasis is on local solutions to development and sustainability. Moderate population growth, intermediate economic development, and less rapid and more diverse technological change.

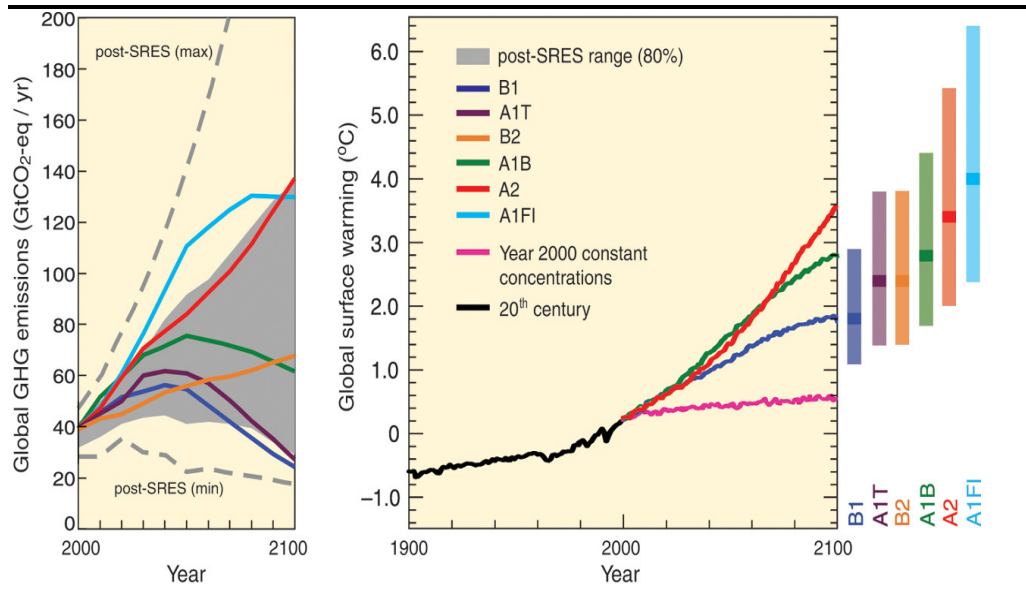
IPCC, 2007 ⁽²⁾

The projected impacts of each of these emissions scenarios on annual emissions of GHGs and the associated resulting temperature change are illustrated in *Figure 5.2*:

(1) IPCC, 2000 - Nebojsa Nakicenovic and Rob Swart (Eds.) IPCC Special Report on Emissions Scenarios, Cambridge University Press, UK

(2) IPCC, 2007: 'Summary for Policy Makers', Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, pp7

Figure 5.2 SRES Emissions Scenarios in Terms of CO₂ Emissions and Likely Future Global Average Annual Air Temperature Rises



IPCC, 2007 ⁽¹⁾

Because of time lags in the atmospheric system the climatic response to different emissions pathways does not diverge significantly until the 2040s, because most of the climate change that will occur between now and 2040 will be as a result of historic emissions which have already been released. This relative commonality until the 2040s, and the differences between emissions scenarios, can be seen in the modelling results section of this report in *Section 7*, where both the medium (A1B) and high (A1FI) emissions scenarios are illustrated.

This assessment relies on the precautionary principle and so both the medium (A1B) and the high (the A1FI) emissions scenarios have been used to develop characteristics for threshold and consequence analysis at Heathrow.

Considering two different emissions scenarios is in line with IPCC best practice guidance which recommends avoiding using a one scenario approach, or what it terms '*picking a winner*', as such an approach is insufficiently robust to counter the considerable uncertainty involved.

The central case used in this assessment is the 90th percentile of the medium emissions (A1B) scenario which was chosen to be consistent with the approach taken by the Mayor of London and Transport for London.

An upper bound of the 90th percentile of the high emissions scenario has also been considered for stress-testing purposes. In terms of expressing the upper and lower likely extremes of climate change, whilst A1FI is most representative of the existing SRES scenarios as a reasonable worst case scenario it should not be considered that

(1) IPCC, 2007: 'Summary for Policy Makers', Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, pp7

this represents the absolute upper case, as the science is rapidly progressing and absolute upper bounds cannot be stated with certainty.

The lower bound used for this analysis is the 10th percentile of the medium emissions scenario.

Box 5.1 Emissions Scenario Summary

For this report the 90th percentile of the medium emissions scenario has been selected as the central case as this represents for each climate variable a threshold that most models suggest is unlikely to be exceeded. This has been stress-tested with an upper bound of the 90th percentile of the high emissions scenario and a lower bound of the 10th percentile of the medium emissions scenario.

The choice of emissions scenarios used in this study is illustrated with an example for clarity in Table 5.2 with the central case shaded in grey, and the upper and lower sensitivities (10% medium emissions and 90% high emissions) for each time period shaded in yellow.

Table 5.2 Example of the Scenarios Used (Mean Annual Temp. (°C))

Likelihood	Medium Emissions		High Emission	
	Short Term 2020s	Medium / Longer Term 2040/50s	Short Term 2020s	Medium / Longer Term 2040/50s
10% (very unlikely to be less than)	0.778	1.264	0.804	1.46
50% (central estimate, equally likely to be above or below this amount)	1.434	2.122	1.441	2.304
90% (unlikely to be greater than)	2.164	3.129	2.152	3.307

Source: UKCP09

We can see that for this example the central case of change to mean annual air temperatures for the medium term (2040s) is a rise of around 3.1 °C, with an upper and lower bound (used for testing sensitivities) of between +1.3 to +3.3 °C by this date.

In line with the precautionary principle the risk assessment (see Chapter 9) will be carried out against the low, central and high scenarios. Where risks assessed differ depending on future climate scenario this will be identified.

5.8 METEOROLOGICAL VARIABLES

Climate change projections for the following meteorological variables have been extracted from the UKCP09 datasets ⁽¹⁾:

- mean air temperature;
- seasonal mean air temperature;
- temperature of the coolest day;
- temperature of the warmest day;

(1) <http://ukcp09.defra.gov.uk/>

- temperature of the coldest night;
- temperature of the warmest night;
- precipitation;
- precipitation on the wettest day;
- total cloud cover;
- relative humidity; and
- relative sea level rise (m).

Other climate variables, many of which are of significant interest to the aviation and airport operation sectors, were not able to be modelled in a probabilistic manner and included in the UKCP09 projections, largely due to issues of modelling complexity and the uncertainty associated with these variables. It is important that these key variables are considered because of their potential significance for Heathrow. To assist with this, alternative information sources have been consulted in line with the UKCIP technical guidance for the following additional meteorological variables:

- fog frequency (1);
- storm frequency and severity (with storm being defined here as low pressure storm systems as opposed to convective thunderstorm events) (2);
- surface wind speed (3) ;
- lightning (4); and
- snow (5).

Regrettably, other climate variables which may be of particular interest to airport operators, such as changes to wind direction (which could affect runway utilisation) and wind speed at altitude (which could affect the time aircraft take to fly sectors), are not currently encapsulated within the UKCP suite of climate projections and the GCMs (Global Climate Models / General Circulation Models) on which UKCP is based, due to inherent methodological difficulties in modelling and projecting these complex characteristics.

(1) UKCP09 Additional Product: Future changes in fog frequency from the UKCP09 ensemble of regional climate model projections
http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_fog_technote.pdf

(2) UKCP09 Technical Note: Storm Projections
http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_Storm_technote.pdf

(3) UKCP09 Technical Documentation: Interpretation for use of surface wind speed projections from the 11-member Met Office Regional Climate Model ensemble
http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_wind_technote.pdf and Supplement to: Interpretation for use of surface wind speed projections from the 11-member Met Office Regional Climate Model ensemble
http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_wind_technote_supplement.pdf

(4) UKCP09 Technical Note: Future changes in lightning from the UKCP09 ensemble of regional climate model projections
http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_Lightning_technote.pdf

(5) UKCP09 Technical Note: Interpretation and use of future snow projections from the 11-member Met Office Regional Climate Model ensemble
http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/ukcp09_snow_technote.pdf

6 ASSUMPTIONS AND UNCERTAINTIES

6.1 INTRODUCTION

This chapter describes the key sources of uncertainty relating to the climate change science and modelling. It also describes how these uncertainties have been treated by the methodology, and details the assumptions that have been made in the course of this study.

6.2 SOURCES OF UNCERTAINTY

6.2.1 *Scientific Uncertainty*

The assessment completed and presented within this report has been undertaken with the latest probabilistic climate models. Climate change science, however, is a field that is rapidly advancing, as modelling techniques, the datasets of observed change and the scientific understanding of the complexity of the climate system all improve.

A level of uncertainty will always be inevitable as the degree of future climate change will be determined by factors which are yet to be realised, including future emissions and population levels. Thus no climate change projection should be seen as a prediction, and the modeling referred to in this report should be considered to be the best available evidence at this time.

Sources of uncertainty which may affect the validity of climate projections are highlighted below:

- A key area of uncertainty relates to the scale and rate of climate change and the ability of policy documents and consensus agreements (such as the negotiations at Copenhagen and Cancun) to be informed by the latest science. Much new research has emerged since the findings of the IPCC's Fourth Assessment Report (on which much of the UKCP09 modelling is based, some of which changes our understanding of climate change.
- There is a lack of understanding of positive feedback effects in the climate system. Many of the complex interactions between the biosphere, cryosphere, hydrosphere and atmosphere have not been possible to quantify or translate meaningfully into GCMs. Without adequate incorporation of positive feedback mechanisms into climate models it is possible that the timescale for changes may be considerably less the modelling suggests.
- There are limitations relating to climate models and computing power. Climate models are not able to reproduce the full complexities of the real climate system due to limitations in scientific understanding, modelling techniques, availability of data, and computer processing power.
- There are limitations and uncertainties imposed by the manner in which probability is treated in climate change models.

6.2.2 *Uncertainties relating to Heathrow and the Aviation Industry*

There are also uncertainties with regard to the future development and role of Heathrow, the regulatory environment surrounding airport operation and the future evolution of the wider aviation industry.

6.2.3 *Uncertainties regarding Critical Thresholds*

Assets at Heathrow stem from different time periods and are subject to different levels of knowledge on their technical specification and consequently the thresholds at which climate change will become critical. Where improved understanding is judged important this has been identified.

6.3 RESPONDING TO UNCERTAINTY

To counter the sources of uncertainty described in the proceeding sections, this study has employed a number of methodological approaches to help manage this uncertainty. These are presented in the following paragraphs:

6.3.1 *Use of the Best Available Climate Projections*

The use of the UKCP09 projections which represent the best available modelling and projection data in itself makes the uncertainties clearer, providing as they do a range of potential outcomes, together with their associated probability based on evidence and expert judgement. To create UKCP09, a total of 31 model parameters were varied to provide around 300 model versions, creating a large ensemble of projections of future global climate.

The UKCP09 projections do not have an objective probability, but rather provide results with a subjective probability attached, i.e. they provide an estimate based on the available information and strength of evidence (similar to horse-racing odds). This approach does not inherently reduce uncertainty; it does, however, make the uncertainty attached to projections more transparent.

The methods used to create UKCP09 have been reviewed by scientific experts and judged to be credible and to represent best practice in climate modelling.

6.3.2 *Consideration of Reasonable Worst Case Scenarios*

To respond to the uncertainty regarding the pace and scale of climate change it has been important to make the precautionary principle central to this assessment. Therefore the emissions scenarios and probability percentiles selected for the study represent for each climate variable a threshold that most current models suggest is unlikely to be exceeded i.e. a reasonable worst case, based on the science available today.

6.3.3 Consideration of the Likely Timescales for Change

For each risk the approximate time period (i.e. short or medium / longer term in line with the UKCP09 modelling periods described in *Chapter 5*) when they may occur, and / or become important for Heathrow has been presented where there is sufficient detail or certainty in the data to allow assessment in this way. Changes to the consequence and likelihood of a given climate risk have also been presented i.e. for many risks there is a small likelihood and consequence of their occurring in the short term but their likelihood and / or consequence is likely to increase in the future without the instigation of additional control measures.

The time periods associated with each climate change risk should be considered as based upon the best available evidence today rather than absolute predictions as to when an impact could become problematic for HAL, and the likelihood and consequences of any climate change risk occurring should be subject to revision as the scientific understanding, or events on the ground, progress.

6.3.4 Risk Review

Because of the incremental and cumulative nature of climate change it is important that a watching brief is kept with regard to risks identified for the medium to long term and if evidence – either from events on the ground or from the latest science, suggests that a risk is inappropriately defined - that it is revisited.

6.3.5 Confidence ratings

The risks identified as part of this assessment have also been given a confidence rating based upon scientific consensus and understanding of the processes involved. This will help to inform the need for future research.

6.4 ASSUMPTIONS

The following assumptions have been made through this assessment:

- UKCP09 projections are an accurate representation of the climate change impacts which will occur;
- risks to the supply of key services upon which Heathrow relies, i.e. electricity, gas, water will be adequately managed by the authorities and organisations responsible for their supply;
- aviation infrastructure and technology continues to operate fundamentally in the same way as envisaged today;
- third party organisations, whose business affects HAL's activities and resilience continue to operate in the same manner and at the same performance standards that they do today;
- passenger and cargo requirements for air transportation will continue to develop in line with HAL and CAA forecasts, and that UK population levels develop in line with Government forecasting; and

- Heathrow's current business and development plans are assumed to be acceptable to the Regulators and Government.

7 CLIMATE CHANGE PROJECTIONS FOR HEATHROW

7.1 INTRODUCTION

This chapter summarises the climate change projections extracted from UKCP09 for Heathrow for a range of climate variables.

Full technical results of the climate modelling illustrating the range of likely impacts associated with different emissions scenarios and different probability percentiles are presented in *Annex B* of this document. The implications of these changes for Heathrow Airport are discussed in the results of risk assessment presented in *Section 9* of this document.

7.2 UKCP09 RESULTS

The central case used for this assessment (the 90th percentile of the medium emissions scenario) is indicated by the figures in the tables without parentheses. Figures in parentheses represent the range of results projected from a lower bound (the 10th percentile of the medium emissions scenario), to an upper bound (the 90th percentile of the high emissions scenario). The projections are presented alongside baseline conditions, and a reasonable worst case (RWC) of the likely absolute future values for each variable is given in bold text. Where uncertainty regarding the direction of change of a variable arises from the models (i.e. some model ensembles suggest that summer rainfall may increase, other suggest a decrease), then both extremes are presented in bold text as the RWC.

7.2.1 Temperature Change

Box 7.1 Temperature Change Summary

Temperatures are projected to rise in all seasons over the coming century, with the most extreme changes witnessed in the longer term, and most observable in the summer and autumn months. Summer extremes including temperatures on the hottest day rising into the 40°C s is likely to be increasingly challenging for existing infrastructure, building stock and vulnerable population groups. Freezing temperatures are projected to become less likely in the winter but due to large scale phenomena such as the Arctic Oscillation (whose relationship to climate change is unclear) cannot be ruled out even by the longer term.

Table 7.1 UKCP09 Modelling Results for Temperature Variables at Heathrow

	Baseline Conditions	Short Term 2020s	Medium / Longer Term 2040/50s
Change to Mean Annual Temperature (°C)	10.19	+ 2.16 (0.78 to 2.15) 12.35	+ 3.13 (1.26 to 3.31) 13.5
Change in Mean Daily Maximum Temperature (°C) Spring	13.15	+ 2.19 (0.54 to 2.25) 15.4	+ 3.16 (0.93 to 3.46) 16.61
Change in Mean Daily Maximum Temperature (°C) Summer	21.19	+ 3.53 (0.57 to 3.47) 24.72	+ 5.19 (0.96 to 5.47) 26.66
Change in Mean Daily Maximum Temperature (°C) Autumn	14.68	+ 2.25 (0.33 to 2.32) 17	+ 3.18 (0.58 to 3.29) 17.97
Change in Mean Daily Maximum Temperature (°C) Winter	7.28	+ 2.24 (0.46 to 2.26) 9.54	+ 3.15 (0.67 to 3.36) 10.64
Change in Temperature of the Warmest Summer Day (°C)	37.9	+ 4.63 (-2.07 to + 5.03) 42.93	+ 6.51 (-1.73 to + 7.28) 45.18
Change in Temperature of the Warmest Summer Night (°C)	29.5	+ 3.10 (-0.79 to + 2.97) 32.6	+ 4.15 (-0.05 to + 4.36) 33.86
Change in Temperature of the Coldest Winter Day (°C)	-5	+ 3.20 (-0.44 to + 3.03) -1.8	+ 3.53 (-0.13 to + 3.85) -1.15
Change in Temperature of the Coldest Winter Night (°C)	-13	+ 3.52 (0.13 to 3.55) -9.48	+ 4.33 (0.72 to 4.62) -8.38

All outputs from UKCP09 have been rounded to two decimal places.

The results above show that warming is projected to occur in all seasons and across the diurnal cycle as a result of climate change. In the short term the changes are likely to be most pronounced in the summer and autumn months. By the 2040s mean summer temperatures are likely to be in the mid to upper 20 °Cs.

Extremes are likely to see significant change with for example the temperature experienced on the hottest summer day likely (according to the central estimate) to rise by some 6.51 °C (upper bound of +7.28 °C) by the 2040s. By the 2020s the temperature on the hottest summer day could exceed 40 °C and night-time temperatures in the mid 30 °Cs may be witnessed. This represents a significant change from today's conditions, where the highest day time temperature recorded at Heathrow was 37.9 °C, and the hottest summer night-time temperature observed to date is 29.5 °C. Put another way, the extraordinary summer heat wave of 2003 will be considered normal by the 2040s.

Conversely in the winter months, temperatures below freezing are likely to become increasingly infrequent at Heathrow, but given the greater inter-annual variability likely to result from climate change, and uncertainty as to how climate change may interact with large scale climatic phenomena such as the Jet Stream and Arctic Oscillation; cold

winters such as that experienced in 2010-11 can not be ruled out, even by the latter half of the century. Further consideration of winter conditions and the likelihood of snow at Heathrow in the future are given in *Section 7.3.2* of this chapter.

7.2.2 Precipitation Changes

Box 7.2 Precipitation Change Summary

There is greater uncertainty regarding projected changes to rainfall. One of the features of climate change is likely to be significant year to year variations in rainfall and difficulty in predicting seasonal precipitation, thus wash-out summers could alternate with summers dominated by drought. Overall a modest annual increase is projected, with significant shifts toward considerably more winter rainfall and drier summers. What rain does fall is increasingly likely to fall in torrential downpour.

Table 7.2 UKCP09 Modelling Results for Precipitation Variables at Heathrow

	Baseline Conditions	Short Term 2020s	Med./Longer Term 2040/50s
Change in Annual Precipitation (%)	603.2mm	+ 5.02 (-4.41 to + 5.31) 576.59 to 635.23mm	+ 4.98 (-4.34 to + 5.69) 577.02 to 637.52mm
Change in Seasonal Precipitation (%) Spring	135.9mm	+ 8.94 (-6.89 to + 9.05) 126.54 to 148.2mm	+ 7.86 (-7.39 to + 9.13) 125.86 to 148.31mm
Change in Seasonal Precipitation (%) Summer	142.3mm	- 14.67 (-26.35 to -4.46) 104.80 to 135.95mm	- 12.09 (-34.54 to -12.9) 93.15 to 125.1mm
Change in Seasonal Precipitation (%) Autumn	176.8mm	+ 11.81 (-8.10 to + 14.43) 162.48 to 202.31mm	+ 12.49 (-7.19 to + 14.53) 164.09 to 202.5mm
Change in Seasonal Precipitation (%) Winter	148.4mm	+ 17.54 (-4.31 to + 17.83) 142 to 174.86mm	+ 26.60 (0.55 to 27.96) 149.22 to 189.89mm
Change in Precipitation on the Wettest Summer Day (%)	100mm	+ 24.83 (- 20.77 to + 24.26) 79.23 to 124.86mm	+ 22.06 (-26.03 to + 22.9) 73.97 to 122.9mm
Change in Precipitation on the Wettest Winter Day (%)	n/a	+ 21.09 (-8.29 to + 22.21)	+ 29.01 (-4.95 to + 31.34)

The confidence attached by climatologists to precipitation projections is lower than that for temperature variables and hence the wider range of potential values for precipitation in the future as a result of climate change.

