A STRATEGIC APPROACH FOR ASSESSING AND ADDRESSING THE POTENTIAL IMPACT OF CLIMATE CHANGE ON THE HISTORIC ENVIRONMENT OF WALES

Final Report, September 2012

To

The Historic Environment Group – Climate Change Subgroup

By

The Countryside and Community Research Institute, the Dyfed Archaeological Trust, and the Centre for Environmental Change and Quaternary Research

Summary of Project

Project Title:	A strategic approach for assessing and addressing the potential impact of climate change on the historic environment of Wales
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Contents

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Cadw
Royal Commission on the Ancient and Historical Monuments of Wales
The National Trust Wales
Countryside Council for Wales
Institute for Historic Buildings Conservation.
Forestry Commission
Heritage Lottery Fund
Historic Research Wales

Executive Summary/Crynodeb Gweithredol

GWEITHIO MEWN FFORDD STRATEGOL AR GYFER ASESU A MYND I'R AFAEL AG EFFAITH BOSIBL NEWID HINSAWDD AR AMGYLCHEDD HANESYDDOL CYMRU

Adroddiad Terfynol, Medi 2012
I'r Grŵp Amgylchedd Hanesyddol – Is-grŵp Newid Hinsawdd
Gan
Y Sefydliad Ymchwil Cefn Gwlad a Chymuned, Ymddiriedolaeth Archaeolegol Dyfed, a'r Ganolfan ar gyfer Ymchwil Newid Amgylcheddol ac Ymchwil Gwaternaidd

Crynodeb Gweithredol

Mae'r adroddiad hwn yn ymwneud ag effeithiau uniongyrchol newid hinsawdd ar yr amgylchedd hanesyddol. Nid yw ymatebion ymaddasol i newid yn yr hinsawdd, mesurau lliniaru i leihau bygythiad newid hinsawdd a chyfleoedd a gynigir gan y newid yn yr hinsawdd ar yr amgylchedd hanesyddol yn cael eu hystyried.

Bydd effeithiau newid hinsawdd ar yr amgylchedd hanesyddol yn amrywio'n aruthrol gan ddibynnu ar y math o ased neu leoliad hanesyddol. Yn ddiau fe fydd rhai o'r digwyddiadau tywydd eithriadol a ragwelir yn effeithio'n sylweddol ar rai dosbarthiadau asedau'r amgylchedd hanesyddol, ond y tueddiadau disgwyliedig hirdymor, fel hafau sychach a phoethach, tymor tyfu hwy a lefelau'r môr yn codi, a allai gael yr effeithiau mwyaf.

O'r holl asedau hanesyddol a asesir yn yr adroddiad hwn, mae'n debygol mai tirweddau hanesyddol y bydd newid hinsawdd yn effeithio arnynt fwyaf, gyda phob un o'r pedwar senario newid hinsawdd a nodwyd – tymereddau cymedrig cynhesach, hafau sychach a phoethach, gaeafau gwlypach a chynhesach/hafau gwlypach, tywydd eithafol yn amlach – yn cael effaith niweidiol gyffredinol. Mae cyfres o effeithiau posibl wedi'u nodi ac aseswyd fod iddynt arwyddocâd cymedrol: yn gronnus, mae arwyddocâd mawr i'r rhain.

Asesir bod risg sylweddol i asedau hanesyddol (gan gynnwys adeiladau hanesyddol, aneddiadau hanesyddol, safleoedd archaeolegol a thirweddau archaeolegol) sy'n gorwedd islaw'r gyfuchlin un metr yn sgil lefelau'r môr yn codi ynghyd ag ymchwyddiadau stormydd aml. Mae rhannau o lawer o ardaloedd trefol Cymru yn gorwedd yn y parth hwn, ac felly mae cryn botensial difrodi a cholli, nid o ran elfennau hanesyddol unigol yn unig, ond y cymeriad hanesyddol cyffredinol yn ogystal.

Fe allai maint ac amlder llifogydd effeithio'n ddifrifol ar asedau hanesyddol. Effeithir yn sylweddol ar adeiladau hanesyddol (rhai rhestredig ac anrhestredig) a'u ffitiadau, nid gan effaith sydyn llifogydd yn unig, ond yn y tymor hwy gan ddifrod yn cael ei achosi gan blâu ffwngaidd a phryfed, a chan beryglu cyfanrwydd adeileddol. Gall difrod ddigwydd i gelfi stryd hanesyddol, wynebau strydoedd ac elfennau hanesyddol eraill aneddiadau. Bydd safleoedd ac adeileddau archaeolegol, fel pontydd hanesyddol, yn cael eu difrodi a'u dinistrio wrth i afonydd newid eu cyrsiau.

Bydd yr effaith fwyaf niweidiol ar adeiladau hanesyddol yn cael ei hachosi gan lifogydd yn digwydd yn amlach, fel yr amlinellwyd uchod. Hefyd, nodwyd cyfres o effeithiau negyddol cymedrol ar adeiladau hanesyddol yn

cael eu hachosi gan newid hinsawdd, yn cynnwys difrod yn cael ei achosi gan blâu ac afiechydon, pridd clai yn sychu a chrebachu, effeithiau rhewi-dadmer ar garreg wlyb, yr angen i wneud gwaith cynnal a chadw'n amlach oherwydd tywydd mwy llaith, a difrod yn cael ei achosi gan wyntoedd cryfion a stormydd yn digwydd yn amlach. Gall plâu ac afiechydon fod yn broblem arbennig i'r tai hanesyddol hynny sydd wedi cadw eu haddurn, eu gosodiadau a'u ffitiadau gwreiddiol.

Bydd yr hafau poethach a sychach a ragwelir yn achosi dysychiad mewn rhai ardaloedd o fawnydd ucheldir, gan eu gwneud yn fwy tueddol o erydu, erydu a fydd yn cael ei waethygu gan y glawiad uwch a ragwelir yn y gaeaf, a stormydd amlach. Yn ogystal, yn y tymor hir, fe allai priddoedd mawnog ac organig gael eu trawsnewid yn briddoedd mwynol, gan olygu y bydd canlyniadau i'r dirwedd hanesyddol. Bydd colli gorgorsydd yn amlygu safleoedd archaeolegol a dyddodion sydd wedi'u selio a'u gwarchod am filoedd o flynyddoedd, gan eu gwneud yn agored i erydu.

Bydd lefelau'r môr yn codi, law yn llaw â stormydd amlach a ffyrnicach, yn effeithio ar ystod eang o safleoedd archaeolegol sydd i'w cael ar y blaendraeth, er bydd arwyddocâd yr effaith yn amrywio'n fawr yn ôl yr amodau lleol. Mae perygl hefyd i adeiladau, safleoedd archaeolegol a thirweddau ar hyd ymyl yr arfordir, naill ai mewn lleoliadau isel neu ar glogwyni agored.

Mae effeithiau newid hinsawdd ar barciau a gerddi hanesyddol yn anodd eu hasesu gan y byddant yn amrywio'n aruthrol yn ôl y math o barc neu ardd, a bydd effeithiau cadarnhaol yn ogystal ag effeithiau negyddol. Bydd yr effaith negyddol fwyaf yn digwydd mewn parciau a gerddi na reolir lle na fydd unrhyw blannu newydd yn cael ei wneud yn lle coed a phlanhigion eraill a gollir i blâu, afiechydon a difrod stormydd, a bydd cyflymder diraddio ac erydu nodweddion gardd 'caled' yn cynyddu dan stormydd amlach. Bydd y colledion hyn yn cael eu hunioni i raddau helaeth mewn parciau a gerddi a reolir, ac mewn parciau a gerddi sy'n enwog am eu planhigion egsotig, gall amodau poethach a sychach fod yn gyfle i wella'u cymeriad.

Mae rhai o'r safleoedd archaeolegol sydd wedi'u cadw orau yng Nghymru i'w cael mewn amgylcheddau ucheldir, ac felly maent yn sensitif i newid oherwydd eu natur. Bydd stormydd amlach a mwy grymus yn arwain at y safleoedd hyn yn erydu, ond gallai'r prif fygythiad ddod yn sgil y cyfle a gynigir gan dymereddau cymedrig cynhesach a thymor tyfu hwy i wthio ffiniau tir amaethu yn ôl i gyrion y parth hwn.

Mae natur ymaddasol a dynamig cynefinoedd twyni tywod yn ei gwneud yn broblematig rhagweld o gwbl sut byddant yn ymateb i newid hinsawdd. Fodd bynnag, yn gyffredinol, mae'n debygol y bydd cynnydd yn lefelau'r môr a chynnydd yn amlder stormydd grymus a gwyntoedd cryfion yn arwain at newidiadau i systemau twyni, gan effeithio ar y safleoedd archaeolegol niferus a phwysig ynddynt ac o danynt. Fodd bynnag, mae systemau twyni'n cael eu rheoli'n ofalus yn gyffredinol, ac felly mae'n bosibl y gellir lliniaru newid.

Mae coetiroedd hynafol yn debyg i asedau hanesyddol eraill i'r graddau eu bod yn cynnwys tystiolaeth gymhleth o'u defnydd gan ddyn yn y gorffennol. Ystyrir mai newid hinsawdd yw'r bygythiad mwyaf y mae coetir hynafol yn ei wynebu erbyn hyn. Mae'r bygythiadau hyn yn cynnwys plâu ac afiechydon yn mudo, straen ar goed yn cael ei achosi gan hafau poethach a sychach a stormydd amlach a mwy grymus. Mae coetiroedd yn ecosystemau cymhleth ac amrywiol, fodd bynnag, ac maent felly'n fwy tebygol o ymateb mewn amrywiaeth o ffyrdd gwahanol, ac er eu bod yn sensitif i newid hinsawdd, caiff y newid hwn ei liniaru i ryw raddau gan y rheolaeth ofalus dros rai ardaloedd coetir hynafol. Felly, er mai newid hinsawdd ar goetir fydd yn cael yr effaith fwyaf ar y coetir ei hun, fe allai colli coed ar raddfa fawr ac erydiad pridd yn sgil hynny, newid defnydd tir ac ailblannu, gael effaith ar asedau hanesyddol unigol sydd o fewn coetir.

Ni fydd tymor tyfu hwy yn sgil tymereddau cymedrig uwch yn effeithio'n uniongyrchol ar safleoedd archaeolegol ar dir amaethu, ond y cyfleoedd a gynigir gan y newidiadau hyn, fel cynyddu maint y tir sy'n cael ei drin, cyflwyno cnydau newydd a newidiadau eraill i arferion amaethu, a allai gael effaith sylweddol.

A STRATEGIC APPROACH FOR ASSESSING AND ADDRESSING THE POTENTIAL IMPACT OF CLIMATE CHANGE ON THE HISTORIC ENVIRONMENT OF WALES

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To The Historic Environment Group – Climate Change Subgroup
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Executive Summary

This report is concerned with the direct impacts of climate change on the historic environment. Adaptive responses to climate change, mitigation to reduce the threat of climate change and opportunities offered by climate change on the historic environment are not considered.

The impacts of climate change on the historic environment will vary enormously depending on the type of historic asset and location. Some of the projected extreme weather events will undoubtedly have a significant impact upon certain classes of historic environment asset, but it is the projected long term trends, such as hotter drier summers, a longer growing season and rising sea levels that potentially have the greatest impacts.

Out of all the historic assets assessed in this report, it is likely that historic landscapes will be most affected by climate change, with all of the four identified climate change scenarios – warmer mean temperatures, hotter drier summers, warmer wetter winters/wetter summers, more frequent extreme weather – all having an overall adverse impact. A series of potential impacts have been identified and assessed as being of moderate significance: cumulatively these are of high significance

Historic assets (including historic buildings, historic settlements, archaeological sites and landscapes) lying below the one metre contour are assessed as being at significant risk from rising sea levels coupled with more frequent storm surges. Parts of many of Wales' urban areas lie in this zone, and thus the potential damage and loss, not just to individual historic elements, but also to the overall historic character is considerable

The scale and frequency of flood events will potentially have severe impact on historic assets. Historic buildings (listed and unlisted) and their fittings will be significantly affected, not just by the sudden impact of a flood, but in the longer term by damage caused by fungal and insect infestation, and by compromising structural integrity. Damage may occur to historic street furniture, street surfacing and other historic elements of settlements. Archaeological sites and structures such as historic bridges will be damaged and destroyed as rivers shift their courses.

The most damaging impact on historic buildings will be caused by more frequent flooding events, outlined above. In addition a series of moderate negative impacts on historic buildings caused by climate change have been identified, including damage caused by pests and diseases, drying and shrinking of clay soils, freeze-thaw effects on wet stone, more frequent maintenance required due to damper conditions, and damage caused by more frequent high winds and storms. Pests and diseases may be a particular issue for those historic houses that retain their original decoration, fixtures and fittings.

The predicted hotter, drier summers will cause the desiccation of some areas of upland peats making them more susceptible to erosion, erosion that will be exacerbated by the predicted higher winter rainfall and more frequent storms. In addition, in the long-term, peaty and organic soils could be transformed into mineral soils, with consequences for the historic landscape. Loss of blanket bog will expose archaeological sites and deposits that have been sealed and protected for several thousands of years, making them vulnerable to erosion.

Rising sea levels combined with more frequent and violent storms, will impact on the wide range of archaeological sites found on the foreshore, although the significance of the impact will vary widely according to local conditions. Also at risk are buildings, archaeological sites and landscapes along the coast edge, either in low-lying locations or on exposed cliffs.

The impacts of climate change on historic parks and gardens are difficult to assess as they will vary enormously according to the type of park of garden, and there will be positives as well as negatives. The most significant negative impact will occur in unmanaged parks and gardens where trees and other plants lost to pests, diseases and storm damage will not be replaced, and the speed of degradation and erosion of ‘hard’ garden features will increase under more frequent storms. In managed parks and gardens these losses will be largely made good and in parks and gardens celebrated for their exotics, hotter, drier conditions may be an opportunity to enhance their character.

Some of the best preserved archaeological sites in Wales are located in upland environments and so by their very nature are sensitive to change. More frequent and intense storms will result in erosion of these sites, but the main threat could result from the opportunity offered by warmer mean temperatures and a longer growing season to push back the boundaries of farmland into the margins of this zone.

