Water
Climate Change Impacts

Report Card 2016

This updated report card is for anyone who works with or has an interest in water in the UK. It looks at the effect of climate change on fresh water from source to sea – including rainfall, floods and droughts. The report card is intended to help people understand the scale of possible change and to help inform decisions about the way that water is managed. The report card looks forward over the rest of the 21st century.

Water is an essential and familiar part of everyday life, at home, at work and at leisure. Water is also at the heart of some of the most serious natural hazards faced in the UK – floods and droughts. Climate change may have many impacts on water; while some may be beneficial or easily managed, others require careful planning to avoid unacceptable consequences.

This report card is the 2016 update to the 2012-13 version. The update considers the scientific evidence published since 2013, as well as including new sections on snow, urban water, and estuaries. It complements other UK climate change report cards: the Marine Climate Change Impacts Partnership (MCCIP) marine report card and the Living With Environmental Change (LWEC) series that covers biodiversity, infrastructure, human health, and agriculture and forestry. Together these report cards provide a picture of past and future impacts of climate change in the UK.

The report card covers the following topics:

- Temperature
- Rainfall
- Sea level
- Evapotranspiration – water that evaporates or is transpired by trees and other plants
- River flows
- Droughts
- Groundwater recharge and levels
- River water temperature
- River water quality and ecology
- Groundwater temperature and quality
- Water use
- Snow
- Urban Hydrology
- Estuaries

The climate is changing

Global average temperature increased over the 20th century, with the greatest warming in northern latitudes. Globally, 2015 was the hottest year on record, over 1°C warmer than the pre-industrial average. Global sea level is rising at about 3 mm every year. Across northern Europe rainfall increased significantly over the 20th century, with a decrease in rainfall in the Mediterranean region.

The UK climate is changing too

All of the ten warmest years in the UK record that starts in 1910 have occurred since 1990, and 2014 was the hottest year on record in the UK. Average annual rainfall has not changed since records began in the 18th century, but in the last 50 years more winter rainfall has fallen in heavy events. This trend towards more rainfall falling in heavy events is expected to continue, and average winter rainfall may increase. The picture for summer rainfall is less clear. Sea level rise is increasing the risk of storm surges: sea level will continue to rise through the rest of the 21st century, by up to 1 m. As the climate changes UK summer temperatures may increase by up to 4°C by the 2080s.

Many people will experience climate change through its effects on water

In the UK, many people will experience climate change through its effects on water, and especially through floods and droughts. We expect more, bigger floods particularly during winter. Summer flash flooding may become more common. Rising sea levels will increase the risk of damage from storm surges. Average summer river flows may decrease across the UK, leading to reduced water availability and lower river water quality.

Planning for future impacts will help to avoid unacceptable consequences

Actions to adapt to climate change must consider the scale of the possible change, the uncertainties in projections of the future, and the variability of the UK climate. Flexible solutions that can deal with a range of weather will often be the best way forward. Many actions will take many years to design and implement. This means that we need to anticipate future changes and start to take steps to adapt to them now, despite uncertainties in future projections.

What has changed since the previous water report card?

The format and contents of this new edition of the water report card will be familiar, as it builds on the previous card. Most of the previous findings remain valid, but in some areas new research adds detail or provides additional confidence. For this revised card, we commissioned a new paper to examine all the relevant new research. We have also added coverage of three new themes, each supported by a new working paper: snow and snowmelt, urban hydrology, and estuaries. This whole section has been reviewed and revised to reflect the latest understanding of climate change impacts in the UK. In line with the new report cards published since the first water climate impacts report card, we have changed the way that confidence is reported. We have also added new statements explaining the link between observed changes and anthropogenic climate change. We have also updated some of the other parts of this document, expanding the 2012-13 report card's section on uses of water to cover water more widely and adding further information on recent weather patterns and events. The report card has been reordered to make it easier to find the main results. The availability of a new global assessment from Intergovernmental Panel on Climate Change (IPCC) gives additional confidence in global changes, and new observations confirm global and regional trends in some climate variables.

How was the report card developed?

This water report card was an initiative of the Living With Environmental Change (LWEC) Network. LWEC was succeeded in 2016 by the Research and Innovation for our Dynamic Environment (RIDE) Forum. The forum brings together 21 public sector organisations with a stake in environmental change research, innovation, training and capabilities and aims to ensure that decision-makers in government, business and society have the knowledge they need to respond to the challenges and opportunities presented by environmental change.

The report card is supported by a series of detailed scientific working papers. These were written by leading experts in their fields, underpinning the report card with the best available science from the peer-reviewed literature.

This high-level summary and the technical summary papers have been reviewed by a group of independent experts to assure their quality. Many of the working papers have been developed into peer-reviewed publications in the academic literature, confirming that the report card is based on sound science. The report card and working papers are available from the RIDE website.

Drinking water quality in the UK is among the highest in the world. In England and Wales in 2014, there was a **99.96%** compliance rate with UK and European standards for drinking water quality.

The cost of the 2013/14 flooding to the insurance industry was estimated to be **£1.5 billion**

In 2013 more than **1 million** anglers purchased rod licences to fish in the UK.

Retrofitting a property with water resistant plaster could cost as much as **£8200**, compared to **£3240** for a new-build.

The **spring of 2011** was exceptionally dry across the UK, with **wildfires** affecting parts of Highland Scotland, Northern Ireland, mid-Wales, Lancashire and Berkshire.

The winter of 2013 and 2014 was the wettest on record, with over **8,330** homes and nearly **4,800** commercial properties affected by flooding in England. in the same period, more than **1.4 million** properties were protected from flooding.

Low rainfall between January and June 2010 and the resulting low reservoir levels let to a hosepipe ban in north-west England, affecting **six million** consumers.

The Office for National Statistics estimated that in 2012 the monetary value of UK freshwater systems was **£39.5 billion** covering all wetlands and water-bodies.