Heathrow is projected to experience a relatively modest increase in annual precipitation (of the order of 5%) in the future. However, this modest annual increase masks significant seasonal shifts in rainfall patterns. UKCP09 projects that by the 2040s winter rainfall could increase by 26.6% (from 148 mm today to 190 mm), and summer rainfall could according to the lower bound, decrease by up to 34.5% (from 142 mm today to 93 mm) within the same time period.

There is also likely to be greater inter-annual variability and lack of predictability (in terms of annual and seasonal rainfall bearing resemblance to past patterns), with what rain does fall being more likely to occur in torrential precipitation episodes. Perhaps the most significant change projected for rainfall relates to changes to precipitation on the wettest winter day which could increase by 29% (+ 31% according to the upper bound) by the 2040s.

7.2.3 Changes to Other Meteorological Variables

Box 7.3 Cloud Cover and Relative Humidity Changes Summary

There is significant uncertainty related to projected changes to cloud cover and relative humidity, not least because many climate change models have difficulty in expressing changes to water vapour content in the atmosphere. Changes to cloud cover and relative humidity are projected in all ensemble runs and emission scenarios to be modest (i.e. <5% change over current conditions).

Table 7.3 UKCP09 Modelling Results for Other Variables at Heathrow

	Baseline Conditions	Short Term 2020s	Med / Longer Term 2040/50s
Change in Total Cloud Cover (%) Annual	n/a	+ 0.62 (-5.64 to + 0.89)	- 0.37 (-7.76 to + 0.18)
Change in Total Cloud Cover (%) Summer	n/a	+ 3.31 (-13.92 to + 4.55)	+ 2.57 (-17.88 to + 2.78)
Change in Total Cloud Cover (%) Winter	n/a	+ 2.59 (-1.89 to + 2.69)	+ 2.81 (-2.29 to + 3.29)
Change in Relative Humidity (%) Summer	n/a	+ 1.99 (-8.88 to + 3.24)	+ 1.93 (-11.62 to + 1.60)
Change in Relative Humidity (%) Winter	n/a	+ 0.56 (-0.77 to + 0.58)	+ 0.68 (-0.99 to + 0.70)

It is difficult to model changes to cloud cover and relative humidity due to considerable uncertainties in how best to translate these phenomena into algorithms that can be used with climate models. Generally cloud cover is expected to reduce on an annual basis and this trend is likely to be most discernable during the summer. In the winter small increases in cloud cover may occur. Relative humidity is likely to increase under the central estimate for both summer and winter. The upper and lower bounds suggest that the moisture content of the air in the summer may become drier. Changes to relative humidity and cloud cover at Heathrow are projected therefore to be modest.

7.3 RESULTS FROM UKCP09 ADDITIONAL TECHNICAL PRODUCTS

It was not possible for UKCP09 to include probabilistic projections for all climate variables of potential interest to users, for a variety of reasons often related to modelling constraints. Therefore, a further set of technical reports was produced to summarise the best presently available advice that can be given for several additional variables specifically; wind speed, fog, lightning and snow. In all cases, the advice is based on an ensemble of 11 RCM (Regional Climate Model) projections run for the medium emission scenario at 25 km resolution, forming part of the wider suite of simulations carried out for UKCP09.

No RCM modelling was undertaken by UKCP09 for any of these variables using the low or high emissions scenarios.

Furthermore for these additional technical reports, interim projections for the early and middle periods of the coming century were not produced; all data in the following projections refers to the 2080s – a period beyond the scope of this present assessment which considers the medium / longer term up to the 2050s. Nevertheless these long term projections have been considered within this assessment as the best available evidence for these climatic variables despite this temporal difference. This is consistent with the precautionary principle, although it should be noted that the changes projected for the 2080s may not occur in the 2040s/50s.

The projections for these variables from the supplementary UKCP09 technical reports are discussed in the following sections.

7.3.1 Changes to Visibility and Fog

Box 7.4 Fog Changes Summary

There is significant uncertainty related to projected changes to fog frequency, not least because many climate change models have difficulty in expressing changes to water vapour content in the atmosphere. The UKCP09 projections suggest that fog frequency is likely to dramatically decrease in percentage terms in the spring, summer and autumn months by 2080 and there will be a reduction in the annual number of fog days. In relative terms this represents a modest reduction in fog days of 2-3 days over the year from a baseline of 11 days, so any changes are unlikely to be particularly significant. Increases in fog frequency are projected for the winter months for Heathrow in the order of 20% (or one extra foggy day) over current conditions.

Table 7.4 UKCP09 Results for Fog Variables at Heathrow

	Baseline Conditions	Long Term Projection (2080)
Change in Number of Fog Days (%) Annual	11	- 19 8.91 days
Change in Number of Fog Days (%) Spring	1	- 38 0.62 days
Change in Number of Fog Days (%) Summer	0.3	- 67 0.1 days
Change in Number of Fog Days (%) Autumn	4.7	- 28 3.4 days
Change in Number of Fog Days (%) Winter	5	+ 20 6 days

Note that fog frequency data are not available from UKCP09 for earlier periods or in a probabilistic format, thus upper and lower bounds are not presented. The long term projection is therefore worst case in the context of risks assessed by this study out to 2040/50

Fog occurrence presents considerable difficulty from a climate modelling perspective. The approach taken by UKCP09 ⁽¹⁾ has some limitations including an inability to replicate past fog observations accurately. UKCIP notes that while the evaluation of past performance in simulating fog is an important check, it should not be assumed either that a reasonable historical simulation guarantees a credible projection of future changes, or that the presence of biases in the historical simulations (provided they are not too large) precludes the possibility of obtaining credible future projections. UKCP09 uses a visibility threshold of 1000 m as an indicator of the presence of fog which is greater than the <600m used by HAL to define low visibility.

In winter, when fog days are most numerous (both today and in the projected future), an increase of 20% is projected for the Heathrow site. Heathrow today experiences, on average, 5 days of foggy weather during the winter months and this is projected to increase to 6 days in a typical 2080s winter. In spring, reductions in fog frequency are postulated to be approximately -38% over current conditions. At present Heathrow experiences an average of 1 foggy day in the spring so this would be a reduction of less than half a day of fog conditions.

In summer, large reductions in fog frequency are projected in most parts of England, and are likely to approach nearly -70% for Heathrow. Heathrow doesn't experience much foggy weather in the summer time today (less than a third of a day in a typical summer) so this reduction represents a big change to a small baseline value. It is important to note that this change relates to fog only, and that due to increasing temperatures, and dependant on the future energy mix – haze could become more common in the 2080s during warm conditions. Unfortunately the frequency of haze has not been able to be modelled by UKCP09. In autumn, projected reductions in fog frequency over most of the UK are generally -10 to -30% for the 2080s compared to today. Heathrow today is most fog-prone in the late autumn and winter months and this projection would suggest a

(1) UKCP09 Additional Product: Future changes in fog frequency from the UKCP09 ensemble of regional climate model projections http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_fog_technote.pdf

decrease in foggy days from 4.7 days in a typical autumn today to 3.4 days by the 2080s.

7.3.2 Changes to Snow

Box 7.5 Snow Changes Summary

Based on the temperature changes projected for the winter months by UKCP09, the number of days with snow falling and lying on the ground is likely to decrease significantly in the long term (2080s); however there is considerable uncertainty relating to snow fall projections. Increased inter-annual variability means that even by the 2080s snowfall is still possible for Heathrow. Climate change models are not able to incorporate some large scale 'chaotic' climatic phenomena i.e. the Jet Stream and Arctic Oscillation which have a significant bearing on UK snowfall and thus there is the potential that in a warming world, changes to the position of these features could result in increased days of snowfall, and even potentially increases in the rate of snowfall compared to today. Considerable research effort is ongoing in this area.

Table 7.5 UKCP09 Results for Snow Variables at Heathrow

	Baseline Conditions	Long Term Projection (2080s)
Change in Number of Days with Snow Falling (%) Spring	4	- 80 0.8 days
Change in Number of Days with Snow Falling (%) Autumn	0.7	n/a n/a
Change in Number of Days with Snow Falling (%) Winter	10.3	- 70 3.09 days
Change in Heavy Snow Events (90 th percentile of snowfall rate) (%) Annual	n/a	- 80 (+ 30) n/a
Change in Heavy Snow Events (90 th percentile of snowfall rate) (%) Spring	n/a	- 80 n/a
Change in Heavy Snow Events (90 th percentile of snowfall rate) (%) Autumn	n/a	n/a n/a
Change in Heavy Snow Events (90 th percentile of snowfall rate) (%) Winter	n/a	- 60 n/a

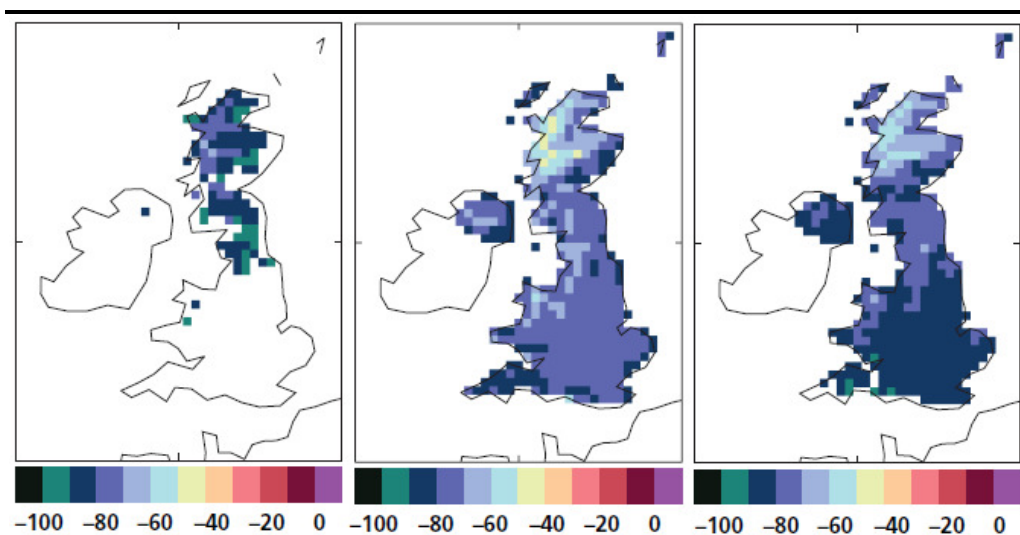
Note that snow frequency data are not available from UKCP09 for earlier periods or in a probabilistic format, thus upper and lower bounds are not presented. The long term projection is therefore worst case in the context of risks assessed by this study out to 2040/50.

Probabilistic projections of future changes in snow were not provided in UKCP09, due to the low confidence in the statistical methodology which produced unrealistically large uncertainties for this variable at the highest percentiles. However, daily values of snowfall occurrence are available from the ensemble of 11 Met Office regional climate model (RCM) variants for the period 1950–2099 using the medium emissions scenario.

Projections of future change in days of falling snow show large reductions that are largest in the south of England and least for western Scotland, with ensemble mean winter changes of -85% and -55% using a threshold of 0.02 mm/day to define days with snow. The individual ensemble members show variations in the magnitude of the projected change, but confirm the robustness of the sign of the change. The projections of reduced snowfall are consistent with the influence of warming temperatures but do not include all factors which could influence future snowfall.

Significant reductions in the number of days with snow are also seen in other seasons, for all regions. The largest reductions occur in spring and autumn, typically $>70\%$, with values of -40 to -70% occurring in winter. Compared to analogue conditions, this would mean days with snow would fall from the 4 days snow conditions currently experienced during the spring months at Heathrow, to 0.8 days by the 2080s. In the winter the reduction is likely to decrease from just over 10 days in the current typical Heathrow winter, down to just over 3 days in the average 2080s winter. The mean ensemble results for changes to snowfall in autumn, winter, and spring for the 2080s are illustrated below:

Figure 7.1 Changes in number of days with snow falling (%) by Season for 2070–2099 relative to 1961–1990, Ensemble Mean for the 11 individual RCM projections



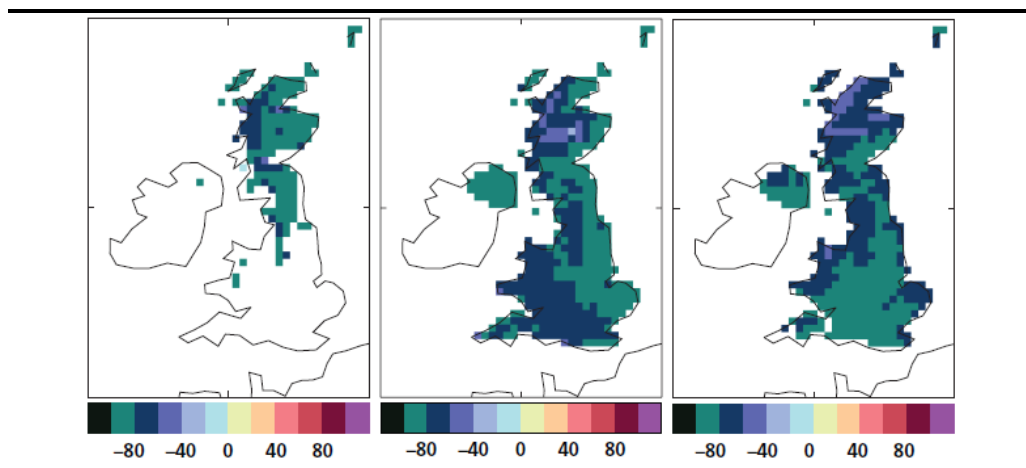
From left to right: Autumn, Winter, and Spring. Source: UKCP09 Technical Note: Interpretation and use of future snow projections from the 11-member Met Office Regional Climate Model ensemble

* Points with fewer than 4 observed days with snow per year are masked out in white.

For Heathrow, UKCP09 modelling suggests that by the 2080s the number of winter days experiencing snowfall could reduce by -70% , and the number of spring days (March, April, May) with snowfall could reduce by -80% . Modelling was not undertaken for the autumn period as Heathrow has historically experienced less than 4 days of snowfall in the months of September, October and November on a typical year and this baseline figure was too small to model without high uncertainty.

Changes in the 90th percentile of winter snowfall rate, a measure of heavy snow events, are illustrated in *Figure 7.2* and suggest reductions of greater than 80% for most of the UK. For Heathrow, this suggests a reduction in heavy snow events of -60% in the winter months, and of up to -80% in the spring. However, one ensemble member does not follow this pattern and predicts reductions for England and Scotland of generally -30% or more but increases for small regions including southern England of circa 30%. These results suggest that although in general there is a reduced likelihood of snowfall and of reduced snowfall rate, large snowfall events with a potentially increased rate of snowfall in the future cannot be excluded.

Figure 7.2 Percentage changes in the 90th percentile of snow fall rate by Season 2070–2099 relative to 1961–1990, Ensemble Mean



From left to right: Autumn, Winter, and Spring. Source: UKCP09 Technical Note: Interpretation and use of future snow projections from the 11-member Met Office Regional Climate Model ensemble

* Points with fewer than 4 observed days with snow per year are masked out.

For most of the 1990s and 2000s winters in the south of England were relatively mild and largely without snowfall. The winters from 2009 to present have however experienced significant periods of very cold weather and substantial snowfall. Climate change projections of future snowfall are subject to considerable uncertainties and there are a number of climatic features which are as yet unable to be included within climate models including the behaviour of large scale atmospheric systems such as the Jet Stream which could have a significant influence on future snowfall and lead to a more complicated picture than that presented by UKCP09.

The UK's winter weather is strongly determined by the North Atlantic Oscillation (NAO) which is a 'seesaw' of atmospheric pressure difference above the North Atlantic Ocean between the Icelandic Low and the Azores high. The NAO index swings from broadly positive (i.e. a big difference in air pressure between the Arctic and mid-latitudes, which results in milder than average winters in the UK) to negative values (i.e. a small difference in air pressure, which tends to result in colder than average winters for the UK), on a time scale of a few decades. The last period of strong negatives was in 1955 - 1970 whereas the years from 1980 - 2000 were dominated by strongly positive values. For the last two winters the NAO has been negative. It is possible, that the pronounced warming recently observed in Arctic waters may be a causal factor in this change.

Whilst the latest technical guidance from UKCP09 on the issue of snowfall is that snowy winters will become less frequent, it should be noted that climate models are not able to model blocking anticyclones and the NAO which may have an influence on future snowfall. Recent work by the Met Office which attempted to incorporate such uncertainties, suggests that climate change could lead to an increased risk of snow, sleet, blizzards, ice and freezing fog ⁽¹⁾ potentially related to changes in atmospheric circulation patterns and the 4% increase in water vapour in the atmosphere⁽²⁾. The DfT's Chief Scientific Advisor has also recently noted:

There is a general trend for the mean atmospheric temperature across the planet to increase. But whilst this is happening local conditions may well produce perverse weather events. ⁽³⁾

In line with the precautionary principle and in the light of the considerable disruption caused by snowfall, this report has assumed that the future climate may have a potentially increased risk of snow and wintry conditions although as illustrated in this section, the science behind this is far from certain.

7.3.3 Changes to Storm Frequency and Severity

Box 7.6 Storm Changes Summary

There is considerable uncertainty in projecting changes to storm frequency and severity, and at present quantitative projections are not available. Despite some evidence that (low pressure system) storm's may become less frequent and / or severe in the South East of England as a result of climate change, in line with the precautionary principle an increase in both frequency and severity due to more energy in the atmospheric system, has been assumed for this assessment.

Table 7.6 UKCP09 Results for Storm Variables at Heathrow

	Baseline Conditions	Long Term Projection (2080s)
Change in Storm Frequency and Severity	n/a	Increase

Note that storm frequency data are not available from UKCP09 for earlier periods or in a probabilistic format, thus upper and lower bounds are not presented. The long term projection is therefore worst case in the context of risks assessed by this study out to 2040/50.

UKCP09 defines storms as depressions /low pressure areas and the term 'storm' should not be confused in this instance with convective events and thunderstorms which are different and unrelated phenomena.

There is no convincing evidence within the UKCP09 projections of a significant increase in the frequency or intensity of storms in the UK.

(1) Met Office, 2010, Risk Assessment on Future Network Resilience

(2) UKCP09 Technical Note: Interpretation and use of future snow projections from the 11-member Met Office Regional Climate Model ensemble http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/ukcp09_snow_technote.pdf

(3) Heathrow Winter Resilience Enquiry, March 2011

Modelling carried out by the Met Office using the medium emissions scenario suggests that the simulated future changes in storms, and their impact on mean climate conditions, are rather modest ⁽¹⁾. Subtle shifts in the position of the North Atlantic storm track are possible, but are inconsistent between different models and different model variants. The frequency and strength of storms remain relatively unchanged in the future simulations, as does the frequency and strength of blocking events ⁽²⁾. Model projections considered within the IPCC AR4 assessment suggest a general tendency for more intense but fewer mid-latitude storms, associated with a pole-ward shift of the storm tracks. The pole-ward shift was also reported within the recent ENSEMBLES project as was the increased intensity of the most intense storms ⁽³⁾.

There is considerable uncertainty related to projecting future storm frequency, severity and storm tracks, UKCP09 notes that *'the IPCC AR4 assessment concluded that the majority of current climate models show a pole-ward shift of the storm tracks, with some indication of fewer, but deeper, depressions. This can only be concluded when looking at the hemispheric scale; the UK is very much smaller than this scale and any climate change signal is swamped by natural variability and sampling uncertainty resulting in a lack of any robust signal of changes for the UK.'*

In line with the precautionary principle, this report has assumed that the future climate may have an increased risk of storm conditions in both frequency and severity, although, as illustrated in this section, the science behind this is far from certain.