The adaptive, dynamic nature of sand dune habitats makes any prediction as to how they might respond to climate change problematic. However, in general terms, it is likely that a rise in sea levels and an increase in the frequency of intense storms and gales will result in changes to dune systems, impacting on the large number and important archaeological sites within and below them. However, dune systems are generally carefully managed, and thus change might be mitigated.

Ancient woodlands are similar to other historic assets in that they contain complex evidence for past human use. Climate change is considered the greatest threat now faced by ancient woodland. These threats include the migration of pests and diseases, stress on trees caused by hotter drier summers and more frequent and intense storms. However, woodlands are complex and varied ecosystems, and are therefore likely to respond in a variety of different ways, and although they are sensitive to climate change, this change will be mitigated to some extent by the careful management enjoyed by some ancient woodland areas. Thus although climate change on woodland will have the greatest impact on the woodland itself, mass loss of trees and subsequent soil erosion, change of land-use and replanting could impact on individual historic assets lying within woodland.

A longer growing season resulting from higher mean temperatures will not directly impact on archaeological sites on farmland, but it is the opportunities offered by these changes such as increasing the amount of land under cultivation, the introduction of new crops and other changes to farming practices that could have a significant impact.

1. Introduction

Background context

The aim of the study was to develop a strategic approach for both assessing and addressing the potential impact of climate change on the historic environment of Wales, rather than the adaptive response to the consequences of climate change, the mitigation of climate change and the opportunities offered by climate change.

There were two main objectives to the study:

Objective 1: Identify and assess the sensitivity of historic assets to climate change

Objective 2: Produce a risk assessment for historic assets based upon sensitivity to change, including judgements on the likelihood and impact of the risks identified

2. Methodology

The project was divided into four main tasks:

1. Explore the vulnerability of the historic environment to current and future climate change
2. Assess the potential impacts of projected climate change on the historic environment of Wales
3. Review technical guidance, existing initiatives, programmes and case studies that are currently monitoring and measuring the impact of climate change on the historic environment, within, but not exclusively confined to, the UK.
4. Use this review to produce an assessment of how the anticipated climate changes may affect individual elements within the major asset types in order to assess their sensitivity to change.

Task 1 reviewed predicted climate change for Wales and the UK more generally. A range of projections was taken from the UKCIP site (http://www.ukcip.org.uk/) Climate change projections summarising outcomes were based on UKCP high-range emissions for the 2020s and mid-range emissions scenarios for the 2050s (see Tables 2.1 and 2.2 below). The justification for this is as follows.

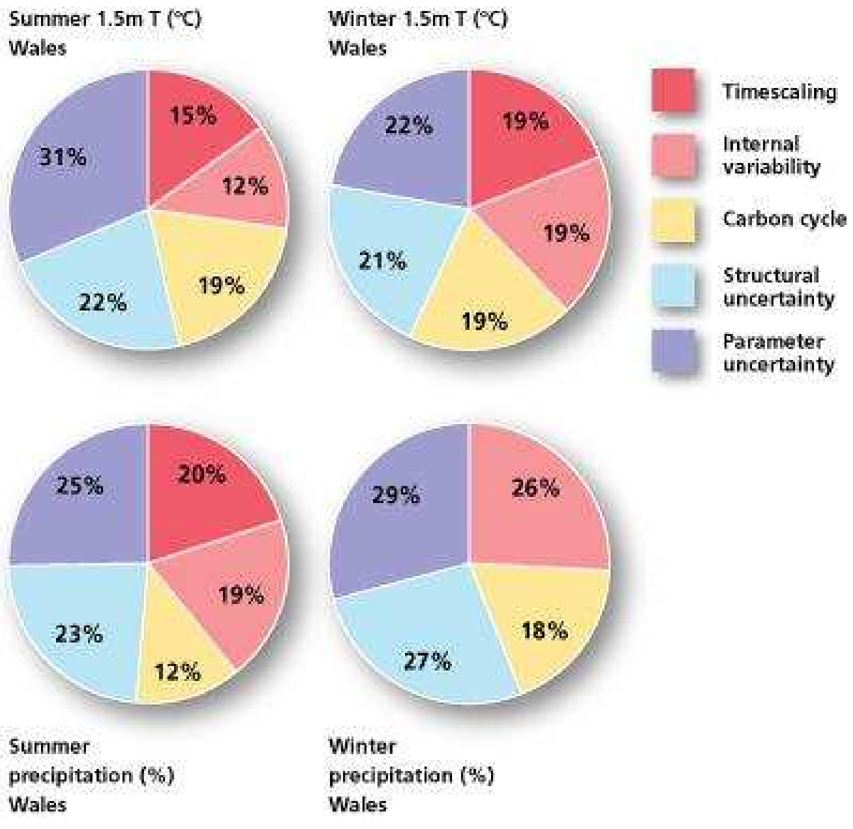
The 2020s' is a 30-year period centred on the 2020s and is therefore of immediate relevance. The high range emissions scenario was selected for the 2020s because there has been only limited success in curbing emissions to date, and the present emissions trajectory is within the high range,

It is not worth exploring 'Low (carbon) Emissions' scenarios, as these are now regarded as unlikely. While a maxim in responding to the challenge of climate change might be to "aim for medium, but plan for high" emissions, it is nevertheless the case that the longer term 'High Emissions' scenarios generally provide a greater change in the same direction as the 'Medium Emissions' . The study therefore utilises the 'Medium Emissions' key findings for Wales from the UKCP09 climate projections for the 2050s (that is, the 30-year period centred on the 2050s).

It should be noted that this Report takes the UKCP09 projections as 'given'. Inherent in the probabilistic climate projections are some of the uncertainties in model parameterization, as shown in Figure 2.1. This Fig. shows the recognised components that contribute to uncertainty in the UKCP09 projections for Wales for the 2080s and 2050s.

Figure 2.1: The relative contributions of different components of uncertainty to the overall spread in UKCP09 projections.

Note: These are calculated for summer and winter and for changes in temperature and percentage changes in precipitation for the Wales global climate model grid box, considering projected changes for 2070–2099 (top) and for 2010–2039 (bottom), relative to 1961–1990. (Caption adapted from, and Figure taken from Annex 2.4 of the UKCP09 online climate change report: http://ukclimateprojections.defra.gov.uk/22965)



Nevertheless, there are cautionary views from a minority of climate scientists, highlighted by Schmittner et al. (2011), that current climate models may significantly over-estimate sensitivity to carbon dioxide. In complete contrast, Hansen et al. (2011, p. 13421), in reviewing forcing factors affecting recent climate, identify "the dominant role of the human-made greenhouse effect in driving global climate change".

Of more immediate relevance to the future climate of Wales is the suggestion that current climate models may underestimate pronounced solar forcing of winter weather in NW Europe during solar minima, perhaps manifested in colder winters over the last three years. This is a particularly important point: the version of the climate model used to generate the UKCP09 projections does not factor in the possible effects on winter weather in Britain and northwest Europe of reduced solar activity, as postulated by Lockwood et al. (2011). This effect, a product of changes in the positioning of the Jet Stream over Europe, is acknowledged by scientists from the UK Met Office, where Ineson et al. (2011, p. 753) point out that “it has proved difficult for climate models to reproduce this signal”. The UK’s ‘wettest summer for 100 years’ (according to the UK Met Office) in 2012 is similarly a product of Jet Stream alterations. Some of the difficulties of climate modelling, though not of course the recent extreme weather experiences, were acknowledged in the UKCP09 Briefing Report (Jenkins et al., 2009).

For these reasons, the assessments produced in this report may under-estimate the effects of severe cold winter weather (as this is not a pronounced feature in UKCP09 projections), and may over-estimate the effect of summer warmth and drought (which are consistent features in the UKCP09 projections). Other phenomena (such as the likelihood of repeat of the severe summer floods of 2007; or the actual incidence of wetter summers) may also be underestimated in the probabilistic projections. That said, the climate projections still allow for the possibility of wetter summers; they also envisage extreme weather events, and it is these that may have a particularly marked impact in some environments.

The details in Table 2.2 below (the mid-range projections) were transformed into qualitative descriptions such as 'warmer summers'; 'drier summers' (or 'warmer, drier summers') 'wetter winters', 'warmer winters' (or 'warmer, wetter winters'), in order to enable a simple qualitative risk assessment to take place. It must be emphasised here that these are central probability estimates; for example, the tail of the probability distribution allows for the possibility of wetter summers, and so this range of possible future weather must be borne in mind for planning purposes.

Table 2.1. UKCP09 Key findings for Wales, 2020s: High Emissions scenario (all comparisons are made with the 1961–90 reference period)

Scenarios Under High emissions	Wider range of uncertainty
...the central estimate of increase in winter mean temperature is 1.2ºC; it is very unlikely to be less than 0.5ºC and is very unlikely to be more than 2ºC.	A wider range of uncertainty is from 0.5ºC to 2ºC.
...the central estimate of increase in summer mean temperature is 1.3ºC; it is very unlikely to be less than 0.5ºC and is very unlikely to be more than 2.3ºC.	A wider range of uncertainty is from 0.5ºC to 2.5ºC.
...the central estimate of increase in summer mean daily maximum temperature is 3.4ºC; it is very unlikely to be less than 1.3ºC and is very unlikely to be more than 6.1ºC.	A wider range of uncertainty is from 1ºC to 6.7ºC.
...the central estimate of increase in summer mean daily minimum temperature is 1.4ºC; it is very unlikely to be less than 0.5ºC and is very unlikely to be more than 2.6ºC.	A wider range of uncertainty is from 0.4ºC to 2.6ºC.
...the central estimate of change in annual mean precipitation is 0%; it is very unlikely to be less than –4% and is very unlikely to be more than 5%.	A wider range of uncertainty is from –4% to 5%.
...the central estimate of change in winter mean precipitation is 5%; it is very unlikely to be less than –3% and is very unlikely to be more than 14%.	A wider range of uncertainty is from –4% to 17%.
...the central estimate of change in summer mean precipitation is –4%; it is very unlikely to be less than –20% and is very unlikely to be more than 14%.	A wider range of uncertainty is from –23% to 14%.

Table 2.2. UKCP09 Key findings for Wales, 2050s: Medium Emissions scenario (all comparisons are made with the 1961–90 reference period)

Scenarios Under Medium emissions	Wider range of uncertainty
...the central estimate of increase in winter mean temperature is 2ºC; it is very unlikely to be less than 1.1ºC and is very unlikely to be more than 3.1ºC.	A wider range of uncertainty is from 0.8ºC to 3.4ºC.
...the central estimate of increase in summer mean temperature is 2.5ºC; it is very unlikely to be less than 1.2ºC and is very unlikely to be more than 4.1ºC.	A wider range of uncertainty is from 1ºC to 4.6ºC.
...the central estimate of increase in summer mean daily maximum temperature is 3.4ºC; it is very unlikely to be less than 1.3ºC and is very unlikely to be more than 6.1ºC.	A wider range of uncertainty is from 1ºC to 6.7ºC.
...the central estimate of increase in summer mean daily minimum temperature is 2.6ºC; it is very unlikely to be less than 1.1ºC and is very unlikely to be more than 4.6ºC.	A wider range of uncertainty is from 0.9ºC to 5.1ºC.
...the central estimate of change in annual mean precipitation is 0%; it is very unlikely to be less than -5% and is very unlikely to be more than 5%.	A wider range of uncertainty is from -6% to 6%.
...the central estimate of change in winter mean precipitation is 14%; it is very unlikely to be less than 2% and is very unlikely to be more than 30%.	A wider range of uncertainty is from -1% to 31%.
...the central estimate of change in summer mean precipitation is -17%; it is very unlikely to be less than -36% and is very unlikely to be more than 6%.	A wider range of uncertainty is from -38% to 13%.
NOTE: The scenarios explored in this study are for only the 2050s.	NOTE: The 'wider range' (referred to above) is from the lowest to highest value for all emissions scenarios and three (10%, 50%, and 90%) probability levels for each 30-year time period.

Task 2 involved selection and categorisation of relevant historical assets. Historic environment assets that may be affected by climate change were identified and plotted on a matrix against potential outcomes of change.

Four basic descriptions of climate change were examined:

- Warmer mean temperatures
- Hotter, drier summers
- Warmer wetter winters/wetter summers
- More frequent extreme weather

the four basic descriptions are associated with the following 8 outcomes of change:

- Rise in sea levels
- Longer growing season
- Migration of pests and diseases into Britain
- Drying out, desiccation and erosion of wetlands
- Stress on some trees and plants
- Drying and shrinking of clay soils
- More flooding events
- Frequent high winds/storms

Twelve classes of historic assets were identified:

1. Historic assets below the 1.0 m contour
2. Archaeological sites on farmland
3. Historic assets on the foreshore
4. Forestry and woodland
5. All historic buildings
6. Historic assets on the coast edge, excluding those below the 1m contour
7. Historic assets on floodplains and valley bottoms
8. Historic parks and gardens
9. Peat, peaty soils and blanket bog
10. Historic landscapes
11. Historic assets in sand dunes
12. Archaeological sites in an upland environment excluding peat bogs

These are very broad classes. Some assets will appear in more than one class; for instance listed buildings will have been considered under 'historic buildings', but may also have been included in 'historic parks and gardens' and 'historic buildings and archaeological sites below the 1m contour'. Urban was not considered as an individual class, as it is adequately covered under other classes.

A total of 36 potential impacts on historic environment assets were identified (see the cells shaded grey in Table 4.1). Risk matrices were created for the 36 impacts on the set of historic assets (not all predicted changes in climate will have an impact on the historic environment). The matrices assess the significance of impacts based on indications of extent, severity, and sensitivity. Specific gaps in knowledge and indicative responses to change are also considered. Information from all matrices for a particular asset is entered into a summary matrix which provides an overview of the likely impacts and allows comparison of assigned qualitative risk. For many of the scenarios (such as an increase in the length of the growing season) quantitative assessment was not possible.