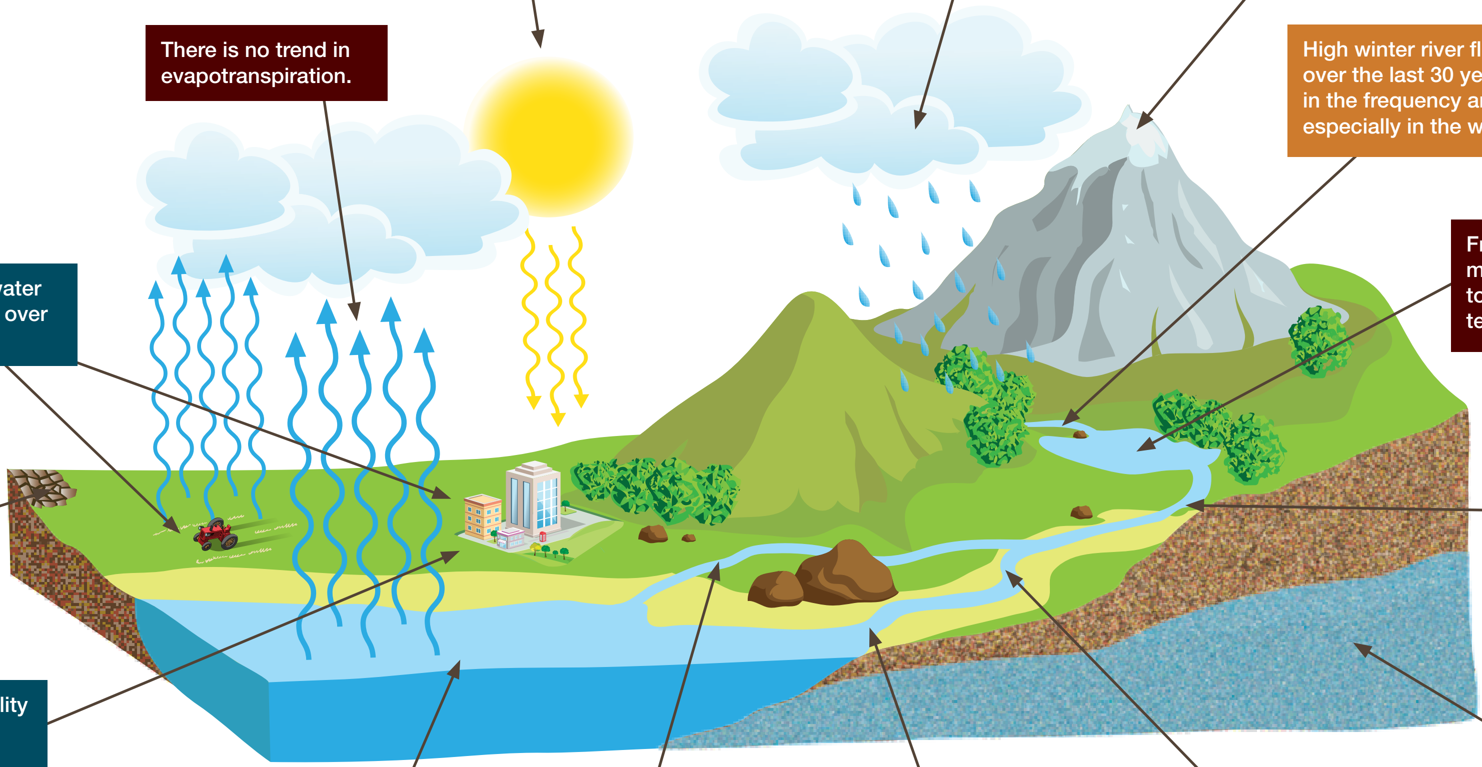
On average, a person in the UK uses **150 litres** of water every day.

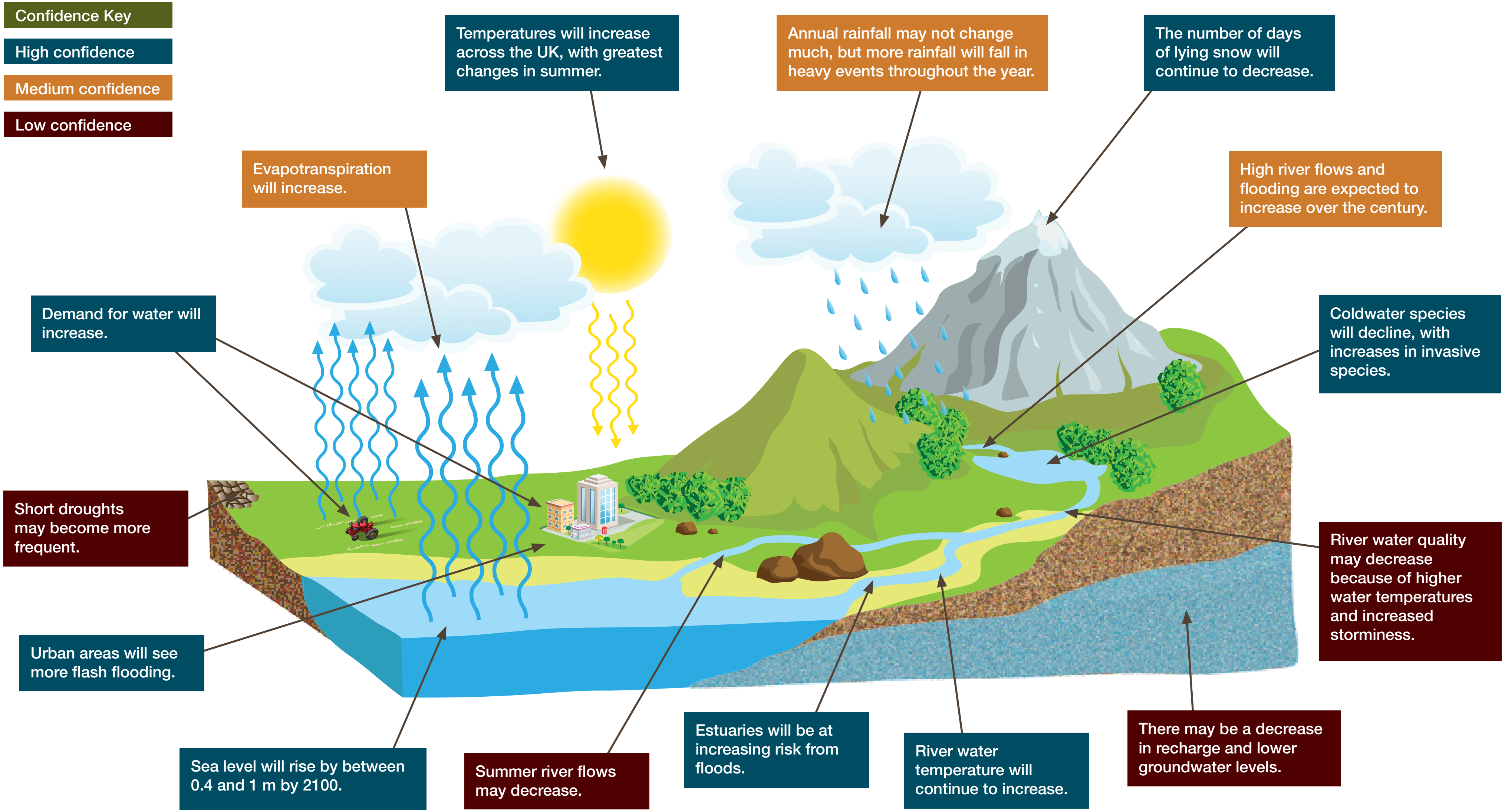
Around **5.2 million** properties in England are at risk of flooding from rivers or the sea.