7.3.4 Changes to Surface Wind Speed and Prevailing Wind Direction

Box 7.7 Wind Changes Summary

There is considerable uncertainty in projecting changes to wind speed and direction. Quantitative modelling of changes to wind direction are not available from UKCP09 and this represents a significant source of uncertainty for airports because of the importance of aligning runways in accordance with the prevailing wind. In terms of wind speeds, a general calming of surface wind speeds (in the order of 5%) has been projected for all seasons.

(1) Annex 6 of the UKCP09 Projections report, 'Future changes in storms and anticyclones affecting the UK'

(2) UKCP09 Technical Note: Storm Projections

http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_Storm_technote.pdf

(3) U. Ulbrich, G. C. Leckebusch and J. G. Pinto (2009) Extra-tropical cyclones in the present and future climate: a review Theoretical and Applied Climatology Volume 96, Numbers 1-2 / April, 2009 DOI 10.1007/s00704-008-0083-8 Pages 117-131

Table 7.7 UKCP09 Results for Wind Speed Variables at Heathrow

	Baseline Conditions	Longer Term 2080s
Change to Surface Wind Speed (%) Spring	7 kt (knots)	-4 6.72kt
Change to Surface Wind Speed (%) Summer	6.4 kt	-2 6.27 kt
Change to Surface Wind Speed (%) Autumn	6.3 kt	-3 6.11 kt
Change to Surface Wind Speed (%) Winter	7.3 kt	-2 7.15 kt

Note that wind speed frequency data are not available from UKCP09 for earlier periods or in a probabilistic format, thus upper and lower bounds are not presented. The long term projection is therefore worst case in the context of risks assessed by this study out to 2040/50.

Probabilistic projections of future changes in surface wind speed (defined by meteorologists as wind speed at a standard observing height of 10 metres above the ground surface) were not provided in UKCP09, due to lack of suitable multi-model climate data. However, daily values of surface wind speed are available at 25 km resolution from the ensemble of 11 Met Office regional climate model (RCM) variants run for UKCP09. This ensemble was run driven by the UKCP09 medium emissions scenario only (1).

Changes to Wind Direction

Changes to the direction of prevailing winds are not able to be modelled with any significant confidence, and this represents an important 'unknown' for airports such as Heathrow because of the requirement for runways to be aligned to the prevailing wind.

7.3.5 Changes to Lightning

Box 7.8 Lightning Changes Summary

There is considerable uncertainty and low confidence attached to projecting changes to lightning frequency in the future. UKCP09 suggests that lightning may become more frequent across the year at Heathrow in the future. The greatest increase in lightning frequency is projected to occur in the autumn.

(1) Interpretation for use of surface wind speed projections from the 11-member Met Office Regional Climate Model ensemble http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_wind_technote.pdf and Supplement

Table 7.8 UKCP09 Results for Lightning Variables at Heathrow

	Baseline Conditions	Long Term 2080s
Change in Number of Lightning Days (%) Spring	4 days	+ 50 6 days
Change in Number of Lightning Days (%) Summer	>6 days	+ 50 9 days
Change in Number of Lightning Days (%) Autumn	3 days	+ 200 6 days
Change in Number of Lightning Days (%) Winter	<1 day	n/a n/a

Note that lightning frequency data are not available from UKCP09 for earlier periods or in a probabilistic format, thus upper and lower bounds are not presented. The long term projection is therefore worst case in the context of risks assessed by this study out to 2040/50.

Limited research has been reported on changes to the frequency of lightning resulting from future climate change. Some studies have projected an increase in global lightning activity of about 30%, with indications of an increase in annual mean lightning frequencies over the UK, for an experiment in which the atmospheric concentration of carbon dioxide was doubled (1) .

The UKCIP02 projections for the medium-high emissions scenario commented that the number of lightning strikes over England was expected to remain about the same (increases in the peak lightning flash rate per convective event being balanced by reductions in the expected number of thunderstorms) (2) .

UKCP09 was not able to produce probabilistic projections for lightning due to uncertainties in modelling a variable with a scarce and in some instances difficult to document, baseline. However, daily values of lightning occurrence are available at 25 km resolution from the ensemble of 11 Met Office regional climate model (RCM) variants run for UKCP09. This ensemble was run for the period 1950–2099 using the medium emissions scenario.

(1) Price, C. & Rind, D. 1994. Possible implications of global climate change on global lightning distributions and frequencies. Journal of Geophysical Research 99(D5)10823–10831

(2) Hulme, M., Jenkins, G. J., Lu, X., Turnpenny, J. R., Mitchell, T. D., Jones, R. G., Lowe, J. A., Murphy, J. M., Hassell, D., Boorman, P. Macdonald, R. & Hill, S. 2002. Climate change scenarios for the United Kingdom: The UKCIP02 Scientific Report. Tyndall Centre for Climate Change Research, UEA, Norwich, UK

7.3.6 Changes to Sea Levels

Box 7.9 Sea Level Rise Summary

There is considerable uncertainty attached to projecting future SLR. The latest body of scientific evidence would suggest that SLR in the order of 1m would be more likely, and the reasonable worst case would push this figure up to 1.9m. Heathrow's altitude above sea level is 25m AOD, so even the RWC would not directly affect the airport although it would alter local drainage conditions, groundwater levels and could impact upon infrastructure in London and coastal areas which are important to the airport.

Table 7.9 UKCP09 Results for Sea Level Rise for the South East of England

	Baseline Conditions	Long Term 2080s
Change in Relative Sea Level Rise (metres)	25m AOD	+0.16 to 1.9 ⁽¹⁾

This study has used a worst case of 1.9m SLR

The sea level rise (SLR) projections included in UKCP09 are based on research summarised in the IPCC's AR4 (4th Assessment Report) (2). The science regarding SLR has progressed very rapidly since the AR4 was published in 2007, and the projections given in the AR4 were caveated at the time of publication as being incomplete because contributions to SLR from loss of terrestrial polar ice sheets were excluded. Sea levels could rise substantially more and faster than predicted in the AR4, according to the latest scientific research published in the intervening years. The IPCC's forecast of an average rise in global sea levels of 28-43cm by 2100 is now widely viewed to be too conservative as it is based on multiple models that all exclude ice sheet flow due to a (then) lack of published literature. Sea level rose at an average rate of about 1.8 mm/year during the years 1961-2003. The rise in sea level during 1993-2003 was at an average rate of 3.1 mm/year. The IPCC was unable to explain this acceleration in sea level rise (SLR). Most SLR projections focus on a more distant date (typically 2100) than that used in this study for the medium / longer term. It is not possible to interpolate these projections back on a linear basis to the end date of this present study (2040s/50s) as the change to ice caps in the Polar regions is expected to be non-linear. Some of the ranges of likely SLR from more recent research which attempt to quantify the contribution from polar ice sheet dynamics are illustrated, alongside the AR4 projections in the table below:

(1) Hansen, J. and M. Sato, 2011, Paleoclimate Implications for Human-Made Climate Change http://www.columbia.edu/~jeh1/mailings/2011/20110118_MilankovicPaper.pdf

(2) IPCC, 2007: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. M.L Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds, Cambridge University Press, Cambridge, UK, 976pp

Table 7.10 IPCC and Alternative SLR Projections

SLR Projection Range	Reference
260mm to 590mm (2100)	IPCC, 2007 Fourth Assessment Report (AR4)
800mm to 1,500mm (2100)	Jevrejeva, S., A. Grinsted, J. C. Moore and S. Holgate (2006): Nonlinear trends and multi-year cycle in sea level records, <i>Journal of Geophysical Research</i> , 111, 2005JC003229. Presented at European Geosciences Union Annual Meeting in 2008 ⁽¹⁾
500mm to 1,400mm above 1990 levels (2100)	Rahmstorf, S., A. Cazenave, J.A. Church, J.E. Hansen , R.F. Keeling , D.E. Parker , R.C. J. Somerville (2007) Recent Climate Observations Compared to Projections. <i>Science</i> DOI: 10.1126/science.1136843. February 1, 2007.
500mm above 1990 levels (2100) ⁽²⁾ 1420mm (2200) 7300mm (3000)	Institution of Mechanical Engineers, <i>Climate Change Adapting to the Inevitable?</i> , IMechE, London, UK, February 2009 using GENIE-1 and HadCM3L GCMs ⁽³⁾
1400mm (22 nd Century)	Herberger, M., H. Cooley, P. Herrera, P. Gleick, E. Moore, 2009: <i>The Impacts of Sea Level Rise on the California Coast</i> , Pacific Institute, Climate Change Center, USA ⁽⁴⁾
500mm to 600mm (2050), and 'multi-metre' (2100)	Hansen, J.E. (2007): Scientific reticence and sea level rise, <i>Environmental Research Letters</i> , 2:2, 024002, doi:10.1088/1748-9326/2/2/024002. Discussed in Hansen, J.E. (2007): <i>Climate Catastrophe</i> . <i>New Scientist</i> , July 28,2007
800mm (most likely), up to 2,000mm (2100)	Pfeffer et al. (2008): Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise, <i>Science</i> , 321:5894, 1340-1343.
Up to 1900mm by 2100	Hansen, J. and M. Sato, 2011, <i>Paleoclimate Implications for Human-Made Climate Change</i> ⁽⁵⁾

In line with the precautionary principle the findings from the latest science will be used to inform a reasonable worst case for SLR projections. Therefore an upper bound of 1.9m (for 2100) which represents a low probability / high consequence event has been considered.

(1) Jevrejeva's comments on her own paper were quoted by the BBC: 'By the end of the century, we predict it will rise by between 0.8m and 1.5m. The rapid rise in the coming years is associated with the rapid melting of ice sheets.' comments can be found at: <http://news.bbc.co.uk/1/hi/sci/tech/7349236.stm>

(2) Thermal expansion of the ocean is estimated to contribute 310mm of SLR and the melting of the Greenland icesheet is estimated to contribute 190mm, and the authors of the report note that this is likely to be an underestimate because the melting of smaller

(3) http://www.imeche.org/NR/rdonlyres/D72D38FF-FECF-480F-BBDB-6720130C1AAF/0/Adaptation_Report.PDF

(4) http://www.pacinst.org/reports/sea_level_rise/report.pdf

(5) http://www.columbia.edu/~jeh1/mailings/2011/20110118_MilankovicPaper.pdf

8 ASSESSING RISKS

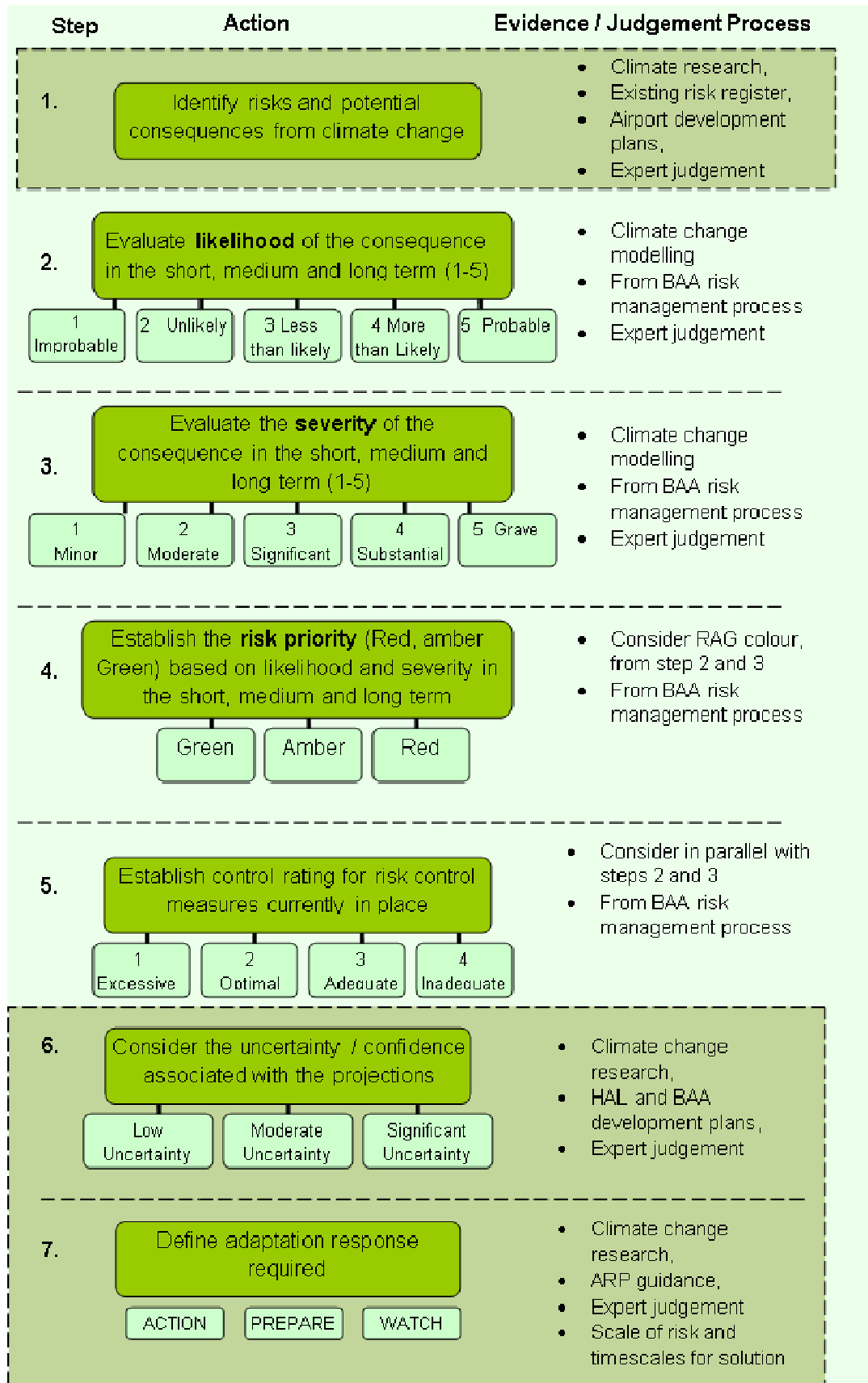
8.1 INTRODUCTION

This section details the methodology used in identifying, rating and prioritising climate change risks for Heathrow.

8.2 SUMMARY OF RISK ASSESSMENT PROCESS

Figure 8.1 overleaf summarises the risk assessment process followed by this study and is designed to build on existing risk management process used by HAL. This has required the definition of additional steps (steps 1,6 and 7) to address the long term time risk and planning horizons relevant to climate change adaptation.

Figure 8.1 Climate Change Risk Assessment Process



8.3 IDENTIFICATION AND ASSESSMENT OF RISKS

Risk identification, and quantification of the likely consequences and likelihood of the climate risks identified in the risk assessment has been based on:

- Knowledge of the climate change projections produced by UKCP09 and the likely impacts arising from the climatic trends projected;
- the engineering specifications and design standards used at Heathrow, both for existing assets and future development plans;
- risks already on HAL's risk registers;
- the findings from the literature review; and
- experience of past weather-related incidents and disruption at Heathrow obtained from HAL staff and key external stakeholders.

Risk scoring has been based on expert judgement informed by the best available evidence and necessarily involves some judgement. Decisions on the appropriate risk scores, and quantification of likely consequences and likelihood and an assessment of the existing control measures for each risk was made by the study team in conjunction with technical experts from across HAL's business units.

The risks identified are summarised in *Section 9* of this document classified by business unit.

8.4 HEATHROW'S EXISTING RISK ASSESSMENT METHODOLOGY

BAA has a comprehensive risk management process in place that is regularly reviewed and updated.

To maximise the accessibility of the findings of this study to HAL staff; to put the risks into the context of day to day risk management activities; and to allow comparison of the risks associated with climate change to other risks on BAA's risk registers for the airport, the results of this assessment have been expressed in terms of the language, objectives and processes currently used at Heathrow for risk management where they are appropriate.

Therefore each risk identified has been assigned a RAG rating of red (significant), amber (medium) or green (low) using BAA's risk matrix (see Figure 8.2), dependent on the **likelihood** and **consequence** of it occurring, and taking into account **existing management controls**.

Likelihood

The BAA Risk Management protocol defines the likelihood of a risk occurring within a five year time horizon in the following manner:

Table 8.1 BAA Risk Management Definitions of Likelihood

Ranking	Definition	Probability of Occurrence*
1	Improbable	< 10%
2	Unlikely	10% - 30%
3	Less than likely	30% - 50%
4	More than likely	50% - 80%
5	Probable	>80%

Source: BAA Risk Management, 2010

* Suggested time frame less than 5yrs

Consequence

In terms of expressing the consequence of a given risk, the following definitions or consequence rankings are used as standard in all BAA risk management documentation:

- 1= Minor;
- 2= Moderate;
- 3= Significant;
- 4= Substantial;
- 5= Grave.

Each consequence is considered across 5 areas of impact i.e. safety, security, environment, financial, and reputational and legal with the worst category being taken. The current consequence category definitions are illustrated in *Table 8.2*.

Table 8.2 BAA Risk Management Consequence Categories

Area	Ranking	Description
Safety	1	Minor Injuries
	2	Major Injuries
	3	Single Fatalities
	4	Multiple Fatalities (<100)
	5	Multiple fatalities (>100)
Security	1	Minor breach of regulations
	2	Reportable breach of regulations
	3	Prosecution
	4	Short term closure of the Airport
	5	Sustained Airport closure
Environment	1	Short term local damage
	2	Short term regional damage
	3	Long term local damage
	4	Long term widespread damage
	5	Widespread permanent damage
Financial (based on EBIT)	1	<£1m;
	2	>£1m-£25m<
	3	£25m-£50m<
	4	>£50m-£100m<
	5	>£100m
Reputation and Legal	1	Improvement notice, minor local reputation damage;
	2	Prohibition notice, major local reputation damage;
	3	Prosecution with fine, national adverse media coverage;
	4	Directors charged with corporate killings, fraud etc; International media coverage short term;
	5	Directors convicted of corporate killing, fraud etc; International adverse media coverage ->1year;

Source: BAA Risk Management, 2010

Controls

BAA's risk registers are graded in terms of how prepared and able Heathrow is to deal with them today. Each risk on the risk register is assigned a control rating based on the scoring system below:

Table 8.3 Control Rating Definitions

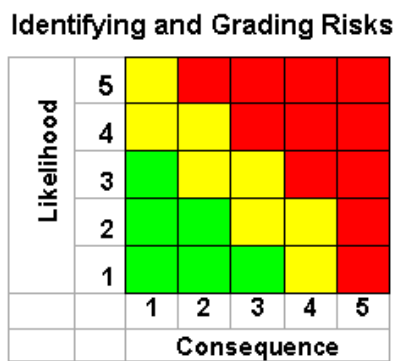
Rating	Control Rating Definition
Excessive	Controls exceed the level required to manage the risk
Optimal	Controls are reasonably practical, comprehensive and commensurate with the risk. All controls are evidenced as working as intended
Adequate	Some shortfall in levels of control but these are not significant and do not materially affect the level of residual risk
Inadequate	Weaknesses and inefficiency in controls do not treat the risk as intended. Remedial action in place and residual risk rating has been adjusted accordingly

Source: BAA Risk Management, 2010

Risk Rating / RAG Score

To rank risks BAA scores the likelihood and the consequence for each risk on its registers. This scoring system is illustrated in *Figure 8.2*.

Figure 8.2 Heathrow's Existing Risk Scoring System



Source: HAL Risk Management, 2010

The risk rating is denoted as red (high), amber (medium) or green (low) based on the assessment of *likelihood*, *consequence* and taking into account the *control rating*.

The risks identified in this climate change risk assessment will be rated using this risk matrix and RAG score system to allow them to be incorporated into the existing risk registers used at the airport as appropriate.

8.5 RISK PRIORITISATION AND CLASSIFICATION OF ADAPTATION RESPONSE

BAA's risk assessment method has been used as the foundation of the climate change risk assessment. The method has been supplemented in three additional ways to meet the specific requirements and objectives of this long term risk assessment and to meet guidelines of DEFRA and learn from early responders to the ARP.