Task 3 reviewed a wide range of technical guidance to identify key issues, potential problems and good practice that could be applied to the historical environment of Wales. The literature was examined and utilised within the risk assessment, and to identify potential for adaptive strategies. Tasks 2, 3 and 4 were linked in that the review of current literature and technical guidance informed the risk assessment of the selected categories of environmental assets. The information from the three tasks was combined in the form of 'asset impact matrices' for each category of historical asset. The matrix consists of the following sections for each identified outcome:

- Description of change
- Outcome of change
- Location: the area(s) to be affected by the change
- Impact on historic environment assets - consisting of a risk assessment score based on:
    - Scale: the extent of the impact on the historic environment caused by the outcome of change
    - Severity: the severity of the impact of the outcome of change on the historic environment
    - Sensitivity: the sensitivity of historic environment assets to change
- A qualitative risk assessment of historic assets
- Specific gaps in knowledge
- Responses to the outcomes of change
- Notes and references

Identified climate change impacts were scored on a 1 – 5 scale (see Table 2.3 below). The severity of each impact was assessed to identify the critical nature of the impact in both positive and negative terms. Scores range from +3 (a large beneficial impact) which might see a great improvement on the condition of the historic environment, to –3 (a large negative impact), which may see severe damage or destruction, with a score of 0 for a neutral impact (see Table 2.4). Sensitivity is scored on a 0 – 5 scale, where 0 indicates no sensitivity to change, to 5 which indicates a high level of sensitivity to change (Table 2.5).
When assessing sensitivity reference has been made to current literature, much of which refers to landscapes (such as that produced by Hampshire County Council in 2006 and Buckinghamshire County Council in 2005) or individual sites and monuments (Collette 2007a and b, Daly 2011). We have not assessed the sensitivity of historic assets in this study, as described by Collette and Daly for individual assets, as this is beyond the scope of this study.

Table 2.3 The extent of impact on the historic environment

Scale point	Description
1	Limited
2	Moderately limited
3	Moderate
4	Moderately extensive
5	Extensive

The extent of impact scale is arrived at by quantifying (or where this is not possible by estimating) the number of historic assets in a class and then estimating the number of assets in the class that are likely to be affected by the outcome of change. Thus if a class contains a large number of assets and all will be affected then the scale point would be five. If a class contains a large number, but only a few will be affected then the scale point would be 1 or 2.

Table 2.4 The severity of impact on historic environment assets

Scale point	Description
+3	Large beneficial impact
+2	Moderately beneficial impact
+1	Small beneficial impact
0	Neutral
-1	Small negative impact
-2	Moderately negative impact
-3	Large negative impact

The severity of impact is a judgement based on expert knowledge and understanding of the historic environmental assets in Wales. Impacts can be both beneficial and negative depending on the particular nature of the asset under consideration and the predicted impacts from climate change.

Table 2.5 The sensitivity of historic environmental assets to change

Scale point	Description
0	Not sensitive to change
1	Slightly sensitive to change
2	Slightly / Moderately sensitive to change
3	Moderately sensitive to change
4	Moderately /Highly sensitive to change
5	Highly sensitive to change

An asset such as an Iron Age promontory fort may be assessed as 5, highly sensitive to change as once eroded it cannot be replaced, whereas an historic building may be assessed as 1 or 2 as it can be repaired or conserved following impact by climate change.

An indication of the overall significance of impact is obtained by multiplying the values calculating extent, severity, and sensitivity, rather than adding the score. The resultant score is used to identify high, medium or low risk to the asset as follows:

Score	Level of significance of impact (and nature of impact)
–75 to –36	high (negative)
-35 to –11	moderate (negative)
-10 to –1	small (negative)
0	neutral
1 to 10	small (positive)
11 to 35	moderate (positive)
36 to 75	high (positive)

3. Review of technical guidance

Impacts

A wide range of impacts from climate change have been identified, with a lot of focus on the natural environment. In some cases the historic environment has been specifically identified, in other situations it is included within the wider built environment. The historic environment has been identified as vulnerable not only to the effects of climate change, but also to impacts from mitigation strategies such as flood defences and water management strategies. (Climate East Midlands, 2010) Climate change may also have a range of more subtle and indirect effects through lengthening of the growing season, changes in biodiversity and vegetation species, ancient woodland, and landscape caused by temperature, rainfall, storms and spread of pests and diseases. (Pomfret, 2007) Historic landscapes may alter in subtle or more dramatic ways through change in species composition, making it extremely difficult to maintain certain types of historic landscapes. (www.forestry.gov.uk/fr/INFD-6GGH6A; Forestry Commission Wales, 2008) This may be compounded by sub-regional variations in change (Farrar and Vase, 2000), which add another layer of uncertainty to predicting local level effects.

Vulnerable assets	Source of impact
Historic towns and archaeological sites in flood plains	river flooding, flash floods, high water tables, abandonment of frequently flooded areas, flood defence construction
Coastal heritage, historic ports, archaeological sites, landscapes	coastal erosion, sea level rise, storm events, managed realignment, salinity
Lowland wetlands	managed realignment, salinity, changing drainage regimes
Landscape	renewable energy (e.g. windfarms); changing agricultural practice, intensive farming, bio-energy crops, woodland removal/addition (e.g. biomass), changes in vegetation patterns (e.g. tree species); pests and diseases
Moorland and upland peats	erosion, drying out, fire
Historic buildings and structures	rainwater, drainage systems, flood management measures removing historic bridges and waterside buildings, ill-suited mitigation measures, assumptions about poor energy efficiency, loss of sustainable building materials/methods, increased extremes of wetting and drying

(Source: Climate East Midlands, 2010; Northern Ireland Environment Agency, 2010)

Brimblecombe, Grossi and Harris (2006) suggested temperature changes alone would not have much impact on cultural heritage such as buildings as the changes would be relatively small, but ‘amplification mechanisms’ based on quite small changes might cause significant damage. Examples given include wind driven rain and more rapid freeze-thaw cycles. One example is a ‘wet frost’ where a relatively small changes in temperature and/or humidity that may cause phase changes, for instance when porous stone becomes saturated with rainfall and this is followed immediately by a freezing event. Hydrometeorological events are indicated as being more significant with potential for heavy rain to increase flooding, and drier summers to increase the impacts of humidity cycles (e.g. through salt crystallisation and drying out of unfired building materials and soils).

English Heritage (2008a) divides effects of climate change on the historic environment into direct impacts, impacts from adaptive responses, and the impact of policies to mitigate future climate change. Direct impacts include:

- rising sea levels and an increase in storms which will affect landscapes, structures and buildings in the coastal zone
- more frequent and intense rainfall resulting in increased erosion and flooding
- changes in hydrology that threaten buried archaeological sites
- increased extremes of wetting and drying that might cause ground movements and accelerate decay of stonework
- changes in vegetation that will alter historic landscapes and affect tree species
- changes in distribution of pests.

The activities undertaken to adapt to the effects of climate change may also impact on the historic environment. Examples include: managed realignment of the coast may create risks to archaeology, buildings and landscapes; flood defences can damage historic waterfronts, changes in agricultural practices can impact on buries sites and landscapes; and, new rainwater collection and disposal systems might damage historic buildings. English Heritage are aware of the more significant impacts that might result from policies to mitigate climate change, especially where understanding and awareness is lacking. Examples include: renewable energy infrastructure (hydro, tidal and wind) which may affect structures, archaeological sites or landscapes; biomass crops may alter landscapes; and, energy saving measures may impact historic buildings if poorly designed or inappropriate.

(Farrar and Vase, 2000) focus on impacts in Wales suggesting a wide range of potential impacts from predicted wetter winters and drier summers. These include:

- Increased rate of deterioration for archaeological sites as a result of changes in ‘preservation regimes’
- Impacts on coastal areas from sea level rise and erosion (e.g. loss of archaeological sites)
- Increased flood frequency and inundation of river corridors (from sea level rise and higher precipitation)

Indirect impacts may also result from building of flood defences, renewable energy infrastructure (such as wind farms), and from climate induced changes in agricultural practices (farmland covers an estimated 70% of the land area and contains most of the archaeological remains). Changes are difficult to predict and could vary from increased scrubbing up of land as a result of decreased grazing, to damage caused by an extension of ‘deep ploughing’.

Adaptation

Adaptation strategies might include specific flood risk modelling, evaluation of options (e.g. flood storage and flood protection measures, managed realignment of the coast), awareness raising, changes to the planning framework, planning and design actions, and cross-sector working to take into account impacts in other areas. (Arkell, Darch and McEntee, 2007) Changing embedded perceptions about the historic environment as inefficient in energy consumption has been identified as a key long-term challenge, given the focus of much policy attention on improving energy efficiency in the built environment. This will require development of new tools and understanding on the complexities of energy consumption and efficiencies in order to achieve the most effective and cost-efficient changes in the built environment. (Department of Culture, Media and Sport, 2010). One promising approach is a new FP7 project, Climate for Culture, is linking together a range of disciplines to develop models and tools for assessing damage, monitoring, and developing new adaption strategies for the built environment. (www.climateforculture.eu) The project aims to develop a new classification system for historic buildings as part of a risk assessment methodology for preventive conservation, undertake an economic impact assessment of cultural heritage, and develop modelling approaches to look at 180 sites across Europe and North Africa using hygrothermal assessment (analysis of heat, vapour, and moisture transfer through multi-layered building elements over time).

An EU funded project 'Noah's Ark' aimed to develop mitigation and adaptation strategies for historic buildings, sites, monuments and materials likely to be most affected by climate change. Key outputs include the following findings:

- Climate change is subtle and occurs over long timescales. However, some climate parameters, such as freezing, humidity cycles and wind driven rain can change very considerably. In particular, phase changes in freeze-thaw cycles and salt crystallisation will be amplified, becoming sensitive to reduced or increased frequency in the presence of quite modest changes in climate.
- Different parts of Europe will experience different changes in heritage climate. For example, a large change in salt crystallisation will be likely under a drier regime across areas of Europe dominated by medieval Gothic architecture. There is a potential for wetter frosts in future Ukraine, Romania, Austria, Hungary and Slovenia.

The aim was to find ways (e.g. web-based climate change maps, a vulnerability atlas, and other web-based tools) to disseminate findings on climate change effects and optimum adaption strategies to cultural heritage managers across Europe through conferences and guidelines, and to inform policy-makers through an 'Advisory panel'. The project developed heritage 'vulnerability' maps for Europe though these maps are of too low a resolution to be meaningful, and guidelines for adaption. Interestingly the project suggested that the changing water cycle might be most critical for the built environment. It was suggested that "increased precipitation in northern Europe could adversely affect stone and wood", while in southern Europe "reduced humidity will lead to a build up in salt deposits, which can also cause deterioration". More specifically the project reported:

"...research activity...highlighted the great importance of water as a threat to heritage. Despite the fact that temperature is often considered the most recognizable agent of climate change, water seems to dominate when European monuments are considered. This may be water as experienced in times of intense rain, flood, or storm surges. In a more subtle, yet more pervasive, way it can be seen in the way increased rainfall can overload roofing and gutters, penetrate into materials or deliver pollutants to building surfaces. Water is also a factor in the humidity change that affects the growth of microorganisms on stone and wood, and the formation of salts that degrade surfaces and influence corrosion. A Europe with heavier rainfall may experience greater water penetration (especially into vernacular architectural materials such as unfired bricks, or thatching) and surface flooding. However, drier summers overall threaten to increase salt weathering of stone, mortar, frescos and wall paintings and the desiccation of soils that protect archaeological remains and support the foundations of buildings and monuments."

The 'Climate for Culture' project builds on the earlier FP6 Noah's Ark project designed to study the impacts of climate change on heritage and cultural landscapes over a 100 year period. (Sabbioni, 2011) The project suggested the following:

- Surface recession of marble and compact limestone expected to increase by 30% in Northern Europe
- Salt crystallisation events likely to increase across Europe
- Damage induced by wet-dry cycles likely to increase in northern Europe due to higher precipitation
- Mediterranean Basin will continue to experience highest levels of risk from thermal stress
- Europe in general will experience a reduction in wet-frost
- Water appears to be the most important in terms of risk to cultural heritage

Risk based modelling can identify the sites/types of historic asset at risk from damage, but adaptive strategies for the historic environment will also require improved understanding of the uncertainties surrounding predicted change to ensure the best decisions are taken. 'No regret' and 'low regret' options are suggested (English Heritage 2008a) for preserving or making the historic environment more resilient. These are policy options that produce a current and future stream of net economic benefits irrespective of the nature of climate change. Examples include basic maintenance of buildings to reduce risks from storm damage; improved maintenance of woodland to maximise health of trees; simple changes to livestock and farm vehicle management to reduce erosion (English Heritage, 2004); ensuring historic assets are included in other agency activity such as shoreline Management Plans (English Heritage, 2003); and, altering grant aid activity to support such no regret and low regret options. As climate change models improve and predictions become more certain policies can be adapted to suit the expected outcomes.

Measuring benefits can prove challenging for developing effective adaptive strategies. Benefits may relate to the value of the historic asset itself (e.g. preserving a historic building), but may also provide benefits to the local economy and wider society through supporting local industries, preserving traditional crafts (providing employment and demand for local materials), reducing energy consumption (through embodied energy and low energy consumption), bringing buildings back into use, integrating historic assets into new development, and retaining a sense of place for local people. (Department of Culture, Media and Sport, 2010) Benefits estimates will require a mix of market and non-market measures to identify the total value of historic assets.

Strategies

The impossibility of saving everything has been noted (Cassar, 2005; Farrar and Vase, 2000), requiring the need to identify value and significance of the historic environment, to prioritise, and to develop strategic plans. Cassar made a number of recommendations (some of which are in the process of being implemented), including:

- Monitoring, management and maintenance

  - Climate change often highlights long standing preservation issues, rather than discovering new problems. The focus should be on streamlining current monitoring, management and maintenance practices to improve the stability of the historic environment, no matter how weak or strong is the impact of climate change.
- Value and significance in managing climate change impacts
  - The 'save all' approach to the historic environment needs to be re-evaluated. It is not realistic to conserve anything forever or everything for any time at all. Value and significance must be part of future planning of the historic environment faced by a changing and worsening climate.
- Participation in the planning of other agencies
- Fully functional heritage information system
  - A need to overcome the weaknesses of paper maps and disparate databases and to transform all existing information to a single standard. A fully functioning and fully integrated heritage information system should replace individual project mapping with a comprehensive digital map base that integrates currently separate data-sets and links them to images such as photographs and plans.
- Emergency preparedness
- Adaptation strategies and guidelines for historic buildings, archaeology, parks and gardens
- Buried archaeology and prediction maps

In Wales, Farrar and Vase (2000) identified a number of potential strategies that could be undertaken to protect the historic environment. A 'strong information base' was identified as the key element for good management, which would enable monitoring and strategic planning to take place. The study noted the significance of including archaeology and the historic landscape in the Tir Gofal agri-environment scheme and the potential for Cadw, the Forestry Commission and the Welsh Archaeological Trusts to work together. The importance of statutory designations was recognised but it was also noted that forestry and agriculture operate outside the planning process and that statutory processes might need to be reviewed to ensure long-term protection in the face of the direct and indirect impacts of climate change. Three threats to integrated and long-term strategic planning for heritage protection were identified: fragmentation within the archaeological professions; lack of promotion (e.g. awareness raising and understanding among the public); and, limited resources.