What is happening

Confidence Key

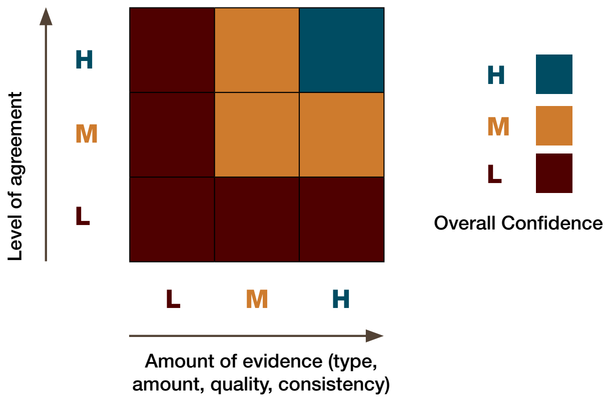
- High confidence
- Medium confidence
- Low confidence




Confidence Key
High confidence
Medium confidence
Low confidence
Temperatures will increase across the UK, with greatest changes in summer.
Annual rainfall may not change much, but more rainfall will fall in heavy events throughout the year.
The number of days of lying snow will continue to decrease.
Evapotranspiration will increase.
High river flows and flooding are expected to increase over the century.
Demand for water will increase.
Coldwater species will decline, with increases in invasive species.
Short droughts may become more frequent.
River water quality may decrease because of higher water temperatures and increased storminess.
Urban areas will see more flash flooding.
Sea level will rise by between 0.4 and 1 m by 2100.
Summer river flows may decrease.
Estuaries will be at increasing risk from floods.
River water temperature will continue to increase.
There may be a decrease in recharge and lower groundwater levels.

Confidence

We have attached a confidence level – high, medium or low – to each of the statements of change. This confidence level, assigned by scientific experts, reflects both the degree of agreement of scientific studies and the amount of information available. For example, we would have low confidence in any conclusion drawn from a few studies or where findings were inconsistent, but high confidence where a large number of investigations led to the same conclusion. In a change from the previous card, the confidence level is now specifically about how confident we are in the preceding statement, rather than in the link to climate change. This change is for consistency with the other report cards.



The Report Card has simplified the assessments to provide an overall confidence level of high (H), medium (M) or low (L). Low confidence results are still based on evidence and still reflect expert judgment.

Attribution

Are observed changes the result of anthropogenic climate change? Attributing environmental change to climate change is a fast-moving area of research. The main method compares observed changes with modelled changes with and without increased levels of greenhouse gases in the atmosphere. This approach, called "optimal fingerprinting", has been used to look at long-term changes, for example in global temperature.

A similar approach can be used to understand the changing probability of extreme events as a result of climate change. Here many thousands of climate model runs are performed with and without increased levels of greenhouse gases. The change in the frequency of the extreme event under investigation shows how much more or less likely such an event has become due to climate change. This is known as "fractional attribution".

In this edition of the report card we have added a new commentary with the title "Attributed to climate change?" Here we explain whether observed changes have been linked formally to anthropogenic climate change using these methods. We have also noted some changes that are consistent with anthropogenic climate change. Where this link has not been tested it is important to note that such consistency could be coincidental or a response to other non-climate factors. Where a link to anthropogenic climate change has not yet been found, it could be because there has been no response to climate change, because there has been a response but that it too small to detect, or because there has not been a suitable study.

High Confidence ■H
Medium Confidence ■M
Low Confidence ■L

Air temperature

What has happened

All ten of the warmest years on record in the UK have occurred since 1990 ■H. 2014 was the hottest year on record so far for the UK ■H. The decade from 2005 to 2014 was on average 0.4°C warmer than the 1981-2010 average, and 0.9°C warmer than the 1961-1990 average ■H.

Attributed to climate change?

Yes: it is thought that warming in the UK is a response to anthropogenic climate change, in line with global temperature changes. This increasing temperature has also increased the likelihood of record warm years.

What could happen

Temperatures will increase across the UK, with the greatest changes in summer. Latest UK projections suggest summer increases of up to 4°C in the south and 2.5°C in the north by the 2080s (■H that temperatures will increase, ■M in this range). The rate of temperature change will be determined by the level of greenhouse gas emissions ■H.