Time Horizon

BAA's standard risk assessment methodology considers only the next 5 years. Climate change is an incremental issue that will take place over a long time horizon. Therefore this assessment has assessed risks (using the BAA matrix) in two time periods for which climate change effects have been modelled, eg short term (2020s) and the medium / longer term (2040/50s).

Uncertainty

Section 6 identifies areas of uncertainty in the assessment. To account for this each risk has been classified into three categories of certainty / confidence as follows:

- **Low** – areas where projections are constrained by low granularity modelling or not available in a probabilistic decadal format from UKCP09, or based on a few peer reviewed studies, or on expert judgement only;
- **Medium** – based on expert interpretation of a number of potentially conflicting peer reviewed studies, and where confidence in modelling is moderate, and in areas where approximate critical thresholds are approximated from experience if not design standards;
- **High** – based on expert interpretation that gives a consistent picture and attempt to explore uncertainty, or where design standards and critical thresholds are known, and where modelling data is available in a probabilistic format from UKCP09.

Adaptation response

Adaptation response actions have been classified into 3 basic categories to reflect the severity of the risk, the uncertainty in what is required (or the uncertainty in the climate science) and the urgency of action:

- **Action:** Action is required in the short term, either to manage short terms risks (classified as high or red risks), or because the solution to longer term risks needs to begin in the short term because of long planning or implementation cycles.
- **Prepare:** Identifies the need for additional research and / or development prior to confirming or implementing any risk management actions.
- **Watching Brief:** Risks are longer term and require an ongoing watching brief to monitor development in the science or the effects of climate change on the ground.

Chapter 9 presents the risk assessment and prioritisation. *Chapter 10* sets out the adaption responses identified.

8.6 STANDARDISED ASSUMPTIONS MADE DURING THE RISK ASSESSMENT

The following assumptions were made to ensure standardisation and consistency during the risk identification and prioritisation (likelihood, consequence, control measure) process:

- Risks are assessed against the “low”, “central” and “high” climate scenarios identified in Chapter 5 in line with the precautionary principle. If the risk varies by scenario this is identified in the assessment.
- Any risk which could increase the risk of an air traffic accident was scored as having a category 5 consequence (Grave);
- The likelihood of lightning strike frequency was assumed to be 1 (improbable) in all periods in line with the low baseline data and modest changes projected;
- In line with the HAL risk methodology all control ratings were assessed in terms of the current measures in place to manage the risk. Any development plans, assets, infrastructure or processes currently in development or construction but not yet operational were not considered in the control rating;
- All risks are assessed assuming no adaptation response beyond those identified within existing control ratings.

9 CLIMATE CHANGE RISK ASSESSMENT RESULTS

9.1 INTRODUCTION

In this chapter, the results of the climate change risk assessment are presented in tabular format and their implications and likely consequences discussed. All risks are assessed based on existing control measures.

9.2 RISK ASSESSMENT PRIORITISATION

A summary of the prioritised climate change risks identified for the short and medium / longer term at Heathrow is shown in *Figure 9.1* below broken down by business unit.

Each risk is prioritised based on the expert judgment made through the study team and stakeholders in terms of;

- The identified effects and its likelihood and consequences on airport operations,
- the likelihood critical thresholds are exceeded, and
- the robustness of existing control measures in place to manage the risk.

This risk prioritisation has been classified into significant (red), moderate (amber) and low (green) risks in the short and longer term in line with Heathrow's risk management framework, and assumes no additional adaption response.

Each risk is additionally characterized in terms of the uncertainty that relates to the core climate modeling and the key climate variable resulting in the risk.

To facilitate management of the risks, each is assigned to a business unit with nominated Director responsible.

All risk prioritisation shown in *Figure 9.1* is common to both the "central" and "high" climate scenarios (see *Chapter 5*) modeled. The "low" scenario assessment is not shown and in most cases results in low (green) risks.


Areas where additional adaptation actions have been identified are also shown in *Figure 9.1* and discussed in *Chapter 10* of this document.

Figure 9.1 Prioritised Climate Change Risks by Business Unit

a) Airside Business Unit Climate Adaptation Risks

Risks and Control Measures							<table border="1"> <tr> <td>R</td> <td>Excessive</td> <td>E</td> <td>A</td> <td>Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now</td> </tr> <tr> <td>A</td> <td>Optimal</td> <td>O</td> <td>P</td> <td>Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based</td> </tr> <tr> <td>G</td> <td>Adequate</td> <td>A</td> <td>W</td> <td>Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.</td> </tr> <tr> <td></td> <td>Inadequate</td> <td>I</td> <td></td> <td></td> </tr> </table>		R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now	A	Optimal	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based	G	Adequate	A	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.		Inadequate	I		
R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now																								
A	Optimal	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based																								
G	Adequate	A	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.																								
	Inadequate	I																										
Risk ID	Risk	Climate Variable	Threshold	Confidence (climate projections and or consequences)	Risk Grading (no adaptation)		Existing Control Measures		Adaptation Response Needed	Business Unit owners	Director/s Responsible																	
					Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy																				
AIRSIDE																												
1	Flashpoint of aviation fuel exceeded on hot days - potential fire hazard.	Temp	Aviation fuel flash point is 38°C. Temperatures during the summer of 2003 peaked at 37.5C	H	A	R	Spill reporting and defined clean up procedures.	A	P	Prepare: Research into spill clean up options currently used at airports in warmer climates to commence to develop policies robust to air temperatures exceeding 38°C.	Airside	Airside Director																
2	Increased incidence of fuel venting from aircraft in warm weather.	Temp	Aviation fuel flash point is 38°C.	H	A	A	Spill reporting, clean up procedures, airport pollution control system	O	P	Prepare: Research into options currently used at airports in warmer climates for spill reporting and clean up procedures.	Airside	Airside Director																
3	Increased fire risk due to hotter temperatures combined with increased lightning and drought potential.	Temp	Requires research	M	G	A	Onsite fire brigade, fire water supply and fire mains, regular drills, smoke and fire detection systems, vegetation management plans, PATS testing of electrical equipment.	O	P	Prepare: Ensure that the planned changes and development of the airport's fire main considers and addresses the potential for increased fire risk resulting from climate change.	Airside	Airside Director																
4	Change in distribution of pests and wildlife species. Potential changes to bird migration patterns and bird strike risk.	Temp	Requires research	L	G	G	PPE, first aid for outdoor workers. Veterinary service, bird management controls.	O	W	Watching Brief	Airside	Airside Director																
5	Reduced lift for departing aircraft due to 'thin air' and reduced engine efficiency in very hot weather.	Temp	Aircraft operate in multiple temp zones, unlikely to be breached	H	G	G	Potential to change load factors, ATM rates, if needed. Existing noise footprint monitoring and mitigation tools.	E	W	Watching Brief	Airside	Airside Director																
6	Torrential rain creates hazardous conditions for vehicles and planes i.e. airside and landside road vehicles, and taxiing and landing aircraft.	Precip.	Defined in Strategic Flood Risk Assessment (SFRA)	H	G	A	Grooved runway, drainage system, ATC procedures i.e. increased separation distances, runway safety zones, operational guidance for pilots/airside staff, warning signs on motorway network to announce hazardous conditions.	O	W	Watching Brief	Airside	Airside Director																
7	Seasonal changes to fog related disruption (increase in winter months, decrease for remainder of year).	Fog	Low Visibility Procedures when the Runway Visual Range (RVR) is < 600m and/or cloud ceiling is < 200 ft. Projections do not suggest any critical thresholds would be crossed	L	G	G	LVPs, operational guidance for pilots and airside vehicles, warning signs on nearby motorway network to alert drivers to hazardous conditions.	E	W	Watching Brief	Airside	Airside Director																
8	Increased risk of schedule interruption from stormy conditions.	Storms	High wind procedures and cross wind procedures enacted at defined criteria (dependent on aircraft type).	L	G	A	ATC procedures i.e. separation distances, contingency plans for disruption.	O	W	Watching Brief	Airside	Airside Director																
9	Increased longevity of wing tip vortex effect due to general becalming of surface wind speeds.	Wind	Wing tip vortex is particularly problematic for small planes taking off in quick succession after large aircraft.	L	G	G	Reparation programme to repair affected roofs, ATC procedures i.e. increased separation distances.	E	W	Watching Brief	Airside	Airside Director																
10	Change to prevailing wind direction affects runway utilisation and schedules.	Wind speed/direction	All commercial aircraft are tested to a "demonstrated" maximum crosswind as part of their certification. Large aircraft are better able to handle cross winds than light aircraft. Technology is improving all of the time.	L			Not able to be assessed due to lack of projection data.		W	Watching Brief	Airside	Airside Director																
11	Disruption to airfield operations from lightning i.e. refuelling suspension, changes to flight routing.	Lighting	All commercial aircraft are tested for resilience to lightning strike as part of their certification. Planes can withstand lightning strike in the air but during take off and landing instrument loss would be critical hence the diversion of routes and stacks.	L	G	A	Suspension of refuelling, changes to stack locations and departure routes, diversions.	O	W	Watching Brief	Airside	Airside Director																

(b) Capital Business Unit Climate Adaptation Risks

Risks and Control Measures												
					R	Significant	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now		
					A	Moderate	Optimal	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based		
					G	Low	Adequate	A	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.		
							Inadequate	I				
Risk ID	Risk	Climate Variable	Threshold	Confidence (climate projections and or consequences)	Risk Grading (no adaptation)		Existing Control Measures		Adaptation Response Needed	Business Unit owners	Director/s Responsible	
					Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy				
CAPITAL												
12(a)	Changes to groundwater levels affect asset integrity and could cause subsidence and water ingress damage to buildings and surfaces.	Precip.	See Strategic Flood Risk Assessment	M	G	A	Design standards and construction practices, emergency contingencies for areas affected by flooding / water ingress, Strategic Flood Risk Assessment (SFRA) on-going to identify risk and solutions.	A	A	Action: Ensure appropriate design standards are applied to new buildings to address risks from water ingress/flooding	Capital	Group Engineering Director
13	Overheating of aircraft on stands. Increased cooling demand and rise in energy use.	Temp	Sustained temperatures above 25-30°C require use of APUs or fixed ground power for cooling aircraft.	H	G	A	Auxiliary Power Units (APUs), Fixed Ground Power at some stands, development of Preconditioned Air (PCA)	A	P	Prepare: Research robustness of PCA and FEGP (and any cooling alternatives) making sure that the design standards used are as robust as practicable against future temperature extremes.	Capital	Group Engineering Director
14	Heat damage to road and apron surfaces caused by temperatures exceeding design standards i.e. melting, cracking.	Temp	UK tarmac standards (roads, aprons) begin to lose integrity once temperatures in the shade exceed 32°C. Tarmac itself is black, absorbs heat and can hit 80°C at such temperatures. Runway surfaces design standards withstand far higher temperatures to be able to cope with aircraft braking.	H	G	A	Regular inspections, rapid maintenance response, regular surface relaying, surfaces defined by detailed design standards based on current best practice.	O	P	Prepare: Review and ensure continued robustness of hard standing (road/apron/runway) assets design standards to future climate change.	Capital	Group Engineering Director
15	Overheating of operationally-critical buildings which could impair performance of critical staff or equipment and breach regulated conditions	Temp	Problems rarely experienced today i.e. only in some areas after temperatures exceed 30-35°C for 2 weeks+. Temperature envelopes of some safety critical equipment not clear.	M	G	A	HVAC, temporary spot cooling (fans) if needed, onsite medical staff, monitoring of temperatures in buildings.	O	P	Prepare: Review and ensure continued robustness of building design standards to future temperature change. Prepare: Ensure design and development of Heathrow's long term masterplan manages risks from future climate change.	Capital	Group Engineering Director Masterplanning Director


(c) Engineering Business Unit Climate Adaptation Risks

Risks and Control Measures							<table border="1"> <tr> <td>R</td> <td>Excessive</td> <td>E</td> <td>A</td> <td>Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now</td> </tr> <tr> <td>A</td> <td>Significant</td> <td>O</td> <td>P</td> <td>Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based</td> </tr> <tr> <td>G</td> <td>Moderate</td> <td>A</td> <td>W</td> <td>Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.</td> </tr> <tr> <td></td> <td>Low</td> <td>I</td> <td></td> <td></td> </tr> </table>		R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now	A	Significant	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based	G	Moderate	A	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.		Low	I			<table border="1"> <tr> <th colspan="2">Risk Grading (no adaptation)</th> <th colspan="2">Existing Control Measures</th> <th rowspan="2">Adaptation Response Needed</th> <th rowspan="2">Business Unit owners</th> <th rowspan="2">Director/s Responsible</th> </tr> <tr> <th>Short Term (to 2020)</th> <th>Medium / Long (2020 to 2050s)</th> <th>Summary</th> <th>Adequacy</th> </tr> </table>		Risk Grading (no adaptation)		Existing Control Measures		Adaptation Response Needed	Business Unit owners	Director/s Responsible	Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy
R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now																																					
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ENGINEERING																																									
12b)	Changes to groundwater levels affect asset integrity and could cause subsidence and water ingress damage to buildings and surfaces.	Precip.	See Strategic Flood Risk Assessment	M	G	A	Design standards and construction practices, emergency contingencies for areas affected by flooding / water ingress, SFRA on-going to identify risk and solutions.	A	A	Action: Investigate and address risks of groundwater flooding to existing critical assets.	Engineering	Operations Director, Engineering & Baggage																													
16	Pollution Control System (PCS) challenged during episodes of extreme weather. Increased severity of first flush effect, less seasonal distinction in PCS operation.	Precip.	Pollution Control System capacity limits	M	A	R	Water quality action plan, Pollution Control System (due to be upgraded), water quality monitoring, debris removal from surfaces, new permitting procedures with EA.	A	A	Action: Continue to liaise with the EA to develop and implement improvement options for the Pollution Control System (PCS), ensuring that the risks identified by this study are considered appropriately.	Engineering	Operations Director, Engineering & Baggage																													
17	Localised flooding if older drainage overwhelmed by heavy rainfall events.	Precip.	Design standards for drainage	M	G	A	Design standards and construction practices, emergency contingencies for areas affected by flooding / water ingress, SFRA on-going to identify risk and solutions.	A	A	Action: Sensitivity test airport drainage infrastructure to ensure as robust as practicable to future climate extremes. Investigate and address risks of flooding to existing critical assets	Engineering	Operations Director, Engineering & Baggage																													
18	Integrity of balancing ponds at risk of subsidence of earth walls and / or extreme rainfall events.	Precip.	See Strategic Flood Risk Assessment	M	G	A	Daily monitoring and evaluation, WQMS, evacuation contingency plans,	O	A	Action: Continue to liaise with the EA to develop and implement improvement options for the Pollution Control System (PCS), ensuring that the risks identified by this study are considered appropriately.	Engineering	Operations Director, Engineering & Baggage																													
19	Increased energy demand for cooling in the summer, and for heating during winter extremes increases energy spend and emissions. High temperatures reduce performance of some plant.	Temp	Challenging only if temperatures exceed 30-35°C for 2 weeks+.	M	G	A	Dual fed supply, back up generation, move toward renewable energy centres.	O	P	Prepare: Ensure that future changes to the airport's heat, power and cooling generation and transmission assets are stress-tested to be as robust as practicable against future climate change projections. Research spare capacity and critical thresholds for plant and transmission infrastructure performance in hot weather and potential to accommodate increased demand.	Engineering	Operations Director, Engineering & Baggage																													
20	Heat stress risk to staff, particularly those in highly physical roles. Additional cooling costs may result.	Temp	Sustained temperatures above 25-30°C require cooling or changes to working patterns.	H	G	A	Onsite medical facilities, PPE, temporary spot cooling (i.e. fans etc) if needed.	O	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage																													
21	Drought conditions affect water availability and cause bore hole levels to drop. Restrictions may be posed to water intensive activities.	Precip.	Borehole capacity	M	G	G	Sustainable water strategy, conservation measures being retrofitted, design standards, WQMS, use of non-potable water where appropriate i.e. toilet flushing. Dual bore hole and mains supply, new permitting procedures with EA.	E	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage																													
22	Freeze / thaw damage of surfaces as winter temperatures become more variable.	Snow/Winter	Requires research	M	G	A	Regular inspections, rapid maintenance response, regular surface relaying, surfaces defined by detailed design standards based on current best practice.	O	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage																													
23	Increased risk of wind damage to assets, standing aircraft, vehicles and injuries to staff.	Wind/Storm	Various wind speed resilience thresholds	L	G	A	Design standards, regular inspections, maintenance as needed, operational guidance for airside staff in high winds, warning signs on nearby motorway network alerting drivers to hazardous conditions.	O	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage																													
24	Impacts of lightning on control systems and electricity supply. Power cuts and voltage spikes to parts of the airport not on UPS during electrical storms.	Lighting	All modern control systems are sensitive to voltage spikes, risk of disruption and equipment failure or damage	L	G	A	UPS for safety critical systems, dual fed electricity supply.	O	W	Watching Brief	Engineering	Operations Director, Engineering & Baggage																													

(d) First and Last Risks

Risks and Control Measures						<table border="1"> <tr> <td style="background-color: red; color: white; text-align: center;">R</td> <td>Excessive</td> <td style="background-color: green; color: white; text-align: center;">E</td> <td style="background-color: red; color: white; text-align: center;">A</td> <td>Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now</td> </tr> <tr> <td></td> <td>Significant</td> <td style="background-color: yellow; color: black; text-align: center;">O</td> <td style="background-color: orange; color: white; text-align: center;">P</td> <td>Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based</td> </tr> <tr> <td style="background-color: yellow; color: black; text-align: center;">A</td> <td>Moderate</td> <td style="background-color: green; color: white; text-align: center;">A</td> <td style="background-color: yellow; color: black; text-align: center;">W</td> <td>Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.</td> </tr> <tr> <td style="background-color: green; color: white; text-align: center;">G</td> <td>Low</td> <td style="background-color: red; color: white; text-align: center;">I</td> <td></td> <td></td> </tr> </table>	R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now		Significant	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based	A	Moderate	A	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.	G	Low	I		
R	Excessive	E	A	Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now																						
	Significant	O	P	Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based																						
A	Moderate	A	W	Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.																						
G	Low	I																								
Risk ID	Risk	Climate Variable	Threshold	Confidence (climate projections and or consequences)	Risk Grading (no adaptation)		Existing Control Measures		Adaptation Response Needed	Business Unit owners	Director's Responsible															
					Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy																		
FIRST & LAST IMPRESSIONS																										
25	Wintry conditions pose health and safety risks for pax and staff.	Snow/Winter	Aircraft and surfaces treated with de-icer when temperatures fall below 3°C.	M	G	G	De-icing, gritting, PPE, additional heating, onsite medical facilities, warning signs on nearby motorway network alerting drivers to hazardous conditions.	O	W	Watching Brief	F&L	Campus Security Director														
26	Offsite impacts (snow, flooding, storms etc) could impede the flow of people (pax, crew and staff) if destination airports or the UK surface transport network is affected.	Offsite impacts	There are limits to the number of people who can be safely accommodated within HAL terminal buildings and min requirement for fire service cover.	L	G	A	Disruption contingency plans (marquees, refreshment vouchers, comfort facilities, flexible working patterns, communications plans), diversification of surface access toward public transport, motorway warning signs.	O	W	Watching Brief	F&L	Campus Security Director														
27	Remote impacts could restrict the flow of essential supplies to the airport.	Offsite impacts	Storage space	L	G	A	Contingency plans for disruption, (limited) storage of critical supplies, investigation of preferential partnership status / alternate supplies of key resources i.e. glycol.	O	W	Watching Brief	F&L	Campus Security Director														
28	Overheating on surface access transport from rising temperatures.	Offsite impacts	Temperatures over 30°C can be problematic for surface transport and underground.	M	G	A	Air conditioning, design standards, onsite medical facilities, coordination with HPA and TL, public information campaigns, availability of refreshments in terminals.	O	W	Watching Brief	F&L	Campus Security Director														