Recent work in the UK, the UK Climate Change Risk Assessment 2012 (CCRA) (Defra, 2012a) has resulted in a wide ranging evidence base for assessing the impacts of climate change and adaptation strategies under five broad themes. The study provides an overview of risks from climate change in the UK but does note the high level of uncertainty associated with predicting the risks from the impacts of climate change. Over 700 potential risks were identified along with the need for continuing mitigation and adaptation strategies. Flood and coastal erosion risk management was identified as one of the areas requiring immediate adaption action. Management of pests and diseases, movements of plants and animals, and management of water resources were also identified as key areas needing immediate action. The report contains very little on the historic environment, but the vulnerability of 'different manmade or natural environment' to the adaption of climate change is noted in the 'Wales' section of the assessment. The assessment notes that the Welsh Government is already responding to the challenge of adaption and has already published Parts 1 and 2 of a guidance document titled 'Preparing for climate change'.

The National Park Service (NPS) in the USA is currently working in a number of areas to address the issue of the sustainability of its historic structures. One approach is an inter-departmental project within the NPS to identify a sample of typical NPS historic structures (about 20), and develop recommendations for sustainable treatment. The aim is to select structures and treatments that represent a wide array of problems faced by the NPS regarding sustainability of historic structures and to develop guidance on best practice and a set of guiding principles. Other proposals include:

- working with green building certification programmes to incorporate the guiding principles into certification processes;
- development of an operations and maintenance checklist for historic buildings
- inter-departmental collaboration to identify, protect, and preserve the historic assets most at risk from climate change.

Defra (2001) put forward a strategy for shoreline management based on five generic policies relating to holding or advancing the line, managed realignment, no intervention, or some form of active intervention. This idea has been extended (Rydin, 2011) as a means for developing strategic thinking for the broader historic environment through a 'futures thinking' process, looking at different potential scenarios and exploring outcomes based on four alternative policy options:

- Do nothing
- Managed retreat
- Hold the line by protecting slightly more sites
- Advance the line by protecting many more sites

Techniques suggested included generation of a business case for heritage to bring about behavioural changes and support protection, development of 'heritage offsets' to enable value of historic buildings to be incorporated into planning for climate change, defining the 'significance' of heritage assets, and mapping values associated with the historic environment in conjunction with community involvement. Specific techniques for managing the shoreline historic environment include environmental appraisal for all flood and coastal defence schemes and provision of adequate information on the significance of historic assets to support this process at a strategic level. It was suggested that assessment procedures must include appraisal, desk-based studies, field evaluation, significance measures, and mitigation strategies for input into the planning process. (Defra, 2001)

Strategic planning requires a high quality information system (based on digital mapping) emergency planning, participation with other agency actions, and understanding of adaptation options. One problem constraining effective strategic development is the number of 'cleavages' within the heritage governance regime which makes strategic development difficult. (Rydin, 2011) Cleavages include: a proactive heritage management approach occurring within a reactive planning system, the cultural vs. natural environment split, terrestrial vs. marine environment split, and local, national and European planning regimes.

Strategies for improving protection of cultural heritage might need to start with simply raising awareness of the value of what might be at risk from climate induced damage. May (2007) described using the threat of a repeat of the 100 year flood on the River Seine to bring about new initiatives for heritage protection plans in France in 2002. The process of adopting heritage protection plans can be slow (in 2007 only 10% of the museum's in France had adopted a protection plan) due to the need for each location to take an individual approach, but also because a protection plan was found to be only one element in a broader 'prevention' plan, which requires a risk-based approach. Increased awareness also includes improved understanding of how we can learn from low energy societies of the past, for example, settlement planning to minimise energy consumption. The archaeological record itself (e.g. in peat bogs) provides valuable information on the climate record over thousands of years that can be utilised in making projections of future climate change; maritime deposits can improve understanding of coastal processes, and the design of historic buildings can provide lessons for reducing energy consumption, as well as how to withstand extremes of weather over time. (English Heritage, 2008a)

Cadw (2011) has recently issued a set of principles building on those developed by English Heritage in 2008 and echoing the principles for management of World Heritage sites. The principles aim to underpin management of the historic environment in Wales:

- Historic assets will be managed to sustain their values
- Understanding the significance of historic assets is vital
- The historic environment is a shared resource
- Everyone will be able to participate in sustaining the historic environment
- Decisions about change must be reasonable, transparent and consistent
- Documenting and learning from decisions is essential

UNESCO (2007) identified a set of short-term actions for mitigating climate change on World Heritage Sites, including development of appropriate adaptation strategies, sharing knowledge among stakeholders, updating management plans, and developing mitigation measures. Essentially the strategy can be paired down to three types of action: preventative actions, corrective actions, and sharing knowledge. Monitoring and vulnerability assessment must underpin such actions along with tailored risk-preparedness measures at the site level and taking preventative action where necessary.

Recent guidance from English Heritage (2009) builds on the UNESCO strategy recognising that effective conservation is about the management of change and provides some advice for conservation of World Heritage Sites. UK World Heritage sites require management plans which should include:

- A shared understanding of the property and its significance by all stakeholders
- A cycle of planning, implementation, monitoring, evaluation and feedback
- Involvement of all partners and stakeholders
- Allocation of resources
- Capacity building
- A transparent and accountable management system

The nature of World Heritage sites, often large with multiple owners and stakeholders, suggests the need for a participatory approach with management driven by a steering group and plans subject to public consultation. Management plans are recommended to include a long term vision for the site (over 30 years) and policies for five years, which can then be turned into annual work plans, and altered if new information comes to light, or conditions change. The elements of successful planning could also be applied to the wider historic environment:

- Understanding what is there
- Identifying what is important and why
- Understanding what makes the values vulnerable
- Identifying what policies need to be in place to protect the values

- Identifying how the policies will be implemented, monitored and evaluated

Policies must then integrate conservation with sustainable use and identify ways of managing sites with loss of value over time.

The 2007 White Paper on Heritage Protection (DCMS, 2007) identified three core principles for heritage protection: a unified approach to the historic environment, maximising opportunities for inclusion and involvement, and putting the historic environment at the heart of the planning system. The proposals included provisions for a simplified designation system, higher involvement of the public in deciding what to protect, and increasing capacity for action at the local level. These ideas have been taken forward into more recent UK government thinking such as the recent Department of Culture, Media and Sport paper (2010), which identifies six strategic aims for managing the historic environment:

- Strategic leadership – based on leadership at all levels of government that considers how the historic environment can assist in meeting their goals, and seeks creative use for heritage assets. Requires policy guidance and standards.
- Protective framework – ensuring protection for assets while allowing for ‘intelligent change’ using the planning process.
- Local capacity – developing skills and understanding at the local level to ensure heritage issues are considered early in the planning stage.
- Public involvement – creating a sense of public ownership in the historic environment
- Direct ownership – ensuring al assets in public ownership meet appropriate standards of care
- Sustainable future – recognition of the role played by heritage in sustainable development.

The strategy places a lot of emphasis on the planning system, and on development of sufficient human capital at the local level in order to achieve success; but without supporting programmes for raising awareness, provision of high quality information, integration of historic environmental issues into other policy sectors, training, and provision of guidance, it is unlikely to bring about the desired level of change. The ‘cleavages’ mentioned above also influence the effectiveness of the local level to respond to climate change in an effective manner. Whereas flood risks are becoming recognised, wider impacts of climate change such as biodiversity, spread of disease, and water resources are not yet realised and integrated into local level planning. A key problem is in understanding the need for adaptation and rationalising short-term local planning horizons with the long-term impacts from climate change. (Wilson, 2006)

In parallel with the DCMS 2007 White Paper, Wales produced a draft Draft Heritage Bill, but as with the DCMS White paper this was not progressed. The Welsh Government is now committed to introducing a Heritage Bill in 2014-15. Consultation has started, and it is clear that climate change and its impact on the historic environment are key issues that need to be addressed in the Bill. The Ministerial Priorities for the Historic Environment of Wales: Discussion Draft (Welsh Government , 2012) as well as committing to introducing a Heritage Bill in 2014-15, set out the government’ s primary objectives for 2012-14 as:

- Conserve Wales’s heritage to the best possible standards
- Help sustain the distinctive character of Wales’s landscapes and towns
- Help people understand and care about their place and history – and the place of Wales in the world
- Make a real difference to people’s well –being in Wales.

Achieving these objectives will require a more detailed assessment of the significance and value of historical assets, as well as improved understanding of the nature of the risks faced by different assets under changing climate conditions.

The Defra strategy is echoed in Historic Scotland's recent strategic document (Historic Scotland, 2011) for the period 2012-17. Six strategic themes are identified, along with some associated actions:

- Reducing energy use in our buildings – development of a carbon management plan and investment in energy efficiency measures
- Improving our operations – through embedding climate change checklists into business planning, reduce waste and increase recycling, improve monitoring of water and energy at properties, and introduce staff training to raise awareness of climate change issues.
- Improve energy efficiency in traditional buildings – conduct research on energy efficiency through pilot studies; undertake research on embodies carbon and energy modelling; ensure knowledge of energy efficiency in tradition al buildings is included in skills training for the construction sector, provide advice for upgrading and adaptation of other sites.
- Building resilience: preparing the historic environment for climate change – develop a methodology for assessing the impact of climate change on heritage assets, undertake climate change risk assessments to identify which sites are most threatened, evaluate specific threats such as stone decay, review the maintenance strategy and modify where necessary, input climate change factors into estate management, prioritise grant funding to respond to emerging climate change threats.
- Improving sustainability – through embedding sustainability checklists and procurement issues into activities.
- Developing and promotion sustainable tourism – through seeking ways to reduce the carbon footprint of tourism.

The proposed actions put into practice some of the key activities identified earlier such as raising awareness, building human capital through training, undertaking monitoring and evaluation exercises to improve understanding of impact of climate change on assets, and adjusting grant funding. The focus is on the built heritage, with little consideration of wider historic assets such as archaeological remains, settlements, and historic landscapes, but the proposed actions, if fully implemented, should make the historic environment more resilient to change.

Summary of key points

There has been general recognition that not all heritage assets can be saved, and at the same time it is clear that there is a need for integration of effort across bodies involved with land management and those that have impacts on land use. Much of the international literature is focused on wider environmental and societal impacts of climate change, while relatively little attention is focused on the historic environment itself. In terms of historical structures there is also a significant focus on restoration of assets and making them more 'sustainable' (e.g. in terms of energy use). Many of the documents located identify broad principles or strategies for managing change rather than on detailed technical guidance. The strategic focus of many documents suggests the following:

- It is important to assess value and significance of assets
- Public involvement is required

- Concerns must be integrated into the wider planning processes, and into policies of a range of government agencies.
- Mitigation and adaptation approaches are required, but these should be integrated into broader monitoring and maintenance regimes.

The risk assessment undertaken in the next sections of this report are a necessary first step towards identifying assets at risk and developing a means of prioritising areas for action.

4. The Risk Assessment

The detailed results of the risk assessment are presented in Section 6 for each of the environmental assets and climate change scenarios explored. Each matrix in Section 6 assesses the risk to a particular category of historical asset (e.g. historic parks and gardens) from a particular type of climate change (e.g. warmer mean temperatures). Risks are described and then assessed using the scoring mechanisms in Tables 2.3 to 2.5 to arrive at a measure of significant risk. Each matrix also describes any particular gaps in the knowledge base used to assess the risk, and any other comments. In addition, each category of historical asset has a summary table which summarises the overall impacts and risks for that particular category.

This section will summarise some of the key issues revealed through the analysis of the risk matrices, which are illustrated in a series of tables below.

Table 4.1 below illustrates which categories of historical assets are affected by the various outcomes of climatic change. It is clear from the table that categories of historical assets are affected by different types of climate change. Looking down the columns the table suggests that 'more frequent extreme weather' will impact in some way on all categories of historical asset. Only archaeological sites under peat bogs, wetlands and below the 1m contour (i.e. those mostly in wet areas already) are not affected in some way. The other climatic change with potential for widespread impact is 'sea level rise'. This could impact upon historic landscapes and the large variety of archaeological remains below the 1m contour, in valley bottoms and flood plains, and on the foreshore. The lowest potential impact comes from drying and shrinking clays as a result of hotter, drier summers, which only is likely to affect a certain proportion of historic buildings sitting on particular clay soils.

Looking across the table it is clear that the asset with the most potential to be impacted by climatic change is 'historic landscapes'. The table suggests that almost all of the predicted climatic changes have the potential to have some kind of effect. Other assets potentially impacted by a wide range of climate change are 'historic parks and gardens', and 'historic buildings'. These are both likely to be influenced by warmer mean temperatures (in the form of a longer growing season and migration of pests and diseases) and by more frequent extreme weather.

Table 4.1. Matrix showing the historic environment assets affected by various outcomes of climate change (grey cells)

Note: Not all the classes of historic environment assets are exclusive. Thus, for instance, historic buildings as well as being considered under the heading 'historic buildings' are also considered in historic parks and gardens, and archaeological sites on farmland are also considered under 'historic assets on floodplains and valley bottoms.