Rainfall

Rainfall varies from year to year but there is no significant trend in annual average rainfall for England and Wales in the long series that began in the 1760s ■H.

Winter rainfall in Scotland and parts of northern England has increased in the last 50 years ■M. Over the last fifty years, more winter rain has been falling in heavy events across the UK ■M.

Summer rainfall varies greatly but appears to have decreased in England and Wales since the 1760s, although the trend is hard to quantify ■L.

Attributed to climate change?

Not at the UK scale, although increases in heavy rain are consistent with a warming atmosphere, which can hold more moisture. Early work suggests that the very heavy rainfall of winter 2015 was more likely as a result of anthropogenic climate change. Globally, anthropogenic climate change is thought to have increased the intensity of extreme rainfall.

The 2009 UK climate projections suggested that UK annual average rainfall may not change much over the 21st century ■M. The same projections suggested summer rainfall reductions, especially in the south of England, but more recent climate models suggest that average summer rainfall is unlikely to change much in the UK (■L in changes to summer rainfall). The trend towards more rainfall falling in heavy, more intense events is expected to continue ■M. Higher temperatures are also expected to lead to increased convective high-intensity rainfall, including thunderstorms ■M.

Sea level

What has happened

Sea level around the UK rose on average by 1 to 2 mm per year during the 20th century ■**H**. The rate has increased and was over 3 mm per year in the last decade ■**H**. The UK land surface is also moving slowly, with Scotland rising by about 1 mm per year and southern England sinking by about 0.5 mm per year ■**H**. This means that the effect of sea-level rise is greatest in the south of the UK ■**H**.

Attributed to climate change?

Global sea level is rising as a response to anthropogenic climate change: warmer oceans have a greater volume, and ice is melting from land glaciers. UK sea level rise is consistent with global change but this has not been attributed to climate change because detection of human influences on sea level at the regional scale is difficult.

What could happen

Sea level will continue to rise around the UK, probably at a faster rate than experienced in recent decades ■**H**. By the end of the century, sea level is expected to rise by between 0.4 and 1 m above the 1990 level (■**H** confidence that sea level rise will be greater than 0.4 m; ■**H** confidence that 1 m is an upper limit this century).

Evapotranspiration

What has happened

Little is known about how evapotranspiration has changed over time (■**L** in historical trends).

Attributed to climate change?

No attribution studies exist for the UK.

What could happen

Potential evapotranspiration is expected to increase in response to increased air temperatures ■**M**.

What has happened

River flows

Annual total river flow has increased since the 1960s in Scotland, Wales and parts of northern and western England ■H; in contrast, no pronounced changes have occurred in the lowlands of south east England ■H.

Winter flows have increased in upland, western catchments ■H. Autumn flows have increased in central England and parts of eastern Scotland ■H. There is no apparent pattern of change in summer flows across the UK (■L in understanding of patterns of summer change).

Over the last 30 years, high winter flows have increased and there has been an increase in the frequency and magnitude of flooding, particularly in the west and north ■M.

There is little evidence of changes in very low flows (■L in understanding of changes in low flows).

Attributed to climate change?

Changes in UK river flows have not been attributed to anthropogenic climate change; there are periods of high and low flows throughout the UK record. The UK floods of winter 2000 and summer 2007 are thought to have been made more likely by climate change, and recent preliminary work suggests that the heavy rain and consequent flooding in December 2015 may have been more likely because of anthropogenic climate change.

What could happen

Projections of future river flow are uncertain because of uncertainties in both future rainfall and evapotranspiration. Studies tend to agree on a trend towards similar or increased average winter flows ■M and reduced average summer flows ■L, with mixed patterns in spring and autumn ■L.

High flows and flooding are expected to increase over the 21st century because of increased rainfall, particularly in winter ■M. Increased convective rainfall would lead to more flash flooding (■M in increased convective rainfall, ■H in flash flood as a response to convective rainfall).

Droughts

There is no trend in UK droughts; some 19th century droughts were longer than those of the 20th century (■M that there is no trend in droughts).

Attributed to climate change?

There is no work linking UK droughts to climate change, though the very hot European summer of 2003 is thought to have been made worse by climate change.

Some studies indicate increases in the magnitude and frequency of short droughts (less than 18 months) ■L, but there is little information on changes in longer droughts (■L in future patterns of long drought).

	What has happened	What could happen
Groundwater recharge and levels	There are extensive records of groundwater levels across the UK, but no evident trends in recharge or groundwater levels (■ **M** that there are no trends). **Attributed to climate change?** There is no evidence of a link between groundwater levels and climate change, partly because the climate change signal so far is small compared to other influences on groundwater such as land-use change and abstraction.	Most but not all studies agree that there may be a decrease in recharge to groundwater throughout the 21st century ■ **L**. By the 2050s changes in groundwater recharge are projected to be somewhere in the range from a 30% reduction to a 20% increase ■ **L**. There is most agreement for chalk catchments in southern England, where increased temperatures may contribute to a reduction in the length of the recharge season ■ **L**.
River water temperature	UK river water temperature has increased over the second half of the 20th century, broadly in line with changes in air temperature ■ **M**. **Attributed to climate change?** Changes have not been attributed to climate change as the processes (energy exchanges and flow) that control water temperature are complex, but increasing river water temperature is consistent with climate change.	River water temperature is expected to increase across the UK through the 21st century ■ **H**, but the rate and pattern of change are not clear (■ **L** in rates and patterns of change). Increases in water temperature will be modified by hydrological changes, which may either magnify or reduce the impact of changes in energy balance (■ **H** that hydrological changes modify water temperature response; ■ **L** in the impact of this modification).
River water quality and ecology	Over the last 30 years there has been an overall improvement in river water quality ■ **H**, although nutrient levels have increased because of the use of fertilisers ■ **H**. Improvements to water quality have mainly been achieved through regulation of point source discharges and a reduction in toxic pollution ■ **H**. Upland catchments have begun to recover from acidification as a result of reductions in sulphur emissions since the 1980s ■ **H**. Freshwater ecosystems may be responding to changes in water temperature, for example with reductions in some fish species in some catchments (■ **L**, as improvements in water quality may be masking the negative effects of warming rivers).	Changes in river flow patterns may lead to changes in the mobility and dilution of nutrients and contaminants (■ **H** that there will be change, ■ **L** in patterns or rates). Higher water temperatures will increase chemical reactions and accelerate biological process (■ **H** in process change, ■ **L** in impact). Lower summer flows may enhance the potential for algal and cyanobacterial blooms and reduce dissolved oxygen levels (■ **H** that this will result from low flows). Storms may flush nutrients and other pollutants from urban and rural areas and may cause acid pulses in some upland catchments (■ **H** that this is a risk, but ■ **L** in pattern or magnitude). Increased water temperatures may threaten cold-water fish species, with invasive and non-native fish species finding conditions more favourable ■ **H**. Future conditions are expected to be more favourable to invasive