(e) Cross Business Unit and Technical Standards and Assurance Climate Adaptation Risks

Risks and Control Measures																
					R		Excessive		E		A		Action Defines actions that are known and required now to mitigate identified short-term climate related risks and/or longer-term risks if the solution requires action now			
					Significant		Optimal		O		P		Prepare Defines tasks to improve understanding of the cause or solution to a significant short or medium term risk. Tasks are therefore predominately research based			
					A		Moderate		Adequate		A		W		Watching Brief Watching brief to be maintained in the short term on the latest climate science developments, and the situation on the ground.	
					G		Low		Inadequate		I					
Risk ID	Risk	Climate Variable	Threshold	Confidence (climate projections and or consequences)	Risk Grading (no adaptation)		Existing Control Measures		Adaptation Response Needed	Business Unit owners	Director/s Responsible					
					Short Term (to 2020)	Medium / Long (2020 to 2050s)	Summary	Adequacy								
CROSS BUSINESS UNIT																
29	Fracture risk to underground infrastructure from increased winter temperature variability and freeze / thaw damage.	Snow/Winter	3rd party infrastructure thresholds not known	M	A	A	Regular inspections, rapid maintenance response and repairs as needed, back up links and spare capacity in utility supply.	A	P	Prepare: Investigate vulnerability of underground services to climate change risks from fracture /damage and ensure appropriate adaptation changes are incorporated into future development plans as appropriate.	Jointly: Airside Engineering	Airside/Ops Directors				
30	Increasing variability of snowfall challenges winter contingency plans, de-icing supplies and staff experience.	Snow/Winter	Aircraft and surfaces treated with de-icer when temperatures fall below 3°C. Contingency plans in place today being updated to incorporate the findings of the Heathrow Winter Resilience Enquiry.	M	G	A	De-icing procedures, snow clearing vehicles, changes to staff working patterns, contingency plans, weather forecasts, findings of the Heathrow Winter Resilience Review implemented.	O	A	Action: Continue to implement the recommendations of the Heathrow Winter Resilience Enquiry and ensure that planned future contingencies consider future climate change.	Jointly: Airside Engineering Standards and Assurance	Airside/Ops/Risk Directors				
TECHNICAL STANDARDS AND ASSURANCE																
31	Heat wave conditions result in negative impacts on air quality. More difficult to comply with air quality standards.	Temp	Standards are clearly demarcated and air quality is regularly monitored and reported.	M	G	A	Heathrow Airwatch, air quality monitoring, targeted landing fees, improved departure procedures, Clean Vehicles Programme, green travel initiatives, move toward PCA, GHG reduction targets for buildings and operations.	O	W	Watching Brief	TS&A	Sustainability Director				
32	Changes to global distribution of disease could increase likelihood and frequency of epidemics and pandemics.	Offsite impacts	Requires research	L	G	A	Daily monitoring and evaluation, WQMS, evacuation contingency plans.	O	W	Watching Brief	TS&A	Sustainability Director				
33	Sea Level Rise / storm surge risks loss of low lying destination airports i.e. Schiphol, Hong Kong (without adaptation).	Sea level rise	Elevation data for coastal airports and their design standards.	L	G	G	Contingency plans for changes to international schedules and airport closures.	O	W	Watching Brief	TS&A	Sustainability Director				
34	Sea Level Rise / storm surge risks disruption to UK infrastructure i.e. utility supplies, surface transport routes (without adaptation).	Sea level rise	Not a direct risk for HAL. Infrastructure being managed and critical threshold being considered by others i.e. utilities, TIL etc	L	G	G	Contingency plans for loss of supplies, disruption to surface transport routes and utility supply problems.	O	W	Watching Brief	TS&A	Sustainability Director				

9.3 RISK ASSESSMENT SUMMARY

The risk assessment has identified 34 risks in the short and medium to longer term based on the central and high climate scenarios (see Chapter 5).

Risks in the short term are generally low (green).

In the medium to longer term as climate change is predicted to accelerate, and assuming no changes to existing airport controls, risk levels are shown generally to rise in significance. This assessment is common to both the central and high climate scenarios.

In a low climate scenario risk levels in the medium to longer term would be essentially similar to those in the short term. The results as presented are therefore a worst case.

For Heathrow the most significant risks arise from climate change from projected longer term changes to temperature and precipitation extremes.

The biggest uncertainties surround future prevailing wind conditions. This is significant since Heathrow's two runways are parallel and the airport does not have a cross-wind runway.

The prioritisation, ownership and timing of adaptation to these risks are considered in *Chapter 10* of this document.

9.4 CLIMATE CHANGE OPPORTUNITIES

Not all of the impacts associated with climate change should be considered as negative for Heathrow. A number of changes arising from climate change could also present opportunities for HAL. It is important that ways to maximise these opportunities are considered in future development plans for the airport. The opportunities identified as likely to arise from climate change are considered below:

- Changes to destination choice due to negative climate change impacts overseas could increase the flow of in-tourists to the UK. Conversely this may reduce outbound tourism if more people decide to holiday in the UK which could be a negative impact for HAL. It is not possible to quantify the net change on the strength of current evidence;
- Disease impacts in other parts of the world and a worsening of health outcomes and thermal comfort (i.e. an increased risk of heat stress in Mediterranean countries) may reduce destination demand for many parts of the world in terms of holiday destinations, and increase demand for travel to the UK. Conversely this may reduce outbound tourism if more people decide to holiday in the UK which could be a negative impact for HAL.
- Loss or damage to competitor hub airports due to sea level rise or other climate change impacts could increase the volume of passengers using Heathrow;

- Warmer temperatures are likely to shorten the heating season at Heathrow, whether this reduction in energy demand for heating is likely to be outweighed by an increase in cooling demand is uncertain;
- A potential reduction in fog frequency over the average year, and a potential decrease in the likelihood of snow could lead to a reduction in weather-related disruption at Heathrow in the future. Given the future variability of the climate projected to result from climate change and the fact that snow and fog cannot be ruled out in the future, it is however, important that control measures to respond to snow or foggy conditions are maintained;
- Changes to the climate could result in a reduction of the bird strike risk at the airport if the avian population in the vicinity of the airport reduces, or the species mix changes toward smaller non-flocking species. However there is considerable uncertainty about how climate change may affect avian populations and migration routes so this opportunity should not be assumed;
- New seasonal or climatic opportunities could arise for HAL and its retail tenants providing that they adapt the seasonality of their retail mix and product offerings accordingly.

10 ADAPTATION STRATEGY

10.1 INTRODUCTION

This section sets out Heathrow's adaptation strategy in response to the identified short and longer term risks of climate change.

10.2 ADAPTATION STRATEGY

The adaptation response to the risks identified in *Chapter 9* has been determined and prioritised through:

- a consideration of the scale and importance of the risk in terms of likelihood and consequence for HAL in the short and medium / longer term;
- an appraisal of the adequacy of the current control measures in place to deal with that risk;
- an understanding of any uncertainties and critical thresholds involved; and finally
- consideration of the timescales involved both in terms of when the risk may occur, and how long it may take to implement adaptation measures.

This has led to 3 types of priority adaptation responses as follows:

Action: Action is required in the short term, either to manage short term risks (classified as high) or because the solution to longer term risks needs to begin in the short term because of long planning or implementation cycles.

Prepare: Identifies need for additional research and or development prior to confirming any risk management actions

Watching Brief: Risks are longer term and require an ongoing watching brief to monitor science and effects of climate change.

The adaptation response to the identified climate change risks is detailed in Figure 9.1 (see Chapter 9) by business unit. Each adaptation response, whether "action", "prepare" or "watching brief" has been assigned a Director responsible.

It is envisaged that the development and delivery of the adaptation strategy identified through this study will be a continuous and on going activity that responds and adapts to new and improved information on the science and understanding of critical thresholds. The working expectation is that the "actions" and "prepare" tasks identified in Figure 9.1 are completed in the next one to 3 years. "Watching brief" requirements are on going and may change to specific actions in the future.

Delivery of the adaptation strategy will require detailed cost benefits of specific remedies as these are developed as well as an assessment of their wider sustainability implications in line with Heathrow's Sustainability policy.

The adaptation strategy will continue to be evolved based on the on going review and monitoring of climate change risks (see chapter 11) and detailed consideration of the barriers to adaptation identified (see Section 10.4) and principles of good adaption (see Section 10.5)

10.3 RESIDUAL RISKS

The adaptation strategy has been designed to address key risks in the short term as well as to prepare Heathrow for risks that may occur in the longer term and which require early action due to long timescales for implementation. This has resulted in a list of adaptation response requirements classified into “action”, “prepare” and “watching brief” that are nominally planned for delivery in the next 1 to 3 years.

Heathrow is committed to the delivery of this strategy and its on going development and evolution with the objective of ensuring that residual risks are managed to acceptable levels.

10.4 BARRIERS TO ADAPTATION

The IPCC notes that adaptation to climate change has significant limits, some posed by the magnitude of the likely changes, others related to the rate of change, and others that relate to financial, institutional, technological, cultural and cognitive barriers. Whilst there are some commonalities in terms of barriers to adaptation (i.e. scientific uncertainty), others are very much determined by an organisation’s own situation. For Heathrow Airport the main barriers to successful adaptation are summarised below:

10.4.1 Scientific Uncertainty

Scientific uncertainty regarding the pace and scale of climate change and particularly scientific uncertainty surrounding some variables not currently able to be modelled in a probabilistic fashion i.e. prevailing wind direction.

10.4.2 Financial Uncertainties and Resource Constraints

Heathrow, like all businesses, acts within financial constraints. The airport has to balance the need to invest in adaptation with other business investment priorities. Furthermore as a regulated company its return is regulated by the CAA in 5 year cycles that don’t necessarily match the long term timescale challenges posed by climate change.

10.4.3 Uncertainty Regarding Future Aviation Industry Developments

Uncertainty with regard to long term development trends within the aviation industry, demand projections, destination trends, aviation technology changes and future development plans at the airport in the medium and longer term can act as barriers to adaptation.

10.4.4 Space Constraints

Heathrow’s footprint is comparatively compact when compared to other major hub airports around the world. Space constraints on the site do limit the storage of supplies onsite,

and limit the ability of HAL to expand some infrastructure and assets which would improve adaptive capacity at the airport.

10.4.5 Runway Capacity Constraints

Heathrow is among the most congested airports in the world and the lack of spare capacity means that unlike many other British or European airport, HAL has very little room to manoeuvre when disruption occurs.

10.4.6 Permitting Constraints

Heathrow's activities are constrained by numerous permitting constraints reflecting the airport's proximity to residential areas i.e. the night flight quota, Cranford Agreement, air quality and noise footprint limits. Some of these permitting constraints may affect the adaptation options available to the airport.

10.4.7 Interdependencies

As a landlord to many other organisations based at Heathrow, HAL is limited in how directly it can shape the adaptation undertaken by other organisations. Not all adaptation decisions will be taken in-house by HAL and the airport operator will be affected by the degree to which other bodies at the airport choose to adapt to climate change. Furthermore HAL relies on external, offsite third party organisations for some of its essential services i.e. fuel, staff transport, power, potable water and should climate change negatively impact these services then the adaptive capacity at Heathrow could be impaired.

10.4.8 Other Legislative Requirements

HAL's adaptation response will need to be balanced with other regulatory requirements. Primary amongst these is the need to maintain airfield and aviation safety.

10.5 PRINCIPLES OF GOOD ADAPTATION

10.5.1 Defining Adaptation

Adaptation has the fundamental aim of reducing the potential adverse impacts of climate change and enhancing beneficial impacts, where they occur, but it should be remembered that the process may incur costs and will not prevent all damages. Adaptation can occur either in anticipation of change (anticipatory adaptation), or be a response to those changes (reactive adaptation) after they have occurred. The Stern Review noted that anticipatory adaptation will likely be less costly than emergency reactive responses. Conversely, developing adaptation measures long before they are needed, particularly if this occurs before the science behind the risks is properly understood can increase the potential for maladaptation (i.e. adaptation which is inflexible and which actually increases the risk to climate change).

There are two main approaches to adaptation: optimisation and resilience. Optimising approaches aim to identify the adaptation solutions that present the greatest benefit for the least cost. Resilience approaches aim to provide increased resilience either in general or in response to specific risks. They generally involve learning from experience. The options favoured in the resilience approach tend to be those considered most robust

against a range of uncertainties ⁽¹⁾. HAL's adaptation strategy needs to consider both optimisation and resilience.

10.5.2 Common Principles for HAL's Adaptation Strategy Development

What should be defined as 'good' adaptation will vary from organisation to organisation and will reflect individual organisational priorities and development plans. However there are some principles which are considered common to all 'good' adaptation strategies and these have been central to the development of a climate change adaptation strategy for Heathrow and these are summarised below ⁽²⁾ :

- No regrets: Priority should be given to measures that are beneficial irrespective of uncertainties, this may be because they meet other organisational needs;
- Synergistic: Priority should be given to measures that are good for both mitigation and adaptation, and adaptation measures should try to avoid increasing the GHG burden;
- Precautionary principle: The worst-case scenario should be considered, even if uncertainties are high because of the unacceptably high consequences should such an event occur;
- Flexible: Adaptation policy should be dynamic and flexible (to account for uncertainties and rapid changes in the science, local conditions and available solutions) so as to prevent maladaptation (i.e. adapting in a way that constrains future adaptation choices);
- Integrated: Disasters, climate risk, or climate change risk should not be compartmentalised. Climate change should be an integral part of all emergency planning;
- Knowledge based: Adaptation policy should be based on scientific evidence;
- Bear losses and manage impacts: When the benefits of taking adaptive action do not justify the costs, accepting the risk and bearing any consequences and costs that result from climate change may be appropriate;
- Exploiting opportunities: Good adaptation considers opportunities as well as risks.
- Effective: Adaptation measures should reduce the risks from climate change and not introduce perverse effects. They should be context specific, implementable, and enforceable.
- Proportional: Measures must be cost-effective and proportionate; and
- Sustainable: Measures must be in line with overarching objectives on sustainable development.

(1) Managing Adaptation: Linking Theory and Practice, 2011, UKCIP (Alastair Brown, Megan Gawith, Kate Lonsdale and Patrick Pringle)

(2) EU Presentation on the White Paper on Climate Change Adaptation

http://ec.europa.eu/environment/climat/adaptation/pdf/pres_white_paper.pdf

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For Heathrow the measure of whether adaptation has been successful is considered to be that the airport continues to meet its statutory functions, and fulfils its organisational priorities, meets stakeholder needs, and achieves its strategic intents in the face of climate change.

11 CONCLUSIONS, MONITORING AND GOVERNANCE

11.1 INTRODUCTION

This chapter summarises how Heathrow's climate change adaptation strategy will be monitored, reviewed and governed as well as key conclusions from the study.

11.2 MONITORING, REVIEW AND GOVERNANCE OF ADAPTATION RESPONSE

The adaptation "responses" identified by this study will be monitored through periodic review at existing senior Heathrow Health, Safety and Environment governance fora to track progress and where this is considered inadequate escalate action.

Additionally it is proposed that the Corporate Responsibility team carries out a "comprehensive" review of the risks and climate science every 5 years to coincide with the development of Heathrow's Capital Infrastructure Plan (to respond to quinquennial regulatory settlements with the CAA) , with an "interim" review at each quinquennial midpoint.

This will manage HAL's climate change business risks, aligns with key decision points around HAL's capital plan and prepares HAL for any future response that may be required by Government.

The review cycle proposed will also ensure that Heathrow's adaptation strategy remains dynamic, responsive and appropriate by ensuring that it reflects latest scientific knowledge on climate change and critical thresholds.

11.3 KEY CONCLUSIONS

This report has assessed the potential physical impacts of climate change upon Heathrow Airport Limited (HAL) and its statutory functions in line with statutory guidance from Defra.

Using best available information on future climatic effects and applying a comprehensive risk assessment approach that took a precautionary worst case approach to future climate change risks this study has concluded that:

- Heathrow has comprehensive control measures and contingency plans for managing climate related risks, and largely these are considered sufficient to manage climate change risks in the shorter term (to 2020).
- It is not feasible at this time to conduct a detailed assessment of climate predictions beyond the 2050s since this time scale falls outside typical airport planning cycles and the climate science becomes increasingly uncertain in the longer term.
- Climate risks in the short term are predominantly low, and where risks are more significant these are largely already being managed through existing mitigation and resilience programmes (eg plans to upgrade the airport pollution control system).

- Assuming no changes to existing control measures the risks associated with climate change impacts in the medium to longer term are predicted to worsen.
- Assuming the adaptation strategy identified by this study is implemented and continually evolved will ensure that residual risks are appropriately managed.
- Key adaptation responses identified in the short term generally build on existing actions planned by the business.
- Delivery of the adaptation strategy will be assured through clear ownership across Heathrow's business units together with a requirement for on going reporting of progress at senior HS&E performance management fora.
- Regular (5 yearly comprehensive and mid point reviews) of the climate risk assessment will ensure continuous updating of the adaption strategy in line with best available information on climate science, risk thresholds and business and infrastructure planning cycles thereby allowing Heathrow to appropriately manage future risks from climate change.

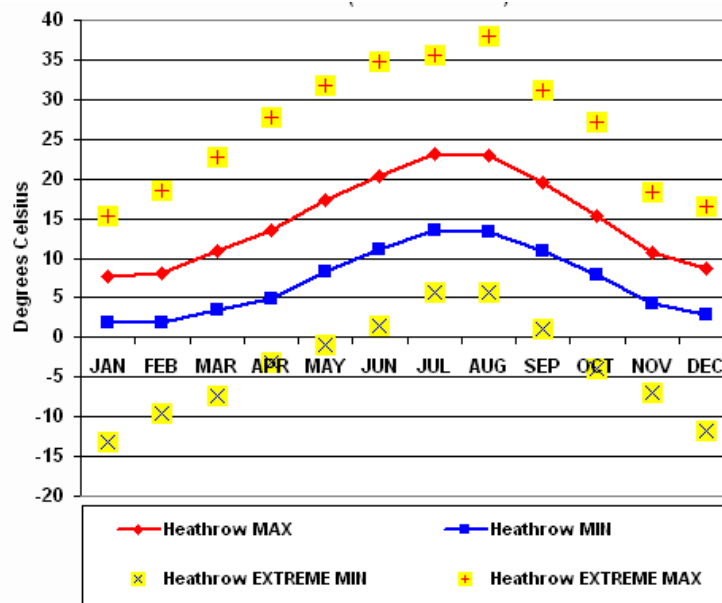
Annex (A)

Baseline Meteorological Conditions at Heathrow

BASELINE METEOROLOGICAL CONDITIONS AT HEATHROW

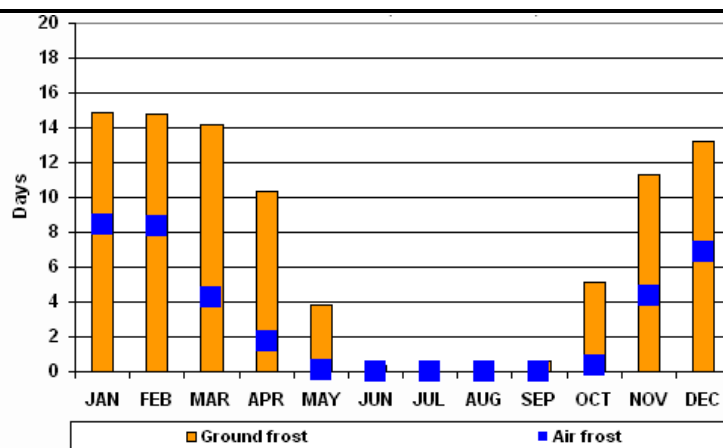
This annex presents additional baseline data for the climate experienced today at Heathrow airport.