Description of change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters/wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests and diseases into Britain	Drying out, desiccation and erosion of wetlands	Stress on some trees and plants	Drying and shrinking of clay soils	More flooding events	Frequent high winds/storms
Historic Environment Asset								
1. Historic assets below the 1.0 m contour								
2. Archaeological sites on farmland								
3. Historic assets on the foreshore								
4. Forestry and woodland								
5. All historic buildings								
6. Historic assets on the coast edge, excluding those below the 1m contour								
7. Historic assets on floodplains and valley bottoms								
8. Historic parks and gardens								
9. Peat, peaty soils and blanket bog								
10. Historic landscapes								
11. Historic assets in sand dunes								
12. Archaeological sites in an upland environment, excluding peat bogs								

Tables 4.2 to 4.5 explore in a little more detail the magnitude (small, moderate, high) and direction (positive, negative) of likely impacts on the categories of historical asset. Table 4.2 suggests that 'hotter, drier summers will for the most part have moderate negative impacts on assets, through for example greater stress on trees and plants in forestry and woodland. On the other hand 'warmer mean temperatures' (see Table 4.3) are likely to have a greater effect on assets, particularly from rising sea levels. The table indicates that rising sea levels could potentially have high negative impacts on historic assets on the foreshore and those below the 1m contour line. Other impacts could occur on historic assets in upland areas and in forestry and woodland, and on historic buildings.

Table 4.4 suggests that warmer, wetter winters/wetter summers will create more flooding events with a consequent potential for high negative impacts on all historic buildings and on all historic assets below the 1m contour and in valley bottoms. Table 4.5 suggests that more frequent extreme weather is likely to have a range of negative impacts on all classes of asset.

Table 4.2. Matrix showing the assessed level of significance of hotter drier summers on historic environment assets.

Description of change	Hotter, drier summers		
Outcome of change	Drying out, desiccation and erosion of wetlands	Stress on some trees and plants	Drying and shrinking of clay soils
Historic Environment Asset			
1. Historic assets below the 1.0 m contour			
2. Archaeological sites on farmland			
3. Historic assets on the foreshore			
4. Forestry and woodland		Moderate negative	
5. All historic buildings			Moderate negative
6. Historic assets on the coast edge, excluding those below the 1m contour			
7. Historic assets on floodplains and valley bottoms			
8. Historic parks and gardens		Small negative	
9. Peat, peaty soils and blanket bog	Moderate negative		
10. Historic landscapes	Moderate negative	Moderate negative	
11. Historic assets in sand dunes			
12. Archaeological sites in an upland environment, excluding peat bogs			

Table 4.3. Matrix showing the assessed level of significance of warmer mean temperatures on historic environment assets.

Description of change	Warmer mean temperatures		
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests and diseases into Britain
Historic Environment Asset			
1. Historic assets below the 1.0 m contour	High negative		
2. Archaeological sites on farmland		Small negative	
3. Historic assets on the foreshore	High Negative		
4. Forestry and woodland			Moderate negative
5. All historic buildings		Small positive	Moderate negative
6. Historic assets on the coast edge, excluding those below the 1m contour	Moderate negative		
7. Historic assets on floodplains and valley bottoms			
8. Historic parks and gardens		Small positive	Small Negative
9. Peat, peaty soils and blanket bog			
10. Historic landscapes	Moderate negative	Moderate negative	Moderate negative
11. Historic assets in sand dunes	Small negative		
12. Archaeological sites in an upland environment, excluding peat bogs		Moderate negative	

Table 4.4. Matrix showing the assessed level of significance of warmer wetter winters/wetter summers on historic environment assets.

Description of change	Warmer, wetter winters/wetter summers
Outcome of change	More flooding events
Historic Environment Asset	
1. Historic assets below the 1.0 m contour	High Negative
2. Archaeological sites on farmland	
3. Historic assets on the foreshore	
4. Forestry and woodland	
5. All historic buildings	High Negative
6. Historic assets on the coast edge, excluding those below the 1m contour	
7. Historic assets on floodplains and valley bottoms	High Negative
8. Historic parks and gardens	
9. Peat, peaty soils and blanket bog	
10. Historic landscapes	Moderate negative
11. Historic assets in sand dunes	
12. Archaeological sites in an upland environment, excluding peat bogs	

Table 4.5. Matrix showing the assessed level of significance of more frequent extreme weather on historic environment assets.

Description of change	More frequent extreme weather
Outcome of change	Frequent high winds/storms
Historic Environment Asset	
1. Historic assets below the 1.0 m contour	High Negative
2. Archaeological sites on farmland	Small negative
3. Historic assets on the foreshore	Moderate negative
4. Forestry and woodland	Moderate negative
5. All historic buildings	Moderate negative
6. Historic assets on the coast edge, excluding those below the 1m contour	Moderate negative
7. Historic assets on floodplains and valley bottoms	High Negative
8. Historic parks and gardens	Moderate negative
9. Peat, peaty soils and blanket bog	Moderate negative
10. Historic landscapes	Moderate negative
11. Historic assets in sand dunes	Small negative
12. Archaeological sites in an upland environment, excluding peat bogs	Small negative

The final table in this series (Table 4.6) summarises the risks in terms of high (red), medium (orange), and low (green) risk of negative impacts, or a neutral/positive impact (blue) and identifies the type of change causing the risk. A relatively small number of assets are at high risk (indicated by a red marker). These are primarily assets in potentially affected sites such as historic assets in floodplains and valley bottoms at risk from increased flood events, historic assets at risk from rising sea levels, and areas of peats and peaty soils. A large number of assets are potentially at moderate risk (amber) resulting from a wide range of climate change events, in particular historic buildings, historic parks and gardens, and historic landscapes fall into this category of risk. Cumulatively these risks should be considered of high significance. Slight beneficial outcomes are identified for just two classes of site.

Table 4.6 Matrix showing the assessed level of significance on historic environment assets

Description of change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters/wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests and diseases into Britain	Drying out, desiccation and erosion of wetlands	Stress on some trees and plants	Drying and shrinking of clay soils	More flooding events	Frequent high winds/storms
Historic Environment Asset								
1. Historic assets below the 1.0 m contour	High negative						High negative	High negative
2. Archaeological sites on farmland		Small negative						Small negative
3. Historic assets on the foreshore	High negative							Moderate negative
4. Forestry and woodland			Moderate negative		Moderate negative			Moderate negative
5. All historic buildings		Small positive	Moderate negative			Moderate negative	High negative	Moderate negative
6. Historic assets on the coast edge, excluding those below the 1m contour	Moderate negative							Moderate negative
7. Historic assets on floodplains and valley bottoms							High negative	High negative
8. Historic parks and gardens		Small positive	Small negative		Small negative			Moderate negative
9. Peat, peaty soils and blanket bog				High negative				Moderate negative
10. Historic landscapes	Moderate negative	Moderate negative	Moderate negative	Moderate negative	Moderate negative		Moderate negative	Moderate negative
11. Historic assets in sand dunes								Small negative
12. Archaeological sites in an upland environment excluding peat bogs		Moderate negative						Small negative

5. Risk Assessment Summaries

Analyses in this report show that the impacts of climate change on the historic environment will vary enormously depending on the type of historic asset and location. Some of the projected extreme weather events will undoubtedly have a significant impact upon certain classes of historic environment asset, but it is the projected long term trends, such as hotter drier summers, a longer growing season and rising sea levels that potentially have the greatest impacts. Consideration of issues such as responses to a changing climate, mitigation to reduce the threat of climate change and opportunities offered by climate change were not part of the remit of this report, but it is these very issues that are likely to have the greatest impact on the historic environment and therefore they are briefly considered where appropriate in the following summaries. Those classes of historic asset considered most at risk from climate change are dealt with first in the summaries, although as noted above the threats and thus the impacts vary greatly, and those affecting historic assets in sand dunes, for example, are very different from those affecting buildings and sites below the 1m contour.

Historic landscapes

No single highly significant impact was identified for historic landscapes, but a series of potential impacts were identified and assessed as being of moderate significance. Cumulatively these are of high significance, and it is the authors' opinion that the impact of climate change will be more severe and widespread on historic landscapes than on any other type of historic asset.

Direct impacts such as a longer growing season and warmer summers may not in themselves have a major effect on the historic landscape, but indirect impacts, the opportunities offered by these changes such as the introduction of new crops and farming practices, an increase in cereal growing, and the expansion of improved pasture onto moorland fringes, could have a very big effect and is recognised as such in the UK Climate Change Risk Assessment 2012. However, any such indirect impacts will be tempered by prevailing economic, political and social conditions, and, most importantly, by agricultural policies and schemes. Some direct impacts could also be mitigated through these schemes with, for example, the loss of trees to disease, to stress caused by hotter summers and to more frequent storms off-set to some degree by new planting under the current New Woodland Creation scheme.

The drying out and desiccation of uplands peats is discussed below. In historic landscape terms the greatest impact of climate change is likely to be, not in the high uplands, but in the lower altitude areas dominated by peaty and organic soils and pockets of thin blanket bog. Loss of organic content in these soils and their transformation into mineral soils will alter the types of vegetation they can support and with it the character of the historic landscape. As with lowland areas, the extent to which the historic landscape is altered will depend largely, although not entirely, on whether the opportunity for change is taken, or whether political and economic policies will prevent the wholesale transformation of open moorland into rough or improved pasture.

As noted above, adaptive responses to and mitigation of climate change will have a big impact. Assessing these lies outside the remit of this study, but it is worth noting the impact that wind farms and other renewable energy generating schemes are having on the historic landscape. Thus, although climate change will have an impact on historic landscapes, both the trajectory and extent of this change will largely depend on other factors. However, not all of this impact needs to be considered in the negative. It could be argued that the change from a largely lowland pastoral farming landscape of hedgerows and small fields to one with a higher arable element, fewer standard trees and larger fields is a reversion to what prevailed several centuries ago and not necessarily a bad thing.

Historic assets below the 1m contour

Sea level is predicted to rise by 0.4m by 2080 and by 2100 storm surge events could occur up to 20 times more frequently. These predictions coupled with potentially more frequent flooding events for those areas on river estuaries combine to pose a very serious threat to historic assets lying between the 0 and 1m contour. The figures of nine scheduled ancient monuments, 77 listed buildings and over 300 recorded archaeological sites between the 0 and 1m contour does not provide the full picture as parts of many of Wales's urban areas lie in this zone, and thus the potential damage and loss, not just to individual historic elements, but also to the overall historic character is considerable. Mitigation ranging from managed retreat to providing heavily engineered defences is possible. However, in some locations sea defence construction could damage or impact on the character of historic assets that it is designed to protect.

Historic assets on floodplains and valley floors

A recent study by the RCAHMW indicates that over 5000 listed buildings, 300 scheduled ancient monuments and 12,000 other archaeological sites are at risk from flooding, but these raw figures require analysis before reaching conclusions:

- First, areas at risk from flooding are taken from the Environment Agency's flood risk data, which is based on 2m Lidar data. This is coarse data and on occasions identifies areas at risk that could lie slightly above the flood risk zone. This is particularly important when considering the core of historic settlements (including numerous listed buildings), many of which lie in river valleys, but are deliberately sited just above the flood zone, but may be included in the Environment Agency's 'at risk of flood' area.
- Second, no attempt was made in the RCAHMW's study to break down by type archaeological sites at risk of flooding. The 12,000 sites include cropmarks, artefact scatters and low earthworks that will be little affected by an increase in the number of flooding events, as well as more substantial earthworks and structures that may be impacted.

Taking into account the above caveats, there is little doubt that an increase in the number and scale of flood events will have a severe impact on historic assets. Buildings (listed and unlisted) and their fittings will be significantly affected, not just by the sudden impact of a flood, but in the longer term by damage caused by fungal and insect infestation, and by compromising structural integrity. Damage may occur to historic street furniture, street surfacing and other historic elements of settlements, and the character of these settlements may be compromised by the construction of flood defences. Archaeological sites and structures such as historic bridges will be damaged and destroyed as rivers shift their courses.

Studies by the University of Aberystwyth (for instance Jones et.al. 2011) show no evidence for an increase in flooding events in Welsh rivers over the past 40 years (see Photo 1 below). It is possible that factors such as extensive upland forestry and dams across the headwaters of many major rivers have provided an unintentional mitigation against flooding. Aberystwyth studies have also shown that barriers across flood plains, such as hedges, reduce the maximum height of a flood, but cause flood waters to linger longer. This highlights just one of the complex relationships between climate change and opportunities taken as a result of change. A possible outcome of climate change outlined in 'Historic Landscape' above, is more arable farming, resulting in the cutting down of hedges and resulting in bigger and faster moving flooding events. This leads to an increase in the threat to historic assets, a threat that will be amplified as flood water moves across plough-land rather than semi-permanent pasture.

Photo 1: Rivers Severn and Vyrnwy in flood, 2007

Summer and winter flooding events may become more common. Here we see Severn and Vyrnwy in flood in 1907. © Crown copyright: Royal Commission on the Ancient and Historical Monuments of Wales, photo reference: AP_2007_1276.

Peat, peaty soils and blanket bogs

A study (Moore 1988) into how the wooded uplands of Britain were transformed in the prehistoric period into a landscape of moorland and blanket bog concluded that climate change was involved, but was not the over-riding factor, as the onset of bog formation did not cluster around climatic deterioration (wetter, colder conditions), and that human involvement was a key factor in bog development and subsequent management. It is not unreasonable therefore to suggest that climatic change in the form of hotter, drier summers and human intervention/management will both be important factors in determining the future trajectory and extent of deterioration of peats and blanket bogs (for instance see the management recording in Photograph 2).

Taking the human factor out of the equation, the predicted hotter, drier summers will cause the desiccation of some areas of peats making them more susceptible to erosion, erosion that will be exacerbated by the predicted higher winter rainfall and more frequent storms. In addition, in the long-term, peaty and organic soils could be transformed into mineral soils, with consequences for the historic landscape as described above. There will be some loss of the palaeo-environment record locked in peat bogs and loss of organic artefacts within bogs. Loss of blanket bog will expose archaeological sites and deposits that have been sealed and protected for several thousands of years, making them vulnerable to erosion.

Photo 2: Grip blocking old drains, Migneint, Snowdonia

The drying, desiccation and loss of peat and peaty soils has been identified as one of the possible results of climate change. Some mitigation is already in place to prevent the drying of peat bogs. For example, here at Migneint, Snowdonia four large machines are at work blocking old drains. © Crown copyright: Royal Commission on the Ancient and Historical Monuments of Wales, photo reference: AP_2011_0332.