	What has happened	What could happen
	Attributed to climate change? Improvements in river water quality as a result of better management have had a far greater impact than any climate change signal.	species ■ **H**.Other changes may be complex and there is little information on how freshwater ecosystems will respond to the combined effects of changes in river flows and water temperature and other changes to water quality (■ **L** in ecosystem response to future change).
Groundwater temperature and quality	There is little information about groundwater temperature, and no analysis of trends (■ **L** in understanding of groundwater temperatures). Groundwater quality has improved over the last fifty years because of reduced pollution (■ **H** in improvement and in cause). The exception is in nitrate levels, which increased in the last half of the 20th century because of increased use of agricultural fertiliser (■ **H** in increase and source of nitrates). **Attributed to climate change?** Observed changes in groundwater quality are a response to changes in catchment management and have not been linked to anthropogenic climate change.	There is little understanding of how groundwater temperatures may change (■ **L** in understanding). As the climate changes, groundwater quality will change in response to changes in recharge and the presence of different pollutants and nutrients, but the scale and pattern of changes is unclear (■ **L** in scale and scope of change).
Water use	Public water supply demand is partly linked to temperature, with greater water demand on hot days ■ **H**. There is no evidence that increasing average temperatures in the UK have yet led to increased demand (■ **H** that there is no sign of increasing demand with annual temperature). This may be because the trend cannot be distinguished from other factors that influence demand. Agricultural demand for water for irrigation has increased over the last two decades ■ **H**, but this increase cannot be linked to climate change (■ **L** in link with climate change). **Attributed to climate change?** Many other factors influence demand, and this means that any impact of climate change cannot yet be seen.	Demand for public water supply may increase with temperature ■ **M**. The main changes are expected to be for increased outdoor use, such as garden watering, and perhaps an increased frequency of showering and bathing. (■ **M** in the direction of change, but ■ **L** in rate or magnitude). Water demand for agriculture is expected to increase with temperature, as crops may need more irrigation to counteract warmer, drier periods. However, increases may be constrained by the availability of suitable soils for growing irrigated crops (■ **H** in increasing water demand; ■ **L** in scale of change). Changes in rainfall patterns will also affect both rainfed and irrigated agriculture (■ **H** that patterns have an impact; ■ **L** in scale of this impact).

Snow

What has happened

In all regions of the UK there have been significant decreases in the number of days of lying snow over the last 50 years ■H. Decreases in both autumn and spring snow cover suggest that the snow season is becoming shorter ■M. However, the snowy winter of 2009-2010 shows that widespread snow remains a feature of UK weather, even in the lowlands, and that snow can be a serious hazard ■H. Changes in snow cover and snow melt may have changed the hydrological regime of some Scottish rivers ■M.

Attributed to climate change?

There are no formal studies that attribute these changes to anthropogenic climate change, though a trend towards reduced snow cover is consistent with warming. The likelihood of cold winters such as 2009-10 and 2010-11 has reduced because of climate change.

What could happen

Climate change will affect snow and ice processes most where winter temperatures are close to 0°C, which includes parts of upland Britain ■H.

Reduced snow cover will change the hydrological regime of some upland rivers, but the impact is unclear (■H that regime will change: ■L in scope or impact of changes).

Urban hydrology

What has happened

From the 18th to the late 20th century, urbanisation led to reduced water quality and increased flood risk ■H. In recent decades better management has improved urban water quality and reduced flood risk ■H.

Attributed to climate change?

Other changes are masking any impact of climate change.

What could happen

Climate change will increase the risk of flash flooding in urban areas, in response to increasing rainfall intensity ■H. Climate change may lead to reduced urban water quality, with flushing of pollutants during storm events and lower dilution from lower summer flows ■M.

Estuaries

What has happened

The UK has around 90 estuaries, which is about a quarter of the estuaries of north-west Europe ■ **H**. Many UK estuaries have an extremely high tidal range ■ **H**. Sea level rise has already affected UK estuaries, increasing the impact of storm surges ■ **H**, although there is no evidence that either the size or frequency of surges have changed because of climate change (■ **H** that there is no evidence of changes in size or frequency of storm surge). Increased winter rainfall may have increased fluvial flows to estuaries ■ **M**.

Attributed to climate change?

UK sea level rise is consistent with climate change: some of the increased impact of storm surges is a result of increased sea level. Other changes have not been attributed to climate change.

What could happen

Rising sea levels will increase flood risk, particularly from storm surges ■ **H**. Increased sea level will also change the dynamics of surges, perhaps changing erosion patterns and morphology ■ **M**, and change the impact of tides and waves (■ **H** that wave action changes; ■ **L** in impact). Changing patterns of river flow will also affect estuaries: lower summer flows increase the risk of eutrophication ■ **M**. In some estuaries higher sea levels will lead to salt water intruding further inland ■ **H**. Increased water temperatures may increase risks to human health through pathogens in water ■ **L**. Habitat loss from rising sea levels may have a serious impact on some protected species ■ **M**.