Heathrow Mean Daily Maximum and Minimum Temperature (1971-2000) and extremes (1948-2007)



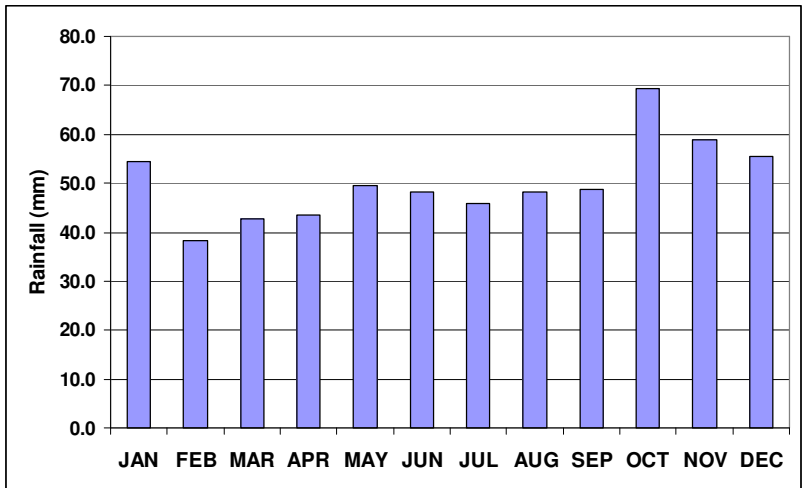
© Crown Copyright Met Office 2010
<http://www.metoffice.gov.uk/climate/uk/so/print.html>

Average Number of Days of Air and Ground Frost at Heathrow (1971-2000)



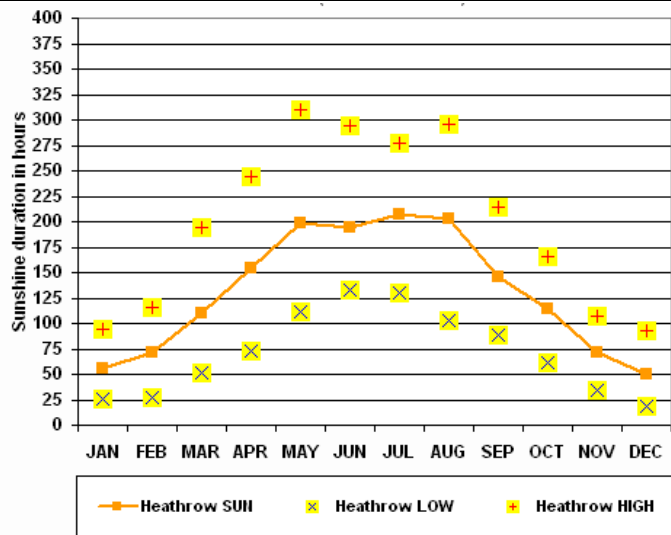
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<http://www.metoffice.gov.uk/climate/uk/so/print.html>

Mean Monthly Rainfall at Heathrow (1971-2000)



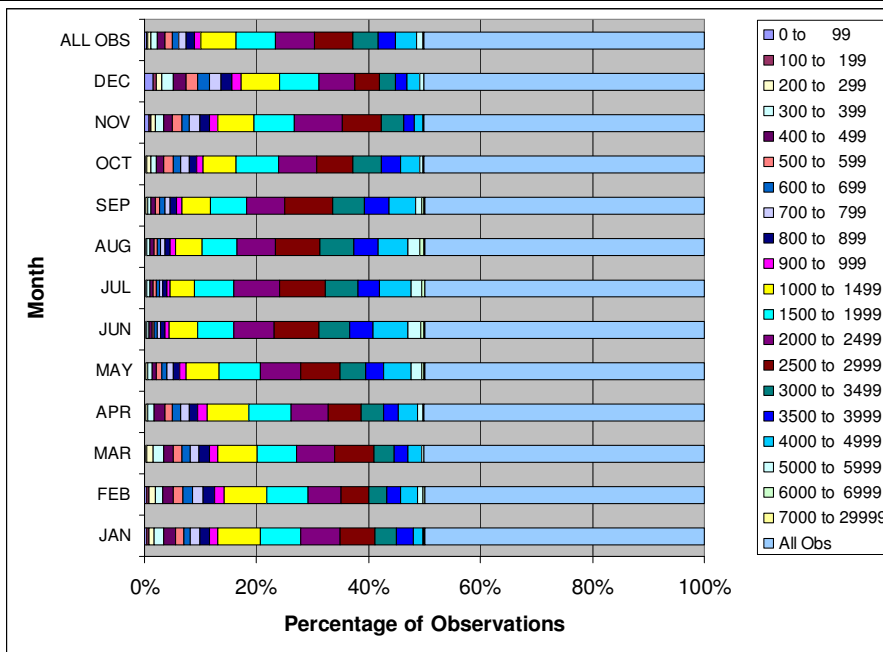
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Data provided by HAL

Sunshine Duration (1971-2000) and Extremes (1957-2005) at Heathrow



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<http://www.metoffice.gov.uk/climate/uk/so/print.html>

Heathrow Historic Visibility Observations 2000-09 (Decametres)



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Heathrow Historic Meteorological Data (Visibility Observations Percentage Table, 2000-09)

Visibility decametres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All Obs
0 to 99	0.9	0.9	0.3	0.1	0.1	0.1	0.1	0.0	0.2	0.5	1.4	2.9	0.6
100 to 199	0.8	0.7	0.6	0.2	0.3	0.1	0.2	0.3	0.2	0.3	0.8	1.1	0.5
200 to 299	1.7	2.3	2.0	0.9	0.6	0.5	0.5	0.4	0.6	1.3	1.6	2.2	1.2
300 to 399	3.6	2.7	3.8	2.4	1.5	0.7	1.0	1.3	1.4	2.0	2.9	4.1	2.3
400 to 499	4.0	3.5	3.6	3.5	1.6	1.1	1.2	1.3	1.4	2.9	3.3	4.6	2.7
500 to 599	3.0	3.6	3.1	2.8	1.9	0.9	1.0	1.2	1.7	3.2	3.1	4.2	2.5
600 to 699	2.2	3.4	2.9	3.0	2.0	1.0	1.2	1.2	1.7	2.7	2.7	4.1	2.3
700 to 799	3.4	3.8	3.0	3.1	2.1	1.4	1.1	1.6	1.8	3.0	3.9	4.1	2.7
800 to 899	3.5	4.3	3.7	3.1	2.6	1.5	1.6	2.0	2.5	2.8	3.4	3.9	2.9
900 to 999	3.1	3.4	3.0	3.1	2.1	1.4	1.3	1.6	1.9	2.2	2.9	3.3	2.4
1000 to 1499	15.0	15.2	14.1	15.1	11.9	10.2	8.7	9.8	10.0	11.8	13.2	13.6	12.4
1500 to 1999	14.6	14.7	14.0	15.1	14.6	13.0	14.1	12.2	13.1	15.0	14.3	13.9	14.0
2000 to 2499	14.0	11.6	13.7	13.0	14.4	14.6	16.4	13.9	13.8	13.7	17.2	13.1	14.1
2500 to 2999	12.4	9.9	14.0	12.0	14.2	15.8	16.2	16.0	16.9	13.1	13.9	8.6	13.6

Visibility decametres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All Obs
3000 to 3499	7.8	6.6	7.3	8.0	9.2	11.1	11.8	12.1	11.6	10.1	8.1	5.9	9.1
3500 to 3999	5.9	4.7	4.8	5.3	6.5	8.1	7.4	8.5	8.4	7.0	3.7	4.0	6.2
4000 to 4999	3.5	6.3	5.0	6.8	9.6	12.6	11.6	10.8	9.6	6.6	2.9	4.6	7.5
5000 to 5999	0.5	2.0	0.6	1.8	4.0	4.6	3.7	4.2	2.5	1.1	0.5	1.4	2.2
6000 to 6999	0.1	0.4	0.1	0.5	0.8	1.2	1.1	1.5	0.8	0.5	0.1	0.2	0.6
7000 to 29999	0.0	0.0	0.1	0.0	0.1	0.3	0.0	0.3	0.1	0.2	0.0	0.0	0.1
All Obs	100	100	100	100	100	100	100	100	100	100	100	100	100

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Data provided by HAL, Note: 1 decametre = 10 metres

Mean Number of Days with Fog in each Season at Heathrow (1961-1990)

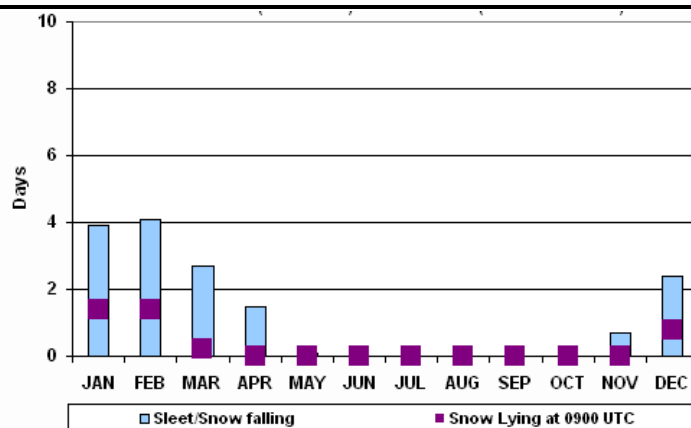
DJF	MAM	JJA	SON
5.0	1.0	0.3	4.7

Source: Met Office data cited by UKCP09 in their technical guidance note on fog⁽¹⁾

Fog conditions as observed at 0900

Winter is December, January and February (DJF), spring is March, April and May (MAM), summer is June, July and August (JJA) and autumn is September, October and November (SON).

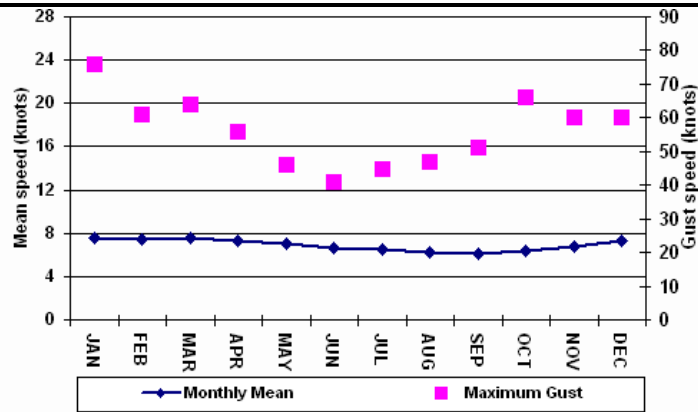
Average Number of Days of Sleet / Snow Falling and Snow Lying (1971-2000) at Heathrow



© Crown Copyright Met Office 2010

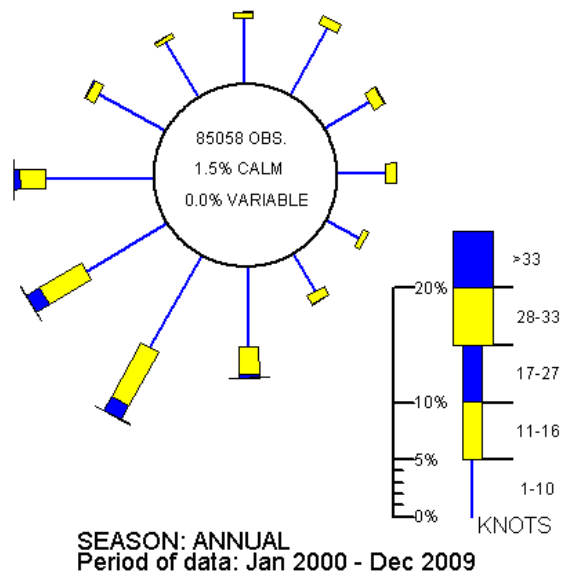
<http://www.metoffice.gov.uk/climate/uk/so/print.html>

Monthly Mean Wind Speed (1971-2000) and Maximum Gust (1959-2007) Recorded at Heathrow



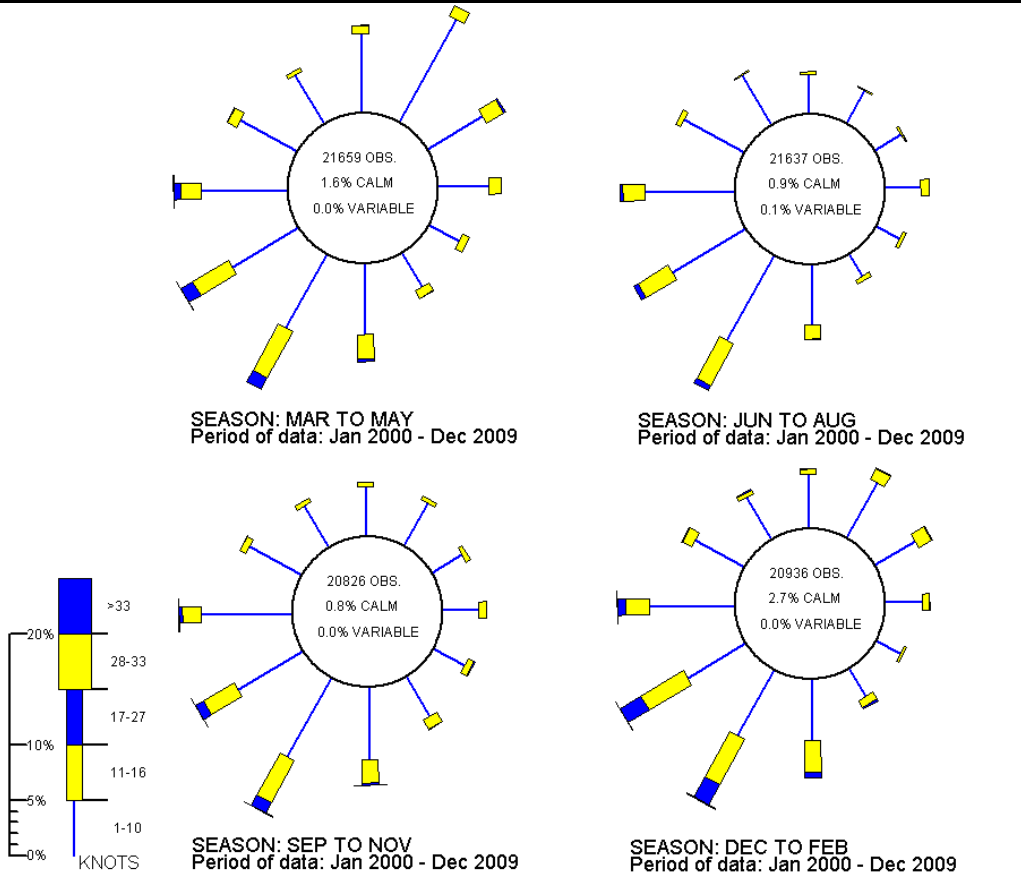
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<http://www.metoffice.gov.uk/climate/uk/so/print.html>

Annual Wind Rose Heathrow (2000-09)



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 Data provided by HAL

Seasonal Wind Rose for Heathrow (2000-2009)



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Data provided by HAL

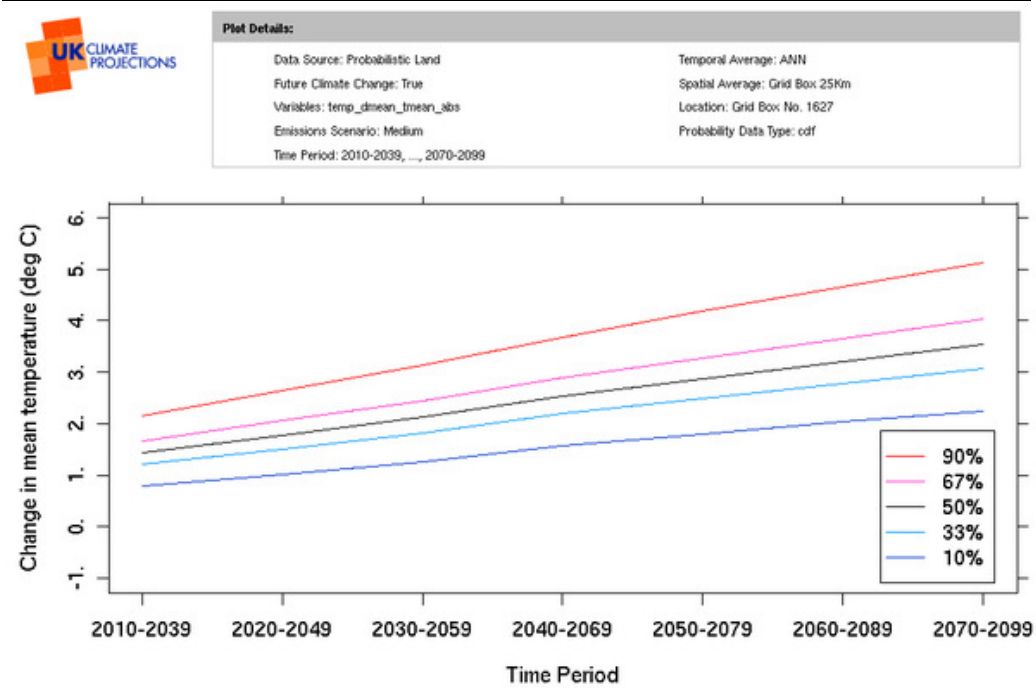
Annex (B)

UKCP09 Climate Change Projections – Technical Annex

CLIMATE CHANGE PROJECTIONS

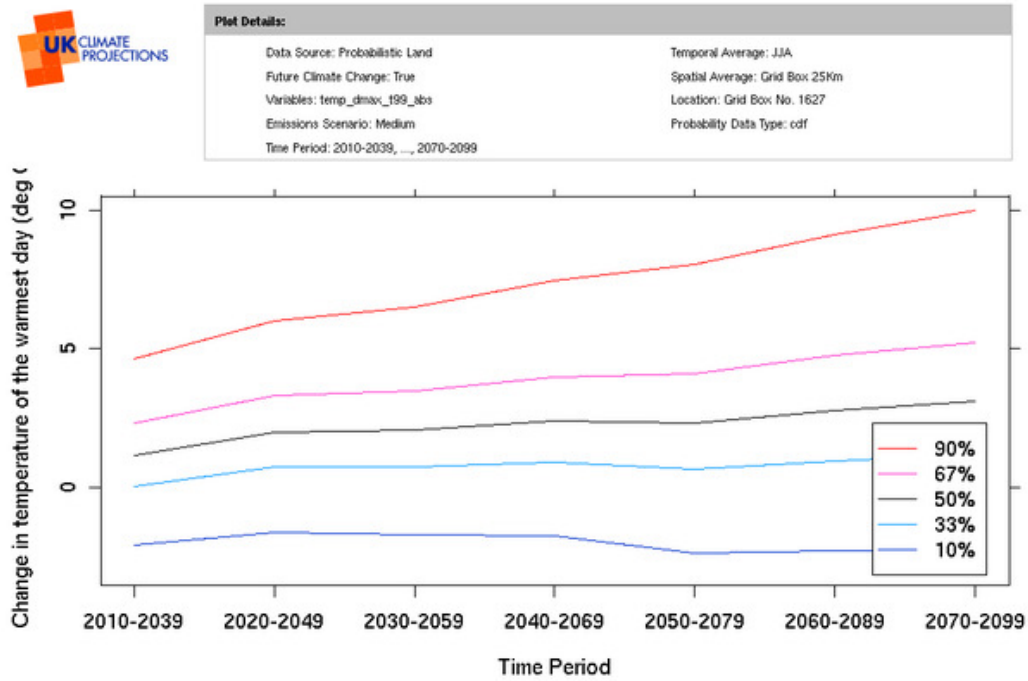
TEMPERATURE

Change in Annual Temporal Mean Air Temperature °C (Medium Emissions)