All Historic Buildings

A series of moderate negative impacts on historic buildings caused by climate change have been identified. These include the migration of pests and diseases, drying and shrinking of clay soils, freeze-thaw effects on wet stone, more frequent maintenance required due to damper conditions, and damage caused by more frequent high winds and storms, and thermal movement of materials such as slate, lead-work, timber and paintwork. Although some of these impacts will be mitigated by the fact that many of our historic buildings are well cared for and will be rapidly repaired following damage. More insidious will be the effects of the shrinking of clay soils and an increase in pests and diseases. The latter may be a particular issue for those historic houses that retain their original decoration, fixtures and fittings.

It is likely that the most damaging impact on historic buildings will be caused by more frequent flooding events. The threat has been dealt with under assets lying on floodplains and those below the 1m contour, but more frequent and bigger floods are likely to impact on those buildings outside these environments, and the significance of these events will be high.

Historic assets on the foreshore

For the past six thousand years sea levels have been remarkable stable. Now they are rising once more and, combined with more frequent and violent storms, will impact on the wide range of archaeological sites found on the foreshore, although the significance of the impact will vary widely according to local conditions. Archaeological sites on the foreshore are sensitive to change (see Photo 3), and most will suffer as a result of climate change. Associated activities, such as construction of sea defences (see Photo 4), may also result in indirect impacts. However, rising sea levels, will help protect some sites, such the submerged forest lying close to the low water mark, but at the same time make them unavailable for study.

Photo 3: Lydstep Haven

People in the past have had to deal with the impact of climate change on their environment. Dramatic evidence of this can be found on the foreshore where tree stumps, peat deposits and other evidence of a terrestrial environment survive in a remarkable state of preservation. For example, in this photograph footprints made by a child over 5000 years ago are clearly visible in a peat deposit on the beach at Lydstep Haven, Pembrokeshire. Photograph: Dyfed Archaeological Trust.

Photo 4: Borth coastal defence construction

The construction of sea defences is likely to become more common as sea level continues to rise and storms become more frequent. This photograph shows off-shore reef construction at Borth, Ceredigion. Photographs: Dyfed Archaeological Trust.

Historic assets on the coast edge, excluding those below the 1m contour

A predicted rise in sea levels coupled with more frequent and intense storms resulting in 20 times more frequent storm surges by 2100 of up to 1.9m height will have a localised and sporadic high negative impact on low lying coastal land lying above the 1m contour, but overall the impact is assessed as moderate negative. The devastating impact of coastal flooding prior to any sea level rise was demonstrated along the Bristol Channel coast in 1607. So devastating was this flood that it was considered a tsunami, but is now known to have resulted from a storm surge coupled with high tides. Analysis by the RCAHMW shows that there are over 1000 listed buildings, over 140 scheduled ancient monuments and over 7000 other archaeological sites at risk in this environment.

Rising sea level and more frequent storms will accelerate the rate of erosion of sea cliffs. The rate of this erosion will depend on many factors, especially exposure and geology. It is not therefore possible to provide figures of archaeological sites and buildings that will be affected, but in the more extreme locations both buildings and sites will be lost.

Photo 5: Porthkerry Bulwarks 2011

Coastal erosion will accelerate as sea levels rise and more frequent storms occur. This photograph captures a recent massive landslip close to Porthkerry Bulwarks Iron Age promontory on the Glamorgan Coast. © Crown copyright: Royal Commission on the Ancient and Historical Monuments of Wales, photo reference: AP_2011_4088.

Historic parks and gardens

The impacts of climate change - warmer mean temperatures, hotter drier summers and more frequent storms – on historic parks and gardens are difficult to assess as they will vary enormously according to the type of park of garden, and there will be positives as well as negatives. The most significant negative impact will occur in unmanaged parks and gardens where trees and other plants lost to pests, diseases and storm damage will not be replaced, and the speed of degradation and erosion of ‘hard’ garden features will increase under more frequent storms.

In managed parks and gardens these losses will be largely made good and the opportunity taken to replace plants with heat tolerant and disease resistant species. This will not always be possible in parks noted for their traditional native woodlands, but in parks and gardens celebrated for their exotics, hotter drier conditions may be an opportunity to enhance their character.

Archaeological sites in an upland environment excluding peat bogs and blanket bogs

Some of the best preserved archaeological sites in Wales are located in upland environments and so by their very nature are sensitive to change. More frequent and intense storms will result in erosion of these sites, but the main threat could result from the opportunity offered by warmer mean temperatures and a longer growing season to push back the boundaries of farmland into the margins of this zone. This could bring archaeological sites into a more intense agricultural regime than they have previously experienced. As discussed above climate change offers this opportunity, but whether it will actually happen will depend on other factors, political, economic and social.

Historic assets in sand dunes

The adaptive, dynamic nature of sand dune habitats makes any prediction as to how they might respond to climate change problematic. However, in general terms, it is likely that a rise in sea levels and an increase in the frequency of intense storms and gales will result in changes to dune systems, impacting on the large number and important archaeological sites within and below them. However, dune systems are generally carefully managed, and thus change might be mitigated.

Forestry and woodland

Ancient woodlands are similar to other historic assets in that they contain complex evidence for past human use. Climate change is considered the greatest threat now faced by ancient woodland. These threats include the migration of pests and diseases, stress on trees caused by hotter drier summers and more frequent and intense storms. However, woodlands are complex and varied ecosystems, and are therefore likely to respond in a variety of different ways, and although they are sensitive to climate change, this change will be mitigated to some extent by the careful management enjoyed by some ancient woodland areas.

Thus although climate change on woodland will have the greatest impact on the woodland itself, mass loss of trees and subsequent soil erosion, change of land-use and replanting could impact on individual historic assets lying within woodland.

Archaeological sites on farmland

A longer growing season resulting from higher mean temperatures will not directly impact on archaeological sites on farmland, but as with other categories of historic assets discussed here it is the opportunities offered by these changes such as increasing the amount of land under cultivation, the introduction of new crops and other changes to farming practices that could have a significant impact. However, whether these opportunities are accepted will depend on economic, political and social factors. The main threat to archaeological sites will be caused by more frequent ploughing of currently cultivated land and the ploughing of fields not recently cultivated.

Erosion to earthwork sites as result of an increase in the frequency and intensity of storms might occur, and locally could be severe.

6. Risk Assessment Matrices for Historical Environmental Assets

1. HISTORIC ASSETS SITES BELOW THE 1m CONTOUR

Description of change
Warmer mean temperatures

Outcome of change
Rise in sea levels

Location
Below the 1.0m contour

Impact on historic environment assets
A. All historic assets below the 1.0m contour

	Extent	Severity	Sensitivity	Significance of Impact
A	4	-2	4	-32 high negative

Risk assessment of historic assets

A. The Royal Commission on the Ancient and Historical Monuments of Wales has applied Geographical Information Systems to analyse the impact of rising sea levels on lower-lying archaeological sites and historic buildings. They were able to identify all coastal Scheduled Ancient Monuments, listed buildings, Historic Environment Record and National Monument Record sites that are located within the range of 0-1metre above sea level. These sites are at potentially higher risk of loss or damage from the predicted (UKCIP) rise in sea level (of approximately 0.40m by 2080)
A rise in sea levels is quantifiable but the extent of damage caused to the historic environment will also be determined by storm surge events, which are predicted to occur up to 20 times more frequently by 2100 (UKCIP, 2002) These events will be variable in their impact and possibly very localised.

Specific gaps in knowledge

Responses to outcome of change
Areas of the Welsh coast have already been affected by coastal flooding and there is currently some 260 miles of man-made sea defences along parts of the coast. However, there have been warnings that these defences cannot keep pace with climate change (Auditor General for Wales, 2009) and homes may have to be abandoned in the future. It therefore seems inevitable that Wales will also lose some of its coastal heritage and the most vulnerable elements need, at least, to be recorded.

Notes and references
A significant amount of the Welsh coast lies less than one metre above current sea-level. When rising sea-level is coupled with storm surges at sea of up to 1.9m, the frequency of flooding of low-lying areas is expected to increase (Friends of the Earth, 2005)

Description of change

Warmer, wetter winters/wetter summers

Outcome of change

More flooding events

Location

Below the 1.0m contour

Impact on historic environment assets

A. All historic assets below the 1.0m contour

	Extent	Severity	Sensitivity	Significance of Impact
A	4	-2	4	-32 high negative

Risk assessment of historic assets

A. All historic assets located below the 1.0 metre contour and in an estuarine or similar location are at risk of flooding from a predicted increase in the frequency of winter storms and mild, wet and windy winter weather (UKCIP, 2002)

B. Low-lying buildings and sites are also at risk from land slippage caused by ground saturation.

Specific gaps in knowledge

Responses to outcome of change Vulnerable archaeological sites and historic buildings need to be assessed for ways to protect them from potential flooding and its damaging effects – flood defences, more effective drainage or water management, consolidation.

Notes and references

Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/storms

Location

Below the 1m contour

Impact on historic environment assets

A. All historic assets below the 1.0m contour

	Extent	Severity	Sensitivity	Significance of Impact
A	4	-2	4	-32 high negative

Risk assessment of historic assets

A. This risk has essentially the same as for rise in sea levels.

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Location Historic assets below the 1.0m contour

Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Warmer mean temperatures	Rise in sea levels	All historic assets below the 1m contour	High negative
Warmer, wetter winters/wetter summers	More flooding events	All historic assets below the 1m contour	High negative
More frequent extreme weather	Frequent high winds/storms	All historic assets below the 1m contour	High negative

Summary
Historic buildings and archaeological sites located at lower-lying areas are at potential, risk of loss or damage from predicted sea-level rises, a greater frequency and intensity of flooding caused by warmer, wetter winters/wetter summers, and more frequent storms. A combination of these events is likely to be disastrous. The greater risk could be seen to be around the coast. Sea level rise is inexorable and global and it is already accepted that some areas will be lost. Flooding events caused by changing weather patterns, although potentially just as damaging, are far less predictable and more likely to be intermittent and localised. Buildings and sites identified to be at risk – perhaps on flood plains, in valley bottoms, beside rivers – can be individually assessed to make them less vulnerable to such events.

Royal Commission on the Ancient and Historical Monuments of Wales analysis demonstrates that the following number of assets lie between the 0 and 1m contour: 9 scheduled ancient monuments, 77 listed buildings and 312 archaeological sites recorded on the Historic Environment Records.

Attempts to respond to the impact of sea level rise may itself have a detrimental effect on the archaeological resource, whether it is the construction of coastal defences or the creation of manageable habitat such as salt marsh.

2. ARCHAEOLOGICAL SITES ON FARMLAND

Description of change

Warmer mean temperatures

Outcome of change

Longer growing season

Location

All archaeological sites on farmland

Impact on historic environment assets

A. More land is brought into cultivation so causing plough damage to some archaeological sites.

B. Sites may become obscured as by scrub growth.

C. Greater use of herbicides and insecticides may change the chemical balance on some sites.

	Extent	Severity	Sensitivity	Significance of Impact
A	3	-2	4	-18 moderate negative
B	2	-1	1	-2 small negative
C	2	-1	1	-2 small negative

Risk assessment of historic assets

A. Warmer mean temperatures and longer growing seasons will not in themselves have an impact on archaeological sites on farmland, but the human response to these changes will mean that the environment of Wales will become more conducive to the growing of cereals and other arable crops. This will mean more frequent ploughing of archaeological fields under cultivation and the ploughing of fields not recently ploughed, causing damage to archaeological sites located in those fields. However, the increase in cultivation may be moderated by agri-environment schemes, such as Glastir.

B. More vigorous growth of scrub and other vegetation may occur in a longer growing season, but this not likely to have a major impact on the historic environment.

C. More land under cultivation may lead to an increase in the use of herbicides and pesticides. It is unclear what if any the impact this will be on buried archaeological deposits. The use of chemicals may be moderated by agri-environment schemes and by other CAP directives.

Specific gaps in knowledge

There has been little research into impact of chemicals on buried archaeology.

Responses to outcome of change

As noted above, the greatest impact on archaeological sites on farmland caused by a longer growing season will be caused by opportunities to increase the amount of land under cultivation and to grow crops not previously grown in Wales.

Notes and references

Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/storms

Location

All archaeological sites on farmland

Impact on historic environment assets

A. Erosion to earthwork sites causes by rapid run-off during frequent storms.

	Extent	Severity	Sensitivity	Significance of Impact
A	1	-1	3	-3 small negative

Risk assessment of historic assets

A. It is likely that more frequent rain storms will not have a great overall impact on archaeological sites on farmland. However, erosion will be localised, and some sites may experience a high negative impact.

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Location All archaeological sites on farmland

Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
More frequent extreme weather	Frequent high winds/storms	Erosion to earthwork sites causes by rapid run-off during frequent storms.	-3 small negative
Warmer mean temperatures	Longer growing season	More land is brought into cultivation so causing plough damage to some archaeological sites.	-18 moderate negative
		Sites may become obscured as by scrub growth.	-2 small negative
		Greater use of herbicides and insecticides may change the chemical balance on some sites.	-2 small negative

Summary

The main impact caused by climate change on archaeological sites on farmland will be indirect, as a longer growing season, possibly coupled with hotter drier summers, will make the environment of Wales more conducive to the growing of cereals and other arable crops, leading the more frequent ploughing of archaeological fields under cultivation and the ploughing of fields not recently ploughed, causing damage to archaeological sites located in those fields.

3. HISTORIC ASSETS ON THE FORESHORE

Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/storms

Location

Foreshore

Impact on historic environment assets

A. All Historic assets

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-2	3	-12 moderate negative

Risk assessment of historic assets

A. The predicted increase in the frequency of extreme weather would accelerate the on-going erosion of archaeological foreshore sites.
Increased storminess could have an adverse effect on archaeological material lying beneath the water in near-shore environments. The Northern Ireland Environment Agency reported (2009) that larger waves have the capacity to impact the seabed at greater depths, resulting in increased scouring.