The sources of information used to compile this table are listed at the end of the report card. For a more detailed summary, see the two technical summary papers (Watts et al. 2013 and Garner and Hannah 2015) and the peer-reviewed journal paper (Watts et al. 2015). For the latest information on the state of the UK climate, see Kendon et al. (2015). The thematic working papers contain more detail on each of the topics

Climate and hydrology of the UK

The UK has a temperate, moist climate, with mild winters and warm, but not hot, summers. Average rainfall is highest in the west and north, with the mountains of Wales, the English Lake District and the Highlands of Scotland wettest: some parts receive an average of over 3 metres of rain each year. The lowlands of eastern England have the least rain, with some areas seeing an average of less than 500 mm of rain a year. Annual average temperatures are highest in the south of England, at 10 to 12°C. The warmest areas are along the south coast and around London, and the same areas have the hottest summer weather. Cornwall has the mildest winters. The coldest areas are the highest hills and mountains of the Pennines and Scotland, where the annual average temperature is below 4°C.

The geology, soils and vegetation of the UK are varied, and these lead to different hydrological responses to rainfall. The high land in the west and north is mainly impermeable, which means that rainfall tends to run quickly into streams and rivers. Rivers here are “flashy” – flows rise quickly after rainfall, but fall quickly too once the rain has stopped. In southern and eastern England the chalk rock is permeable: water sinks into the ground (where it is called “groundwater”) and emerges slowly into rivers, sometimes many months after the rain fell. This means that rivers in these areas tend to respond slowly to rainfall, maintaining flows through all but the driest summers. Limestone in the Cotswolds and the Pennines responds more quickly than chalk but still acts as a reserve that maintains flows for some time after the rain has stopped.

Lough Neagh

River Severn

The principal aquifers of the British Isles

River Tay

River Thames

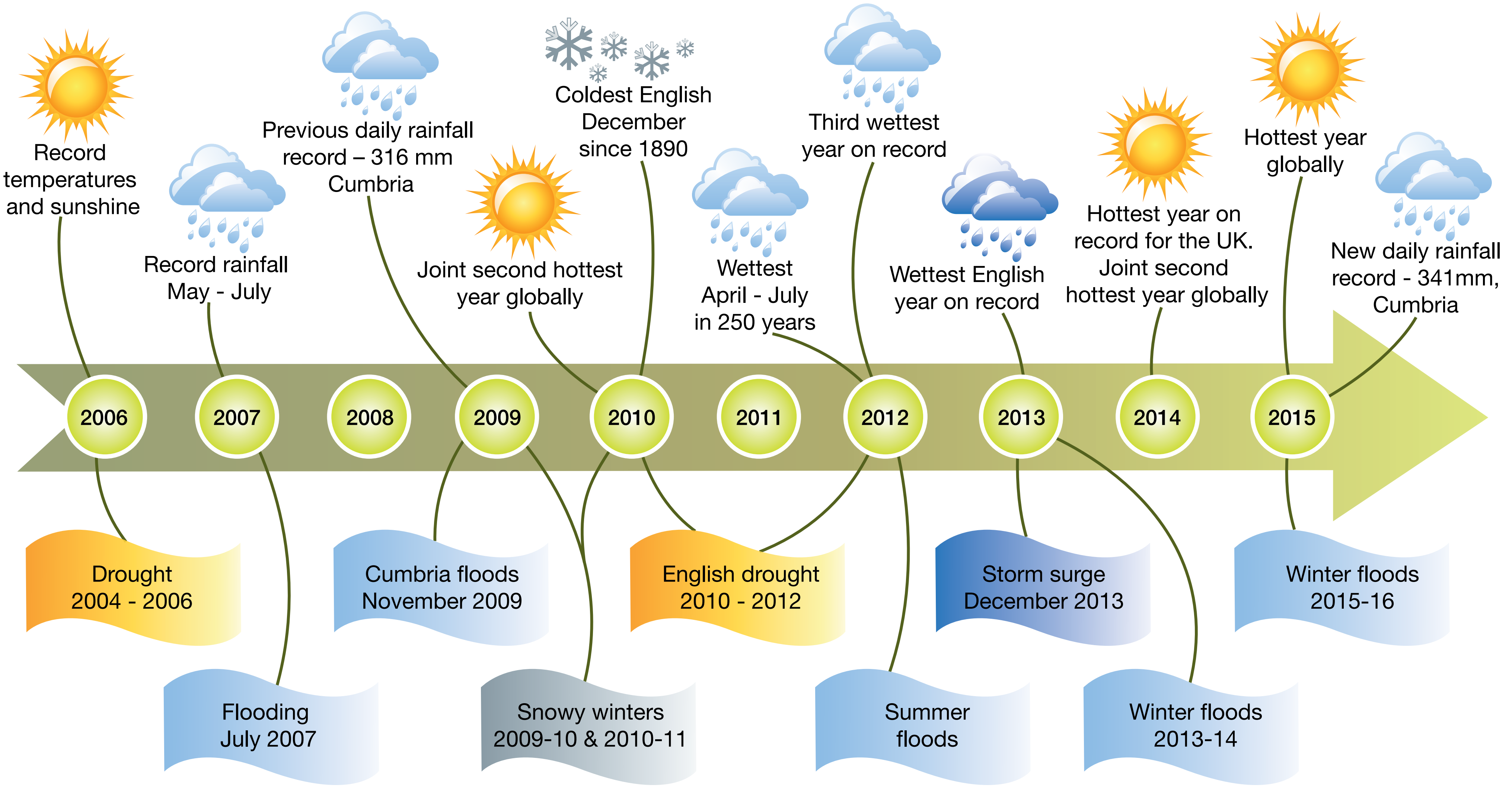
Changes in the climate

Globally, the climate has warmed at an increasing rate over the last 50 years, with the greatest warming in northern latitudes. 2014 was one of the hottest years on record, equalling or perhaps exceeding the previous record from 2010. 2015 exceeded the temperatures of 2010 and 2014, setting a new global record. Over the last 50 years the Arctic has warmed at twice the rate of warming over land. For the last two decades, global sea level has been rising at around 3 mm every year, the result of thermal expansion of water as well as melting ice. Sea-level change around the coast of the UK is broadly following the global trend, taking into account land movement. The oceans are becoming more acidic because of the increased carbon dioxide concentrations in the atmosphere. Taking northern Europe as a whole, annual rainfall increased significantly over the last century, with a decrease in rainfall in the Mediterranean region.