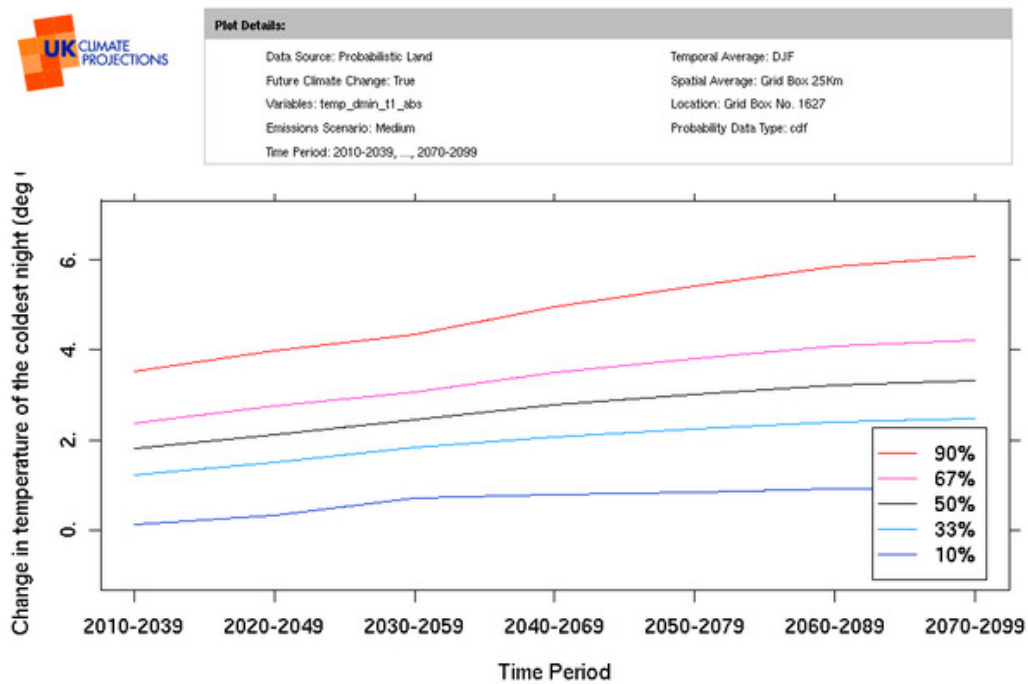


Source: UKCP09
As projected for 1.5m above ground level

Change in Temperature of the Warmest Summer Day °C (Medium Emissions)



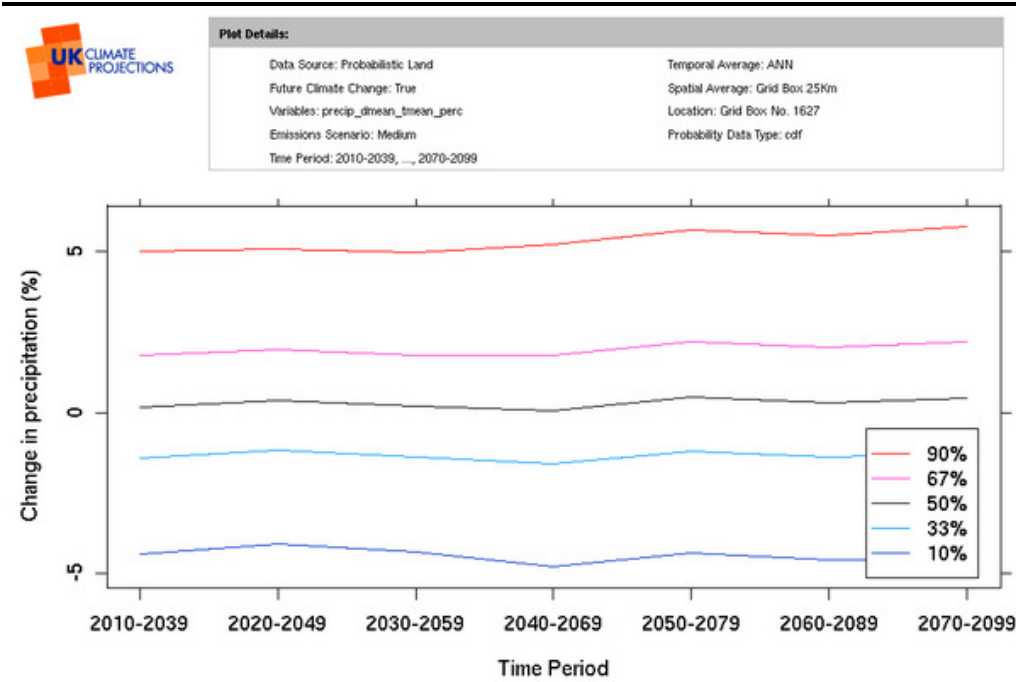
Change in Temperature of the Coldest Winter Night °C (Medium Emissions)



Source: UKCP09
As projected for 1.5m above ground level

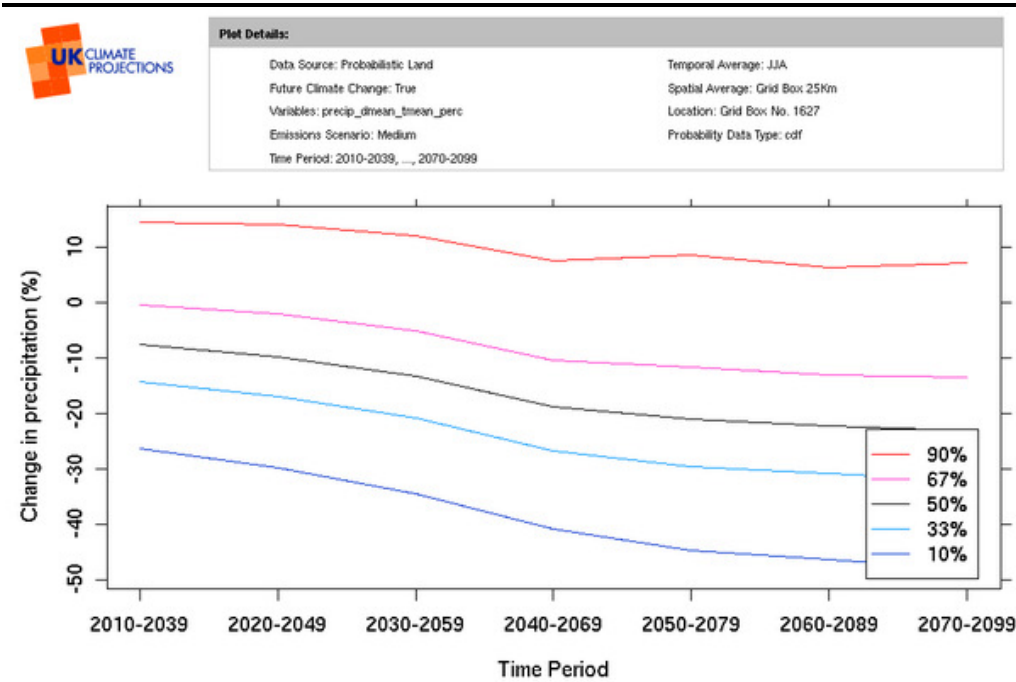
PRECIPITATION

Percentage Change in Annual Precipitation (Medium Emissions)



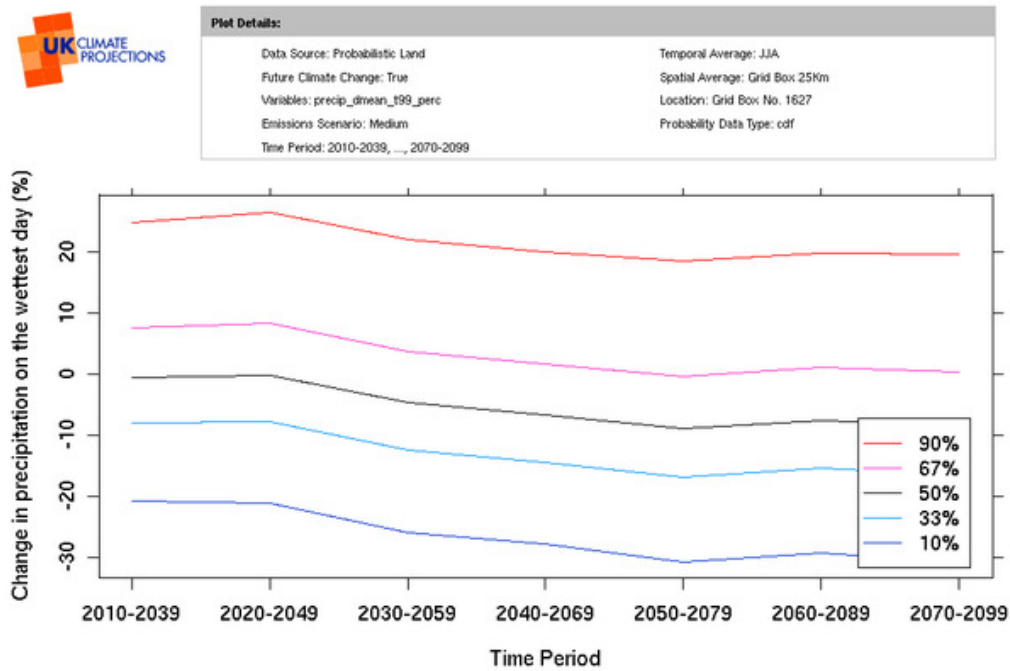
Source: UKCP09

Percentage Change in Summer Precipitation (Medium Emissions)



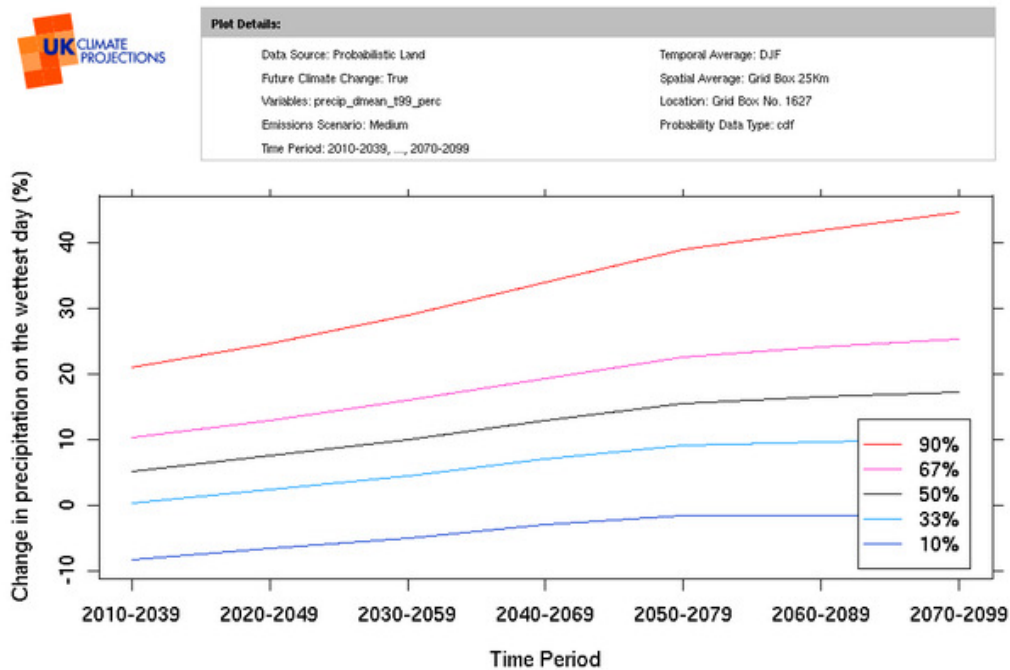
Source: UKCP09

Percentage Change in Precipitation on the Wettest Summer Day (Medium Emissions)



Source: UKCP09

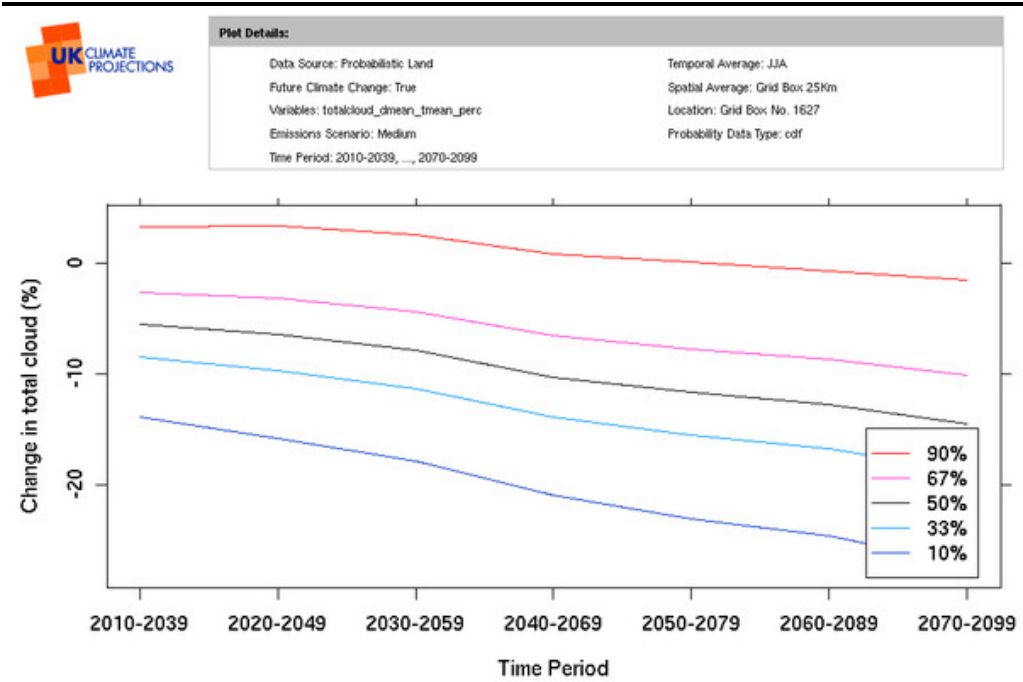
Percentage Change in Precipitation on the Wettest Winter Day (Medium Emissions)



Source: UKCP09

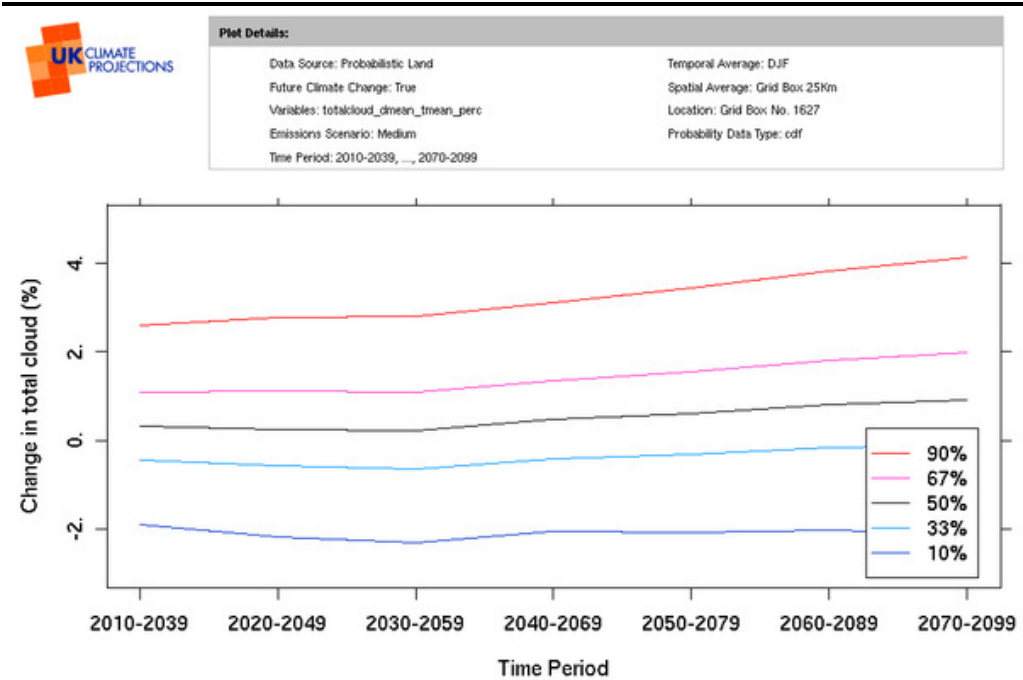
CLOUD COVER AND RELATIVE HUMIDITY

Percentage Change in Total Cloud Cover – Summer (Medium Emissions)



Source: UKCP09

Percentage Change in Total Cloud Cover – Winter (Medium Emissions)

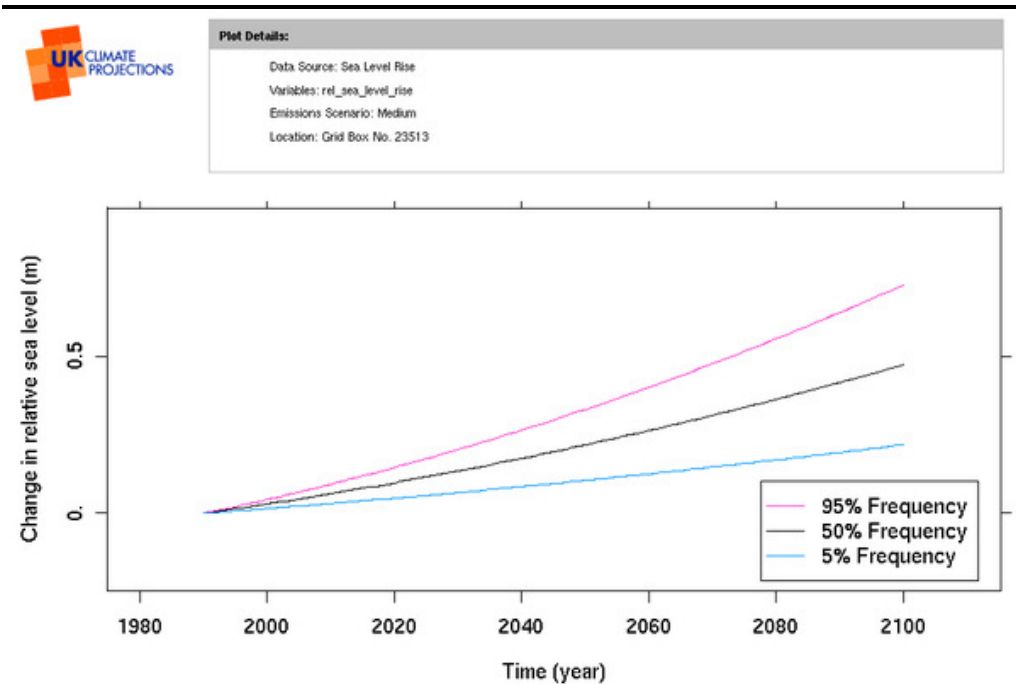


Source: UKCP09

SEA LEVEL RISE

* Note that these figures are based on AR4 modelling and do not include a contribution to sea level rise from polar ice cap melting. Sea level rise shown includes only the contribution from thermal expansion of sea water and loss of terrestrial non-polar ice cap.

Relative Sea Level Rise (Metres) (Medium Emissions)



Source: UKCP09

Sea Level Rise (SLR) Projections Post-AR4

Sea levels could rise by substantially more than the levels predicted by the Intergovernmental Panel on Climate Change (IPCC), according to the latest scientific research published since the IPCC's landmark 4th Assessment of climate change science was released in 2007. The IPCC's forecast of an average rise in global sea levels of 28-43cm by 2100 is now widely viewed to be too conservative by many in the scientific community as it is based on multiple models that all exclude ice sheet flow due to a (then) lack of published literature. Sea level rose at an average rate of about 1.8 mm/year during the years 1961-2003. The rise in sea level during 1993-2003 was at an average rate of 3.1 mm/year. The IPCC was unable to explain this acceleration in sea level rise (SLR), and unable to include the contribution to sea level rise from accelerated melting of polar ice sheets in the 4th Assessment report, because the processes involved were not understood at the time it went to press. In the interim several studies using a range of different methodologies, have been published which suggest that sea levels will rise much higher and faster than previously thought.