Specific gaps in knowledge

The impact of an increased frequency in extreme weather on foreshore sites is difficult to quantify as it could affect widespread areas and/or be very localised, and be influenced by topographical factors. The impact will also vary according to the archaeological site-type

Responses to outcome of change

Notes and references

Description of change

Warmer mean temperatures

Outcome of change

Rise in sea levels

Location

Foreshore

Impact on historic environment assets

A. All Historic assets

	Extent	Severity	Sensitivity	Significance of Impact
A	4	-3	5	-60 high negative

Risk assessment of historic assets

A. The trend towards warmer mean temperatures is creating a global rise in sea levels. It is predicted (English Heritage, 2008) to rise by some 80cm around the UK coast by 2100. Archaeological sites located on the current foreshore are at direct risk from even the minimum predicted sea-level rise and are already being affected. A stark statement from the UCL Centre for Sustainable Heritage (2005) says "we'll never save everything, so hard decisions are needed as to which to 'let go'"

Although many foreshore sites are at risk of being damaged and destroyed others will become flooded and submerged beyond the tidal zone. This may not have a directly negative impact on the actual archaeology but could make these sites less accessible for research purposes and be a loss from our cultural resource.

Specific gaps in knowledge

Responses to outcome of change It is important to identify which sites are at highest risk and take appropriate steps to protect and/or record them in an on-going programme of preservation.

Notes and references

Location Foreshore

Description of change	Outcome of change	Impact on historic environment assets	Significance of impact
Warmer mean temperatures	Rise in sea levels	All Historic assets	High negative
More frequent extreme weather	Frequent high winds/storms	All Historic assets	Moderate negative

Summary

Analysis by the Royal Commission on the Ancient and Historical Monuments of Wales shows that lying within Countryside Council for Wales's Intertidal Phase 1 Map Biotopes there are: 133 scheduled ancient monuments, 80 listed buildings, 883 sites recorded on the Historic Environment Records and 1443 sites recorded on the National Monument Record.

The on-going rise in sea levels and erosion of our coastline is one of the more immediately obvious and dramatic impacts of climate change that we can witness. It is hardly a new phenomenon - in prehistory the sea claimed the hunting grounds of our ancestors – and the archaeology of our foreshore is extremely vulnerable and any effort to protect it is inevitably expensive and possibly futile, with many hard decisions facing us in the future.

Other archaeological sites and deposits may remain intact as they become submerged. For example, the remnant of the ancient Mesolithic woodland that is revealed at low tides. As sea levels rise, sites such as these, although not destroyed (even possibly protected) will become lost, both to academic research and as part of our cultural identity.

4. FORESTRY AND WOODLAND

Description of change

Hotter, drier summers

Outcome of change

Stress on some trees and plants

Location

Forestry and woodland

Impact on historic environment assets

A. Archaeological monuments and deposits

B. Native woodland

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-2	3	-12 moderate negative
B	2	-3	4	-24 moderate negative

Risk assessment of historic assets

A. It is predicted (Forestry Commission) that deposits of organic archaeology could be damaged or lost should the water table drop as a result of a decrease in summer rainfall combined with a continued demand for water from tree cover. Trees could also be killed off by any extended period of drought, making any archaeology vulnerable to soil erosion and wind-throw.
Prolonged periods of drought could also increase the risk of forest fires, potentially causing significant damage to any archaeology.

B. The main threat to broadleaf woodland is drought (Friends of the Earth Cymru, 1997) – “a succession of hot summers is likely to cause a general deterioration in broadleaf tree condition (including mortality) across Southern England and Wales.”

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Oak decline can involve recurrent episodes of drought.

Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/storms

Location

Forestry and woodland

Impact on historic environment assets

A. Archaeological sites and deposits
B. Native woodland

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-3	3	-18 moderate negative
B	2	-1	2	-4 small negative

Risk assessment of historic assets

A. A higher frequency in intense gales and storms will make archaeological sites and deposits located within forestry and woodland more vulnerable to wind-throw.
B. Although occasional storms and heavy rainfall play a positive role in woodland, as they help to open up the canopy and encourage new growth, an increase in their intensity and frequency could become damaging, especially if delicate, fragmented woodland remnants are repeatedly disrupted.

Specific gaps in knowledge

Responses to outcome of change Monitoring of trees growing over/close to archaeological monuments and removing those posing an obvious threat of windthrow or dropping branches. Replacement planting of damaged/dead trees.

Notes and references

Description of change

Warmer mean temperatures

Outcome of change

Migration of pests and disease into Britain

Location

Forestry and woodland

Impact on historic environment assets

A. Archaeological monuments and deposits
B. Native woodland

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-2	4	-16 moderate negative
B	2	-2	3	-12 moderate negative

Risk assessment of historic assets

A. Archaeological monuments and deposits located within woodland and forestry could be threatened by tree loss caused by the migration of pests and diseases. For example, bark beetles thrive in hot summers and can cause serious damage to conifer plantations. If trees become diseased there will be a greater risk of windthrow and if trees are lost a possible change in land-use or replanting could damage the archaeology.

B. Native woodland is itself an important archaeological resource and contains evidence for its historical management, including coppicing, veteran trees, charcoal platforms and saw pits. A demise of our native species of trees would have a dramatic impact on a living landscape that can date back many hundreds of years. Ancient woodland covers only about 2% of the land area of Wales.

Specific gaps in knowledge

The extent and effect of migrating pests and diseases is difficult to predict. It seems likely that areas of forestry comprising a single species are more vulnerable than mixed woodland, although even a single diseased tree can pose a threat to archaeological sites in the immediate vicinity.

Responses to outcome of change Replacement planting of damaged/diseased trees, possibly of species resistant to the new threats.

Notes and references

Notes from *Climate Change Potential Impacts on Wales* (Friends of the Earth Cymru, 1997): Forests cover more than 230,000ha of Wales. In general native broadleaf woodland will suffer under a changed climate, while conifer plantations are predicted to be up to 25% more productive than at present – possible serious consequences for upland Welsh landscapes.

Notes from the Woodland Trust (2007) :Ancient woodland (defined as an area continually wooded since at least 1600AD) is irreplaceable. They are small and often isolated. "…perhaps the greatest threat now faced by ancient woodland is climate change" –Three exotic pests recently found in southern Britain are the pinewood nematode, gypsy moth and Asian longhorn beetle. The latter could cause damage to horse chestnut, poplar, willow and some fruit trees.

The spread of Phytopthora ramorum (sudden oak disease, or SOD) a fungal parasite, amongst several tree species has also been linked with the changing climate. In 2005 a range of tree species – beech, horse chestnut, sessile oak and sycamore – were found with potentially lethal infections of SOD. Elsewhere across Europe there is already oak mortality

Location			
Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Warmer mean temperatures	Migration of pests and diseases into Britain	Archaeological sites and deposits within forestry and woodland	Moderate negative
		Native woodland	Moderate negative
Hotter, drier summers	Stress on some trees and plants	Archaeological sites and deposits within forestry and woodland	Moderate negative
		Native woodland	Moderate negative
More frequent extreme weather	Frequent high winds and storms	Archaeological sites and deposits within forestry and woodland	Moderate negative
		Native woodland	Small negative

Summary

Archaeological sites and deposits located within woodland and forestry will potentially become vulnerable as and when the trees that currently cover them are affected by predicted climate changes, most notably prolonged periods of drought and the migration of pests and diseases. Possible outcomes range from an individual diseased tree falling and the obvious threat to the archaeology from windthrow to the mass loss of woodland or forestry and the subsequent threats from soil erosion, change of land-use or re-planting. Predicted drier, hotter summers also carry the threat of more frequent forest fires, which could have a dramatic impact on any archaeology caught in their path.

The archaeology of woodland, that is, associated with the management of the historic wood (including the trees) is threatened even more directly. "…in a sense, woodlands are monuments like castles and long barrows and have complex and exciting stories to tell" (C.Gerrard, 1998, "Looking for history under the branches", *British Archaeology*).These 'monuments' are very vulnerable to changes in our climate.

5. ALL HISTORIC BUILDINGS

Description of change

Hotter, drier summers

Outcome of change

Drying and shrinking of clay soils

Location

All historic buildings

Impact on historic environment assets

A. Historic buildings located on clay soils

	Extent	Severity	Sensitivity	Significance of Impact
A	1	-2	3	-3 Small negative

Risk assessment of historic assets

A. The predicted hotter, drier summers could result in the shrinking and drying of clay soils. Such seasonal movement is particularly a problem for historic buildings as they are often built with shallow foundations which do not extend below the affected clay layers.

Specific gaps in knowledge

The number of historic buildings at potential risk from clay drying and shrinkage within Wales is currently not known, although clay deposits appear to be mainly confined to areas of South Wales.

Responses to outcome of change

Notes and references

Clay types that have a high shrinkage potential and are associated with damage to buildings are the London Clay, Gault Clay, Weald Clay and Lias Clay (which covers parts of South Wales). This list is not exhaustive and there are other clays which have more limited shrink-swell characteristics (www.buildingconservation.com)

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Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/ storms

Location

All historic buildings

Impact on historic environment assets

A. Historic buildings

	Extent	Severity	Sensitivity	Significance of Impact
A	4	-2	2	-16 Moderate negative

Risk assessment of historic assets

A. The increasing trend for extreme weather such as gales and torrential downpours, with the potential for flooding, is likely to have a negative impact on historic buildings that are often not built to withstand such conditions. An inadequate capacity of rainwater guttering may result in water ingress through the roof, damaging internal fittings and fittings, and flooding can damage the materials used in the construction of historic houses, such as timber frames and panelling or earthen walls and floors. Over extreme weather, such as heavier snow falls could cause structural damage to buildings,

The response to such damage can also be problematic - if timbers are left damp for too long they may swell and distort or suffer from fungal and insect infestation but rapid artificial drying techniques can also damage the fabric of historic buildings.

Specific gaps in knowledge

Responses to outcome of change Adapting historic buildings for changing climatic conditions is problematic as the integrity and appearance of the building needs to be maintained.

Notes and references

Thatched roofs will last for a shorter time. Figures from 2009 (Northern Ireland Environment Agency) claim that a thatched roof will last 15 years in England but only 7 years in N.Ireland before requiring a recoat

Description of change

Warmer mean temperatures

Outcome of change

Longer growing season

Location

All historic buildings

Impact on historic environment assets

A. Surrounding parks and gardens

	Extent	Severity	Sensitivity	Significance of Impact
A	4	+1	1	+4 Small positive

Risk assessment of historic assets

A. Warmer temperatures will also result in a longer growing season, requiring year round maintenance for the gardens and lawns of historic properties. However, such raised costs should be offset by the ability to keep these sites open throughout the year.

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Description of change

Warmer mean temperatures

Outcome of change

Migration of pests and diseases into Britain

Location

All historic buildings

Impact on historic environment assets

A. Interior fixtures and fittings
B. Structural timber elements of buildings

	Extent	Severity	Sensitivity	Significance of Impact
A	3	-2	4	-24 moderate negative
B	3	-2	2	-12 moderate negative

Risk assessment of historic assets

A. The predicted warmer mean temperatures could pose a potential threat to the interiors and furnishings of historic buildings in the guise of possible moulds, fungi, spoors and pests such as wood-boring insects. Temperature plus humidity creates condensation, which can be a problem within older houses and may possibly result in ‘rising damp’. This mixture of warmth and interior damp has caused infestations of Webbing Clothes Moth and Carpet Beetle in some properties.
B. The spread of pests and diseases could threaten the integrity of many historic buildings. This threat is potentially more manageable than that to interior fixtures and fittings, but where not treated could have a devastating impact on an historic building.
Included under this heading is the impacts that warmer mean temperatures and greater hours of sunlight will have on the thermal movements old materials – slates, leadwork, timber and paintwork – resulting in at least more frequent maintenance and possibly structural failure.

Specific gaps in knowledge

It is difficult to make any general predictions regarding the impact of climate change on historic buildings as each is unique, with its own strengths and weaknesses.

Responses to outcome of change

Greater use of pesticides and other chemicals to treat pests and diseases.

Notes and references

Infestations reported by the National Trust. Webbing Clothes moth prefers moist conditions and its larvae feed on natural fibres, such as carpeting.

Description of change

Warmer, wetter winters/wetter summers

Outcome of change

More frequent rainfall and possible flooding events

Location

All historic buildings

Impact on historic environment assets

A. Historic buildings - exteriors
B. Historic buildings
C. Interior fittings and fixtures

	Extent	Severity	Sensitivity	Significance of Impact
A	4	-2	3	-24 moderate-high negative
B	3	-2	3	-18 moderate negative
C	4	-2	4	-32 high negative

Risk assessment of historic assets

A. Warmer, wetter winters, in conjunction with hotter, drier summers, will put stonework at risk of physical and chemical erosion. Limestone buildings are particularly susceptible, especially with an increase in rainfall acidity due to higher concentrations of carbon dioxide in the atmosphere.
B. Historic buildings are often ill-equipped to cope with changes in the climate and the trend towards warmer, wetter winters/wetter summers could potentially result in more flooding events, damaging the materials used in their construction, such as timber frames and panelling or earthen walls and floors
C. Milder, wetter conditions will facilitate the spread of mould and pests, with potential damage to interior fixtures and fittings. Temperature plus humidity creates condensation, which can be a problem within older houses and may possibly result in 'rising damp'.At the very least this will lead to the requirement of more frequent maintenance of historic buildings.

Specific gaps in knowledge It is difficult to make any general predictions regarding the impact of climate change on historic buildings as each is unique, with its own strengths and weaknesses.

Responses to outcome of change Adapting historic buildings for changing climatic conditions is problematic as the integrity and appearance of the building needs to be maintained. Rapid artificial drying methods can be very damaging to the historic building fabric.

A recent (2012) government scheme aims to cut greenhouse emissions from 8 million homes of Victorian, Edwardian and other periods by externally cladding them with up to 8" of insulation. The head of building conservation and research at English Heritage has warned that the cladding of older homes would destroy brick facades and period details – threatening our visual heritage (reported in the *Sunday Times*, 25/03/2012).

Notes and references

The National Trust identifies flash flooding, intense periods of rainfall and the spread of mould, pests and disease through milder, wetter winters/wetter summers as the greatest threats to its buildings and their interior fixtures (reported by the Northern Ireland Environment Agency, 2009)

Location All historic buildings			
Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Warmer mean temperatures	Longer growing season	Surrounding parks and gardens	Moderate positive
	Migration of pests and diseases into Britain	Interior fixtures and fittings	Moderate negative
Hotter, drier summers	Drying and shrinking of clay soils	Historic buildings located on clay soils	Moderate negative
Warmer, wetter winters/wetter summers	More flooding events	Historic buildings	High negative
	Migration of pests and diseases into Britain	Interior fixtures and fittings	Moderate negative
		Structural timber elements of buildings	Moderate negative
More frequent extreme weather	Frequent high winds/storms	Historic buildings	Moderate negative

Summary

Historic buildings are particularly vulnerable to the effects of climate change as they are often constructed from materials that react adversely to extremes of weather. Buildings utilising wood, earth and thatch are all potentially under threat from a greater frequency of intense storms and gales. Cycles of intense wetting and drying can also damage stonework, with limestone buildings being particularly susceptible. Generally, historic buildings are also not designed to cope with the volume of heavy downpours or an increase in humidity. Their often shallow foundations also put them at risk from the potential clay shrinkage that may occur as a result of hotter, drier summers.