Patterns and trends in climate over smaller areas, such as the countries of the UK, are harder to detect and to distinguish from natural climate variability, yet it is at these and smaller scales that the impact of climate change will be experienced and where steps can be taken to manage the most significant impacts. Locally, changes may not reflect global patterns. This report card concentrates on the UK, but the past and future changes reported here should be placed in this wider context of a warming world. People in the UK will be affected not only by direct changes in local climate but also by changes in other parts of the world, for example as cropping patterns change in the countries that grow some of our food.

Global projections of future climate are available from the IPCC. The fifth assessment report (AR5), published in 2013 and 2014, provides the latest summary of past and future changes in the global hydrological cycle. Average flow is expected to increase at high latitudes (like the UK) and in the wet tropics, and to decrease in most dry tropical regions. Climate change will modify the frequency and scale of both floods and droughts, but with considerable regional variation. The UK's latest climate projections from 2009, UKCP09, projected increased winter rainfall, particularly in the west of the UK, and lower summer rainfall, especially in the south of England. More recent work suggests that summer rainfall changes may not be as marked as UKCP09 suggests, emphasising the need to consider a range of different climate projections in any planning. New UK climate projections are expected in 2018.

The IPCC says that it is virtually certain that humans have warmed the global climate, and that it is very likely that anthropogenic greenhouse gases caused more than half of the observed warming in global surface temperature since 1951. The IPCC also has medium confidence that greenhouse gases have contributed globally to intensification of heavy rainfall in the last 60 years. However, it is very difficult both to detect changes at the local or regional scale and to attribute any such changes to anthropogenic climate change. Detecting change is difficult because climate is naturally variable: for example, in the UK we have seen wet and dry periods throughout the long observed record, so it is difficult to tell if recent changes in rainfall are driven partly or wholly by anthropogenic climate change, or part of natural climate variability. This becomes even more difficult in the hydrological system, where many different factors may be changing at the same time: for example, river water quality is improving because of better management, and this improvement is so great that it would certainly mask any climate-driven changes. Modelling systems with and without greenhouse gases allows calculation of the changing probability of specific events: this method suggests, for example, that both the 2003 European heatwave and the summer 2007 English floods were made more likely by climate change. Often, though, we are unable to do more than observe that a change is consistent with anthropogenic climate change. For example, UK river water temperature increases in recent decades are consistent with climate change, but have not been attributed formally to anthropogenic climate change.

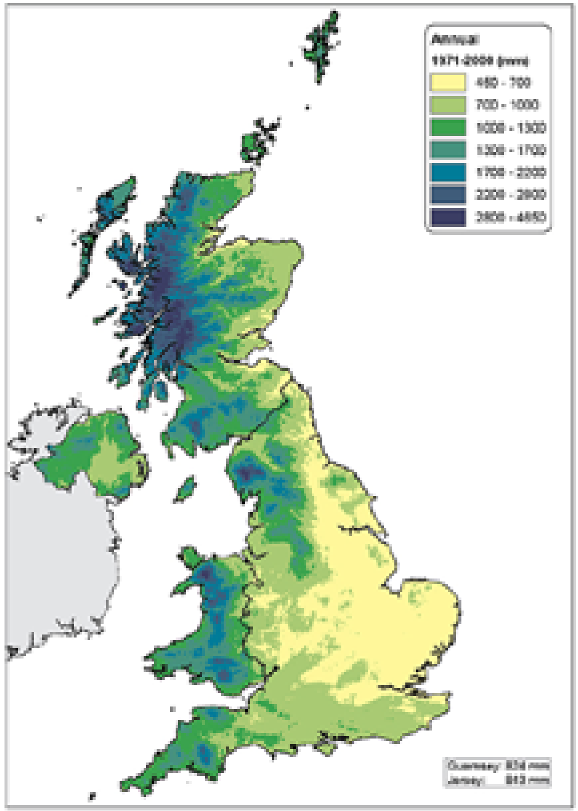

Record temperatures and sunshine
Record rainfall May - July
Previous daily rainfall record – 316 mm Cumbria
Joint second hottest year globally
Coldest English December since 1890
Wettest April - July in 250 years
Third wettest year on record
Wettest English year on record
Hottest year on record for the UK. Joint second hottest year globally
Hottest year globally
New daily rainfall record - 341mm, Cumbria
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Drought 2004 - 2006
Flooding July 2007
Cumbria floods November 2009
Snowy winters 2009-10 & 2010-11
English drought 2010 - 2012
Summer floods
Storm surge December 2013
Winter floods 2013-14
Winter floods 2015-16

Water in the UK – both a hazard and a resource

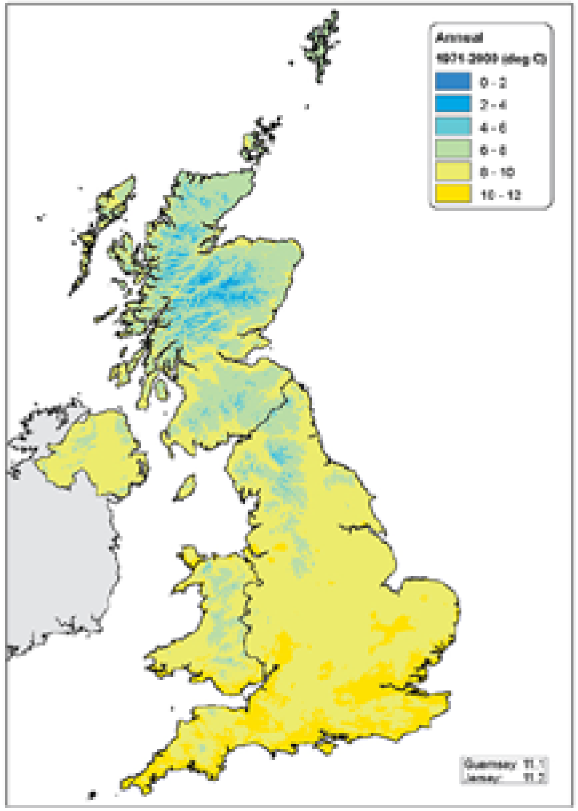
Across the UK, water companies supply around 17 billion litres of clean drinking water every day. Some water users take water directly from rivers or groundwater: this includes some homes without mains water supply, but water taken directly is used mainly in farming, by industry, and for electricity generation. Much of the water used by businesses and at home is returned to rivers, after treatment that makes sure river water quality is maintained.