Some of the ranges of likely SLR from more recent research are illustrated in the table below:

IPCC and Alternative SLR Projections

SLR Projection Range	Reference
260mm to 590mm (2100)	IPCC Fourth Assessment Report (AR4)
800mm to 1,500mm (2100)	Jevrejeva, S., A. Grinsted, J. C. Moore and S. Holgate (2006): Nonlinear trends and multi-year cycle in sea level records, <i>Journal of Geophysical Research</i> , 111, 2005JC003229. Presented at European Geosciences Union Annual Meeting in 2008 ⁽¹⁾
500mm to 1,400mm above 1990 levels (2100)	Rahmstorf, S., A. Cazenave, J.A. Church, J.E. Hansen , R.F. Keeling , D.E. Parker , R.C. J. Somerville (2007) Recent Climate Observations Compared to Projections. <i>Science</i> DOI: 10.1126/science.1136843. February 1, 2007.
500mm above 1990 levels (2100) ⁽²⁾ 1420mm (2200) 7300mm (3000)	Institution of Mechanical Engineers, <i>Climate Change Adapting to the Inevitable?</i> , IMechE, London, UK, February 2009 using GENIE-1 and HadCM3L GCMs
1400mm (22 nd Century)	Herberger, M., H. Cooley, P. Herrera, P. Gleick, E. Moore, 2009: <i>The Impacts of Sea Level Rise on the California Coast</i> , Pacific Institute, Climate Change Center, USA ⁽³⁾
500mm to 600mm (2050), and 'multi-metre' (2100)	Hansen, J.E. (2007): Scientific reticence and sea level rise, <i>Environmental Research Letters</i> , 2:2, 024002, doi:10.1088/1748-9326/2/2/024002. Discussed in Hansen, J.E. (2007): <i>Climate Catastrophe</i> . <i>New Scientist</i> , July 28, 2007
800mm (most likely), up to 2,000mm (2100)	Pfeffer et al. (2008): Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise, <i>Science</i> , 321:5894, 1340-1343.

The UK Institution of Mechanical Engineers has recently published their professional opinion how infrastructure development should best progress within a framework of uncertain science which points toward considering long term impacts (i.e. several hundred years) for impacts such as sea level rise rather than short term perspectives which will require revision and which could lead to the construction of significant maladaptation. The likely long term changes to sea levels expected by the IMechE, and to which they recommend infrastructure is designed to, is illustrated in the figure below:

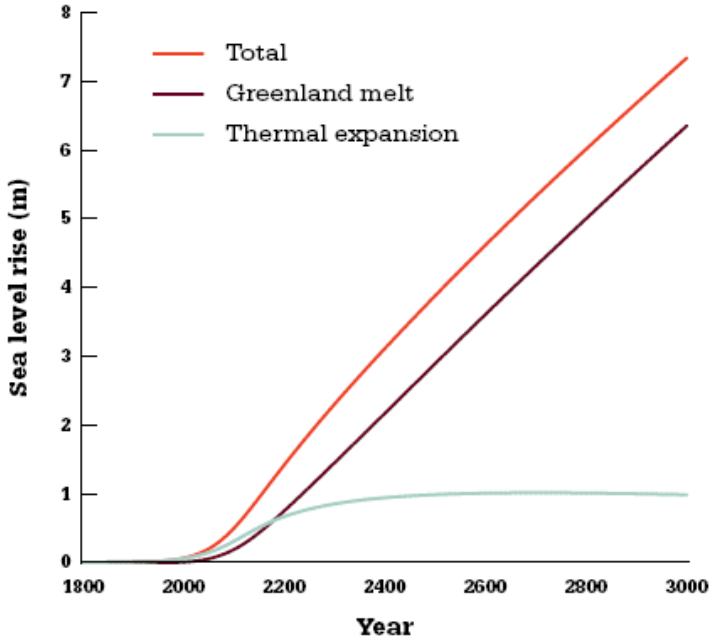
(1) Jevrejeva's comments on her own paper were quoted by the BBC: 'By the end of the century, we predict it will rise by between 0.8m and 1.5m. The rapid rise in the coming years is associated with the rapid melting of ice sheets.' comments can be found at:

<http://news.bbc.co.uk/1/hi/sci/tech/7349236.stm>

(2) Thermal expansion of the ocean is estimated to contribute 310mm of SLR and the melting of the Greenland icesheet is estimated to contribute 190mm, and the authors of the report note that this is likely to be an underestimate because the melting of smaller

(3) http://www.pacinst.org/reports/sea_level_rise/report.pdf

Sea Level Rise Projections (Institute of Mechanical Engineers)



Source: IMechE, 2009

Annex (C)

Pro-Forma for Heathrow Stakeholder Interviews

PRO-FORMA QUESTIONS FOR STAKEHOLDER INTERVIEWS

Operations

Generic Questions:

- In what way does current weather and climate affect your part of the business?
- Can you recall any occasions when a weather event has had an impact on your role/actions?
- How 'resilient' to weather and climate is your part of HAL's business?
- Do you perceive that the future climate will influence the operation of Heathrow airport? Will it bring any opportunities?
- Do you have any suggestions on how your part of the business could adapt to a changing climate or extreme weather events?

Capital Investment Programme

- Is climate change or extreme weather incorporated into the future investment programmes for Heathrow?
- If so, what is the basis for the adaptation measure?
- If not, is this a deliberate decision?
- How far into the future is the planning horizon for Heathrow?

Stakeholders/Supply Chain

- Is your interaction with Heathrow Airport dependent upon, or affected by, weather and climate?
- Are there any specific events you can recall where a weather event has had an affect on your involvement with the airport?
- Do you believe that the future climate will have an effect on operations at Heathrow Airport?
- Are there any measures that can be implemented to make the airport, or your interaction with it, more resilient?

Supplementary Questions (As appropriate)

In what way does current weather and climate affect your part of the business? Do you think your part of business responds well to the current climate?

Can you recall any occasions when a weather event has had an impact on your role/actions?

Can you recall any occasions when a weather event caused a 'near miss' that could potentially have had an impact on your role / actions / assets?

What are the 'weakest links' in the operations that you work in / oversee?

What has worked well in the past when climatic disruption has occurred, what does Heathrow do well at times like this?

Are there any plans to boost the resilience to climatic disruption of the area you work in?

What are your big concerns regarding how climate change could impact on your day to day work? Have you raised your concerns, and if so, are they being taken seriously?

Do you record in a systematic manner when a weather-related interruption has occurred or when the weather has impacted on your role / actions / assets? Are lessons learned from past events and used to shape future procedures?

How are you and your team informed that weather conditions are predicted that could lead to changes to your working practices on a given day? Who is empowered to make decisions that affect how operations respond to the weather on a day to day basis? Are existing information systems warning of climatic extremes adequate?

Could you explain how the weather defines the activities / operations undertaken in your part of the business? Does your role change? What activities are undertaken that are specific to certain weather conditions (ie during heavy snow, hot weather, periods of heavy precipitation, frost etc), and what thresholds are used to define when an activity or operation changes to meet the weather conditions.

What are the implications in terms of direct and indirect consequences of these changes to activities / operations? Are there existing protocols that you follow? Does this involve working with different teams, assets, external partners etc?

How robust is the basic infrastructure at Heathrow in terms of coping with the existing climate? I.e. drainage, staff-transit systems, IT / 'comms', electricity supply, gas supply, heating, cooling, etc

How 'resilient' to weather and climate is your part of HAL's business?

What contingencies do you have in place to deal with climatic disruption?

Is there much 'spare capacity' to deal with climatic disruption in your team / operation?

What activities, assets, locales, interdependencies on the site seem to be most vulnerable from your perspective / experience?

What is the most important element of your job? Is your 'key deliverable' something that is impacted by the weather?

Have climatic events in locations remote from / external to the airport affected your role?

Do you perceive that the future climate will influence the operation of Heathrow airport? Will it bring any opportunities?

Have you witnessed the impact of what you perceive to be 'climate change' on the airport already? Please discuss in terms of both extreme events and gradual change where possible.

Do you have any suggestions on how your part of the business could adapt to a changing climate or extreme weather events?

Are there any obstacles or barriers that prevent greater resilience to the climate or adaptation to climate change?

Is there anyone else that you think we should be speaking to?

Annex (D)

Consultees

STAKEHOLDER CONSULTEES

Job Title	Organisation
Environmental Assurance Manager	BAA (Edinburgh Airport)
Transport Manager	BAA (HAL)
Campus Security Director	BAA (HAL)
Head of Environmental Compliance	BAA (HAL)
Head of Climate Change	BAA (HAL)
Head of Engineering Technical Leadership	BAA (HAL)
Facilities Manager, T1	BAA (HAL)
Corporate Responsibility & Environment Director	BAA (HAL)
Health and Safety Manager	BAA (HAL)
Head of Risk & Business Continuity	BAA (HAL)
Environment Manager	British Airways
Head of Health, Safety and Environment	BAA (Stansted Airport)
Health and Safety Manager	BAA (HAL)
Water Resources Manager	BAA (HAL)
Heathrow ATC Manager	National Air Traffic Services (NATS)
Risk and Safety Management Director	BAA (HAL)
Head of Airside Assurance	BAA (HAL)
Environmental Assurance Manager	BAA (Glasgow Airport)
Landside Masterplanning	BAA (HAL)
Facilities Manager	BAA (HAL)
Business Assurance Manager	BAA (Heathrow Express)
Head of Ramp Operations and Ground Handling	BAA (HAL)
Chief Fire Officer	BAA (HAL)
Operations Director, T5	BAA (HAL)
Engineering & Landside Facilities Manager	BAA (HAL)
Strategy and Environment Manager	British Airways
Health and Safety Manager	BAA (HAL)
Group Engineering Director	BAA (HAL)
Civil Protection Manager	London Borough of Hillingdon
Head of Waste, Water and Land Quality	BAA (HAL)
Facilities Manager – Connections and Baggage	BAA (HAL)
Head of Heathrow Property Services	BAA (HAL)
Head of Business Resilience	British Airways
Portfolio Technical Leader	BAA (HAL)
Airside Environment Manager	BAA (HAL)
Environmental Compliance Manager	BAA (HAL)
Engineering Projects Manager	BAA (Heathrow Express)
Head of Airside	BAA (HAL)
Environment and Climate Change Coordinator	Transport for London (TfL)
Project Manager (Liaison Officer for Heathrow)	Environment Agency (EA)

Annex (E)

Heathrow Winter Resilience Enquiry – Recommendations

RECOMMENDATIONS OF THE HEATHROW WINTER RESILIENCE ENQUIRY

INTRODUCTION

The recommendations put forward by the Heathrow Winter Resilience Enquiry were presented under four themes:

- Preparation and Planning: how can the Heathrow community plan for events like the snowfall of December 2010 to minimise their impact?
- Command and Control: how should BAA and the Heathrow Community direct and control serious weather related disruption events like this better?
- Communications: how can all parties (passengers, airlines and BAA) get better information on what is happening?
- Passenger Welfare: how can welfare for stranded passengers be improved?

RECOMMENDATIONS

Recommendation 1:

The panel recommends that BAA work with airlines, NATS and the CAA to agree an enhanced snow plan. This should seek to ensure that Heathrow never closes for circumstances under its control, except for safety or other emergency situations. The snow plan should adopt a systems approach and should define, for a broad range of expected snow events, the tasks, priorities, resources and operating standards that should apply. The plan should:

- Be tailored to the Heathrow environment, recognising the high occupancy levels, capacity constraints and stand configurations;
- Address a broader range of snow and cold conditions than the current plan, taking into account current scientific advice on future climate;
- Describe clearly the sequence of clearance for specific weather and runway use scenarios, the direction of vehicle movements, giving priority to runway clearance, then taxiway and stand clearance;
- Define the processes, specialised equipment, resources and logistical requirements that are needed to achieve these plans;
- Define the locations for storing and, if possible, recycling media from contaminated snow;
- BAA should continue to rely on multiple weather forecasts and should routinely assume the worst forecast;
- Establish an operating instruction that specifies clearly the role of ground handlers, airlines and BAA in cold weather and defines the standards for aircraft de-icing clearing operations from stands.

Recommendation 2:

The Panel recommends that BAA work with airlines, NATS and other relevant stakeholders to review and invest in the aircraft de-icing processes and infrastructure to ensure the airport can maintain its flow rate in inclement weather. Consideration should be given to reviewing the slot procedure in conditions of freezing precipitation to support remote de-icing procedures

Recommendation 3:

The panel recommends that BAA, together with the airlines and other relevant stakeholders, establish processes continuously to review its snow plan through regular review, external review, benchmarking, desk and field rehearsals and post-event reviews. BAA should work closely with the Met Office to understand better the expected impact of climate change on the airport. Every year, HAL should review its snow plan and establish the level of contingent resources required for the execution of the snow plan, that are needed to supplement permanent airport staff and other airside workers. The snow plan should be reviewed at the BAA Executive Committee each year.

Recommendation 4:

The panel recommends that at an early stage, when a forecast indicates a possible snow event, BAA should hold a Snow Contingency Meeting with the airlines, their ground handlers, NATS and the AOC to plan an effective response and contingencies.

Recommendation 5:

The panel recommends that BAA dynamically maintain its levels of stock of anti-icing/de-icing media and other emergency supplies at levels that are driven by the forecast weather, expected rate of use, reliability of supply, and other factors.

Recommendation 6:

The panel recommends that:

- there is a need for BAA to adapt its approach to emergency planning response and recovery to better align with best practice. It should involve simplifying BAA's Crisis Management process to the standard three tier process, used by central, regional and local government and the emergency services across the UK. Staff in BAA and stakeholders should be trained in the new structure and the different roles they play in it;
- key stakeholders (e.g. airlines, Met Police etc.) be automatically invited at the appropriate level as members of the new "Gold" "Silver" and "Bronze" crisis teams;
- wherever practical, and where time permits, decisions critical to airport status (e.g. flow rate restrictions) be made in consultation with key Heathrow stakeholders;
- the "Silver" command team automatically include BAA representatives from Communications and IT and a representative dedicated to Passenger Welfare;
- all crisis teams use an advanced web-based Incident Management System to record decisions, events and communicate with other teams;
- sufficient resources be made available to support the crisis management process;
- BAA needs to establish a formal, disciplined communications structure with clear interfaces between BAA, airlines, NATS and other appropriate parties;
- the BAA Crisis Management Process be the responsibility of the CEO and should be reviewed at least annually with the Board;
- all the above processes are tested regularly with relevant stakeholders.

Recommendation 7:

The Panel recommends that triggers for escalation should be defined that are clear and ensure early deployment of the higher level command and control structures. Any forecast snow event of a material size should automatically trigger:

- The implementation of the snow contingency process, including holding a snow contingency meeting, the mobilisation of the "snow cell" with BAA, airlines and their ground handlers, NATS and ACL representation. The snow cell, once activated should remain fully operational and functional until the event is over and operations have normalised. The snow cell should not be deactivated without a closing debriefing with stakeholders;
- The notification of non-operational staff and contractors that they may be called up (subject to prior contractual agreement);
- The invocation of the Bronze, Silver or Gold Command depending on the nature and expected severity of the event;
- The mobilisation of the Capacity Constraints Group as soon as it is clear that Heathrow is expected to have an extended period of constrained capacity (see below);
- The planned and rehearsed terminal congestion response (referred to later), including the early erection of marquees, and the procurement of heating, hot food, water, phone chargers, and computers for rebooking;
- Accelerated clearance (with prior DfT agreement) of access rights for any staff or contractors expected to work airside;
- A constant review of the level of escalation by the "Gold Commander".

Recommendation 8:

The Panel recommends that the Capacity Constraints Group (CCG) be strengthened and formally recognised as the preferred mechanism for establishing an emergency timetable in times of crisis. This group should be formed as soon as it is clear that Heathrow is expected to have an extended period of constrained capacity and that its authority to maintain an emergency timetable be recognised explicitly in the Conditions of Use. As part of an airline's Condition of Use, there should be an obligation to operate under the agreed emergency timetable and implement this through its own operational systems so that passengers get a consistent status.

The CCG should be charged with restoring flow rate to the airport as quickly as possible given the current status of the airport and the need to operate safely.

The CCG should be chaired by a dedicated BAA official who should be designated as the lead to drive joint decision-making with NATS, airlines, the AOC and ACL

Recommendation 9:

The panel recommends that steps be taken – by BAA and airlines – to ensure that every crisis response team has sufficient on-call dedicated resources rostered to enable it to function 24 x 7 for a sustained period. Such staff need to be trained and competent, and have the necessary leadership skills, to do that role in the event of a crisis.

Recommendation 10:

The panel recommends that:

- There should be a review of the process through which airport status changes and capacity constraint agreements are converted into updated airline flight schedules, and subsequently published on the websites of airlines and BAA, and on terminal flight information display screens. It is essential that these are undertaken in a timely manner which is agreed as acceptable by all parties. The agreed process should be tested regularly;
- Clear agreement should be established between BAA and the airlines serving Heathrow on the manner in which decisions concerning flight status will be taken and communicated to passengers, media, governments and the public at large;
- BAA should have the authority to control flight information in terminals during emergencies to ensure there is a single authoritative source of information;
- Airlines should seek to increase their website and rebooking capacity at times of disruption;
- BAA should work with airlines and NATS to improve the clarity and accuracy of global media communications.

Recommendation 11:

The panel recommends that:

- A physical control centre should be established for the management of major incidents (at "Silver" level), where parties can convene to combine situational awareness with face-to-face communications. Consideration should be given immediately to co-locating the CST and STAR rooms;
- HAL's communication infrastructure should be centralised under one unified Airport Communication and Control Centre that utilises advanced technology to optimise situational awareness, facilitate informed decision-making, and enhance communication with key stakeholders. Technology should include real-time video displays of the airfield (including aircraft and vehicle locations), terminals, and landside areas. Hardware technology should be supported with software analytics, including advanced Incident Management Systems to facilitate improved communications, logging and better problem resolution and to normalise operations as soon as possible;
- An improved control centre should be established for the Bronze Airside LBRT that provides improved CCTV, stand status reporting, and weather telemetry.

Recommendation 12:

The Panel recommends that:

- Heathrow should plan for new systems that use real-time digital CCTV and telemetry to create a real-time and integrated visualisation of airport status and a forward picture of airfield performance;
 - The status of the airfield, terminal and landside areas should be available to key BAA and stakeholder executives through a secure, web-based system that can be readily accessed from remote global locations;
 - Heathrow needs a real-time incident management system available to all stakeholders that tracks and supports decision making.
-

Recommendation 13:

The Panel recommends that the CAA Inquiry establishes how responsibilities under EC Regulation 261/2004 will be enforced and what rights and obligations are placed on an airport in the event of relevant parties failing to comply with those responsibilities.

Until this is complete, the panel recommends that BAA, airlines and the CAA seek to strengthen the current informal agreement to ensure that passengers do not experience distress at times of emergency and that the respective roles and responsibilities of all parties are clear.

Recommendation 14:

The panel recommends that BAA – together with airlines and retailers – prepare and routinely test a sustainable welfare plan that can be triggered immediately in the event of an emergency. The plan needs to:

- Ensure that sufficient persons from BAA, airlines and their agents, and retailers are available at Heathrow to support welfare and hotel booking, manage congestion and support rebooking;
- Mobilise BAA staff to the terminal for which they have been trained;
- Mobilise resources and supplies to retail outlets and provide extra resources to maintain hygiene facilities;
- Provide systems which give all staff timely, accurate and authoritative information on flight and airport status;
- Enable easy and clear communications to passengers in terminals on airport status;
- Allow passenger communications in a number of languages.

All airlines need to be engaged in this plan and need to commit to working together in order to have adequate resources on site. Terminal messages need to be coordinated with airline stakeholders to ensure consistency and clarity.

FURTHER INFORMATION

The full report of the Heathrow Winter Resilience Enquiry is available online and can be found at:

<http://www.heathrowenquiry.com/>

and

http://www.baa.com/assets/Internet/BAA%20Airports/Downloads/Static%20files/Be ggReport220311_BAA.pdf