Water in lakes, rivers and streams is essential for plants and animals too. Many people use rivers, lakes and canals for recreation, including fishing, boating or enjoying quiet time by the water. In the past, rivers and canals were very important for the movement of goods; now most boats on inland water are used for pleasure, and in some places water-based tourism is an important part of the local economy.

As well as being a valuable resource, water can present a hazard, especially through the risk of flooding. Flooding can occur from the sea, from rivers or from heavy rainfall. Combined high river levels and storm surges particularly affect people living near estuaries. Many properties benefit from flood defences, but future changes to sea levels and the intensity and frequency of rainfall events could affect the level of protection afforded to defended areas.



Annual average rainfall between 1971 and 2000



Annual average temperature between 1971 and 2000

Climate variability – UK weather events in the last decade

The UK climate is highly variable from year to year and even within years. In the last decade we have experienced major droughts as well as extremely wet spells, including the wettest English winter on record in 2013-2014. On 5 December 2015 a new UK 24 hour rainfall record was set, when over 340 mm of rain fell in the Honister Pass in Cumbria. Across the UK as a whole, December 2015 was by far the warmest December on record, with an average temperature closer to that of April or May. Extended droughts affected southern and eastern England in 2004-2006 and 2010-2012, with restrictions on water use in many areas. The 2012 drought broke abruptly with the wettest April to July in 250 years. The ten hottest years in the UK-wide record, which starts in 1910, have all occurred since 1990. Even in this period of overall warming, there have been cold and snowy winters, notably in 2009 and 2010: December 2010 was the coldest English December since 1890. The east coast storm surge in December 2013 equalled or exceeded the height of the serious 1953 surge in many places, though modern defences and warning systems meant that this recent storm was much less damaging. In Scotland, spring 2014 was the warmest on record.

The impact of climate change on recent weather is the subject of ongoing research. The variable weather of the last decade serves to remind us that we need to remain prepared for extreme weather of all types. Climate change is warming the UK and changing the frequency of different types of weather. In our variable climate we can still expect to see occasional extremely cold periods throughout the rest of the century, as well as storms, floods and droughts.

What are the implications of climate change?

The UK Government's 2012 Climate Change Risk Assessment (CCRA) found that water was high on the list of possible risks. Agriculture and forestry may suffer from drier soils, reducing crop and timber yields and leading to extra demand for water for irrigation. Increased flooding could reduce the productivity of agricultural land. For businesses the main climate risks include flooding, not only affecting businesses directly but also disrupting transport and communications, as well as reduced water availability. People's health and well-being are particularly affected by flooding, and water-borne diseases may become more of a problem with increased temperatures and lower summer flows. Buildings and infrastructure are vulnerable to flooding. Water supply may become more difficult with more rainfall variability. Rising energy demand may increase the demand for water for cooling. The natural environment depends on water in many ways. Lower summer river flows may lead to poor water quality. Warmer rivers and lakes may suit some species, but others will not thrive. Flooding and erosion can damage important habitats.

Adapting to climate change

The risks identified in this and other LWEC report cards show the importance of adapting to climate change. For many of these water risks there remains considerable uncertainty about the nature and extent of possible changes. Further research and analysis should reduce this uncertainty, but it is very unlikely to be eliminated. This means that future adaptation plans will need to be able to cope with a wide range of possible changes, pointing towards the need for plans that are flexible and adaptable.

The UK Government's first National Adaptation Programme (NAP) was published in the summer of 2013. It sets out policies and actions aimed at reducing climate change risks and making the most of opportunities, with the expectation that effective adaptation will support growth of the economy. The UK Government's second Climate Change Risk Assessment (CCRA2) is due in 2017 and will inform the revision of the NAP in 2018.

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The **original technical summary working paper** is:

Watts G, Battarbee R, Bloomfield J, Crossman J, Daccache A, Durance I, Elliot J, Garner G, Hannaford J, Hannah DM, Hess T, Jackson CR, Kay AL, Kernan M, Knox J, Mackay JD, Monteith DT, Ormerod SJ, Rance J, Stuart ME, Wade A, Wade SD, Weatherhead EK, Whitehead PG and Wilby RL (2013). Climate change and water in the UK – past changes and future prospects.

The **new technical summary working paper** used to inform this update is: Garner G and Hannah DM (2015). Water in a changing climate: past changes and future prospects for the UK.

This new report card was reviewed by Hayley Fowler, Nigel Arnell and Andrew Watkinson.

Supporting working papers

1. Bloomfield JP, Jackson CR and Stuart ME (2013). Changes in groundwater levels, temperature and quality in the UK over the 20th century: An assessment. LWEC working paper.
2. Hannaford J (2013). Observed long-term changes in UK river flow patterns: a review. LWEC working paper.
3. Hannah DM and Garner G (2013). Water temperature. LWEC working paper.
4. Jackson, CR, Mackay JD and Bloomfield JP (2013). Changes in groundwater levels in the UK over the 21st century: an assessment of evidence of impacts. LWEC working paper.
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Other sources

(all are open access and free to download):

Bindoff, NL, Stott PL, AchutaRao KM et al. (2013) Detection and attribution of climate change: from global to regional. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

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