Interiors of historic buildings may also be damaged as changing climate conditions facilitate the spread of moulds and insects.

The greatest threat caused by flooding are to buildings located in river valleys or below the 1m contour. However, more frequent flooding events are likely to affect buildings outside these locations, and with any flood the impact will be significant.

On a slightly more positive note, the trend towards warmer temperatures might allow publically accessible historic buildings to remain open to visitors throughout the year, resulting in a rise in revenue and tourism to the area.

6. HISTORIC ASSETS ON THE COAST EDGE, EXCLUDING THOSE BELOW THE 1M CONTOUR

Description of change

Warmer mean temperatures

Outcome of change

Rise in sea level

Location

The coast edge, excluding that below the 1m contour

Impact on historic environment assets

A. Archaeological sites located on the tops of sea cliffs.

B. Historic assets on coastal plains.

	Extent	Severity	Sensitivity	Significance of Impact
A	1	-2	2	-4 Small negative
B	2	-2	5	-20 Moderate negative

Risk assessment of historic assets

A. An increase in sea levels will lead to acceleration in cliff erosion. This will vary according to exposure and the nature of the cliffs, with the result that some archaeological sites may be destroyed, but most will not experience increased levels of erosion.

B. Low lying coastal plains generally above the 1m contour, such as the Severn Levels and the coastal plains of Carmarthen Bay and Cardigan Bay, are vulnerable to inundation caused by rising sea levels in conjunction with more frequent storm surges. Sensitivity to inundation is dependent on management responses – managed retreat or strengthening sea defences – and therefore it is not possible to quantify the number of sites and buildings at risk. Whilst inundation would not have a major impact on most archaeological sites, its impact on buildings and settlements could be catastrophic, causing damage and even leading to abandonment of some buildings and settlements.

Specific gaps in knowledge

Responses to outcome of change

It is likely that one of the responses will be the strengthening of sea defences around lower-lying landscapes.

Notes and references

Risk Management Solutions, 2007. *1607 Bristol Channel Floods: 400-year retrospective*.

Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/storms

Location

The coast edge, excluding that below the 1m contour

Impact on historic environment assets

A. Archaeological sites located on the tops of sea cliffs.
B. Historic assets on coastal plains.

	Extent	Severity	Sensitivity	Significance of Impact
A	1	-3	5	-15 Moderate negative
B	2	-2	5	-20 Moderate negative

Risk assessment of historic assets

A. More frequent and more intense storms will accelerate the rate of erosion of sea cliffs. The rate of change will depend very much on local factors, such as exposure and geology. A good example concerns the early-medieval graves at St. Brides in Pembrokeshire that have been recorded for some 200 years as eroding out of the cliff. Before more disappeared it was decided to excavate and record (2011) the archaeology most at risk and a survey was made of the current line of the cliff edge to allow the rate of future erosion to be monitored.
B. More frequent and intense storms will increase the possibility of coastal inundation into areas above the 1m contour. This may lead to abandonment of some coastal areas if this inundation becomes a regular occurance.

Specific gaps in knowledge

Responses to outcome of change

It is likely that one of the response will be the strengthening of sea defences around lower-lying landscapes.

Notes and references

Location The coast edge, excluding that below the 1m contour

Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Warmer mean temperatures	Rise in sea level	Archaeological sites located on the tops of sea cliffs	Small negative
		Historic assets on coastal plains	Moderate negative
More frequent extreme weather	Frequent high winds/storms	Archaeological sites located on the tops of sea cliffs	Moderate negative
		Historic assets on coastal plains on coastal plains	Moderate negative

Summary

Rising sea levels will accelerate the rate of erosion of sea cliffs, but this will be variable, with some sites destroyed but with the majority only marginally affected.

The main impact will be on buildings and settlements on coastal plains that may be inundated as result of rising sea coupled with storm surges. The impact of this could be catastrophic, but the areas affected with depend on management regimes – controlled retreat or strengthening of defences.

It is not possible to obtain exact figure of sites and buildings that may be affected due to the diversity of environments. However, Analysis by the Royal Commission on the Ancient and Historical Monuments of Wales shows that lying within Countryside Council for Wales's Coastal and Floodplain Grazing Marsh LBAPHabit there are: 138 scheduled ancient monuments, 1015 listed buildings, 3507 sites recorded on the Historic Environment Records and 7044 sites recorded on the National Monument Record.

7. HISTORIC ASSETS ON FLOODPLAINS AND VALLEY BOTTOMS

Description of change

Warmer, wetter winters/wetter summers

Outcome of change

More flooding events

Location

Floodplains and valley bottoms

Impact on historic environment assets

A. Damage caused to historic buildings and fittings located on floodplains and in valley bottoms.

B. Damage caused to the fabric of historic a towns and villages.

C. Damage caused to archaeological sites located on floodplains and in valley bottoms.

	Extent	Severity	Sensitivity	Significance of Impact
A	5	-3	5	-75 high negative
B	3	-2	-3	-18 moderate negative
C	5	-1	1	-5 small negative

Risk assessment of historic assets

A. In a recent study the Royal Commission on the Ancient and Historical Monuments of Wales calculated that there are 5412 listed buildings at risk of flooding – ie buildings located on floodplains or in other areas susceptible to flooding according to the Environment Agency. This figure is just of listed buildings and does not include unlisted historic buildings. Flood damage to buildings varies from the dramatic following flash floods such as the destruction of structures to long-term damage caused by fungal and insect infestation following a flooding event. The structural integrity of a building can be compromised, and damage can occur to floors, panelling and walls, as well as to historic furniture and furnishings. The Nation Trust has concluded that flash flooding, intense periods of rainfall and the spread of pests and diseases due to milder wetter winters/wetter summers poses the greatest threats to their buildings and fittings.

B. At least parts of many of Wales's historic settlements lie on or close to a floodplain. As well as damage to obviously at risk structures such as historic bridges, damage could occur to historic surfacing and street furniture.

C. There are 302 Scheduled Ancient Monuments and over 12,000 other archaeological sites at risk of flooding, according to the Royal Commission on the Ancient and Historical Monuments of Wales study. Many of these are likely to be crop-marked sites, artefact scatters and low earthwork and therefore will not generally be affected by more flooding events. More severe impact is likely to be localised, but could result in the wholesale destruction of individual sites.

Specific gaps in knowledge

Studies by the Centre of Catchment and Coastal Research, University of Aberystwyth, including a study of the Towy Valley, Carmarthenshire, has demonstrated that changes in climate over the past 40 years are not evidenced in rivers geomorphological/sedimentary records in Wales, demonstrating that, to date, climate change has not resulted in increased flooding events.

Responses to outcome of change

Building of flood defences to protect settlements.

Notes and references

Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/storms

Location

Floodplains and valley bottoms

Impact on historic environment assets

A. Damage caused to historic buildings and fittings located on floodplains and in valley bottoms.
B. Damage caused to the fabric of historic towns and villages.
C. Damage caused to archaeological sites located on floodplains and in valley bottoms.

	Extent	Severity	Sensitivity	Significance of Impact
A	5	-3	5	-75 high negative
B	3	-2	-3	-18 moderate negative
C	5	-1	1	-5 small negative

Risk assessment of historic assets

The threat posed by more frequent high winds storms is essentially the same as that posed by more flooding events.

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Location Floodplains and valley bottoms			
Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Warmer wetter winters/wetter summers	More flooding events	Damage caused to historic buildings and their fittings	High negative
		Damage caused to the fabric of historic towns and villages	Moderate negative
		Damage caused to archaeological sites	Small negative
More frequent extreme weather	Frequent high winds/storms	Damage caused to historic buildings and their fittings	High negative
		Damage caused to the fabric of historic towns and villages	Moderate negative
		Damage caused to archaeological sites	Small negative

Summary

The major impact of more frequent flooding events/more frequent storms will be on listed buildings and other historic buildings located on floodplains, in valley bottoms and in other areas susceptible to flooding. Damage could range from the destruction of a building or structure following a flash flood to fungal and insect infestation as a result of warmer wetter weather.

The fabric of historic settlements could be damaged by more frequent flooding events, but it is likely that the major impact on these settlement will be on their character caused by the construction of flood defence systems.

Archaeological sites are not likely to suffer widespread damage, although occasional localised damage could be severe.

8. HISTORIC PARKS AND GARDENS

Description of change

Hotter drier summers

Outcome of change

Stress on trees, shrubs and plants

Location

All historic parks and gardens

Impact on historic environment assets

A. Trees, shrubs and plants in historic parks and gardens

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-1	4	-8 small negative

Risk assessment of historic assets

A. There seem to be two main factors that put trees under stress during hot dry periods of weather; reduction in the trees ability to photosynthesize and simple lack of water. Additionally, trees under stress are more vulnerable to pests and diseases. In central Europe a study concluded that a series of hot, dry events would have a much more severe impact than a single event on oaks, and the decline in Scots Pines in the Swiss Alps has been attributed to the increasing regular hot, dry summers. However, Wales is close to the northern limits of some native British trees, and species such as beech may expand their territories during successive warmer summers.

Overall, a period of warmer, drier summers is likely to lead to a net loss of examples of native trees and plants parks and gardens, but this loss will be variable across the country depending on microclimate and topography. However, this loss is likely to be offset by some native trees expanding their territories, thus overall the impact has been assessed as a small negative.

Specific gaps in knowledge

An assessment of this change on individual parks and gardens is required.

Responses to outcome of change

Planting of trees resistant to hot summers and drought.

Notes and references

Leuzinger S, Zotzl G, Asshoffl R and Komer C, 2005. Responses of deciduous forest trees to severe drought in Central Europe, *Tree Physiology*, 25, 641-50.
Rebetez M and Dobbertin M, 2004. Climate change may already threaten Scots Pine stands in the Swiss Alps, Theoretical and Applied Climatology, 79, 1-9.

Description of change

Warmer mean temperatures

Outcome of change

Migration of pests and diseases into Britain

Location

All historic parks and gardens

Impact on historic environment assets

A. Trees, shrubs and plants in historic parks and gardens

	Extent	Severity	Sensitivity	Significance of Impact
A	5	-1	3	-15 moderate negative

Risk assessment of historic assets

A. The potential impact of a spread of a previously unknown disease is demonstrated by Sudden Oak Death (*Phytophthora ramorum*), which has devastated oak populations (and other species such as rhododendron) in parts of the world, and Dutch Elm Disease, which has had a major impact on the elm population in Britain since the 1970s. Climate change is not a factor in the spread of these two diseases. The horse chestnut leafminer (*Cameraria ohridella*) is an invasive lepidopteran pest that is currently spreading westwards as a result of warmer mean temperatures. This moth has severely reduced the number of horse chestnut trees in parts of Europe, and is likely to do so in parts of Wales. Leaf rust of poplars is another example of a disease that seems to be extending its limits due to warmer mean temperatures. This particular disease was absent from Belgium until the 1980s, but now has been detected in parts of southern England.

The migration and introduction of pests and diseases into Wales might be due to other factors other than climate change, but warmer mean temperatures and other factors associated with climate change may increase their ability to survive and flourish. The impact of previously unknown pests and diseases is almost impossible to quantify, but is likely to affect a particular species and be widespread, hence the moderate negative impact score. However, some parks and gardens that have a display of one species could be severely affected.

Specific gaps in knowledge

There is a substantial body of evidence concerned with the spread of diseases and pest as a result of climate change and their impact on agriculture and on specific species, but no scientific research on their impact on designed landscapes.

Responses to outcome of change

Planting of disease resistant species and exotics to replace native species affected by disease.

Notes and references

Hulme, P E, 2005. Adapting to climate change: is there scope for ecological management in the face of a global threat?, *Journal of Applied Ecology*, 42, 784-94.

Lonsdale D, and Gibbs J N. 1996. Effects of climate change on fungal disease of trees, i*n:* Frankland J E, Magan N, Gadd G M*, eds.* ***Fungi and environmental change****. British Mycological Society, Symp vol. XX. Cambridge, UK: Cambridge University Press, 1–19.*

Description of change

More frequent extreme weather events

Outcome of change

Frequent high winds/storms

Location

All historic parks and gardens

Impact on historic environment assets

A. Mature trees
B. Historic buildings and structures

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-3	3	-18 moderate negative
B	2	-1	2	-4 small negative

Risk assessment of historic assets

A. More frequent storms and extreme weather events will have a disproportionate impact on mature and veteran trees, as these by their nature tend to be the largest, tallest examples in parks and gardens. As some species take several hundred years to reach maturity, the impact of more frequent storms will have a short, medium and long-term impact.

B. Many historic parks and gardens contain buildings and other structures which are likely to be damaged by more frequent storms.

Specific gaps in knowledge

Responses to outcome of change

Replacement planting damaged trees of species more resistant to storm damage.

Notes and references

Description of change

Warmer mean temperatures

Outcome of change

Longer growing season

Location

All historic parks and gardens

Impact on historic environment assets

A. The character of historic parks and gardens

	Extent	Severity	Sensitivity	Significance of Impact
A	5	2	3	15 moderate positive

Risk assessment of historic assets

A. Even a minor increase in warmer mean temperatures coupled with a longer growing season is likely to have an impact on the character of historic parks and gardens as a greater number of warmth-loving exotic tree, shrub and plant species are able to survive in the Welsh environment. Loss of some native trees and plants could occur with substantial temperature increases leading to their replacement with exotics rarely or not previously seen in Wales. It is likely that under the medium emissions scenario that there will not be a great decrease in native species and that planting of exotics could enhance many of Wales's parks and gardens, hence the moderate positive Significance of Impact score. However, substantial mean temperature increases under the higher emissions scenario could lead to the widespread loss of native species, results in a substantial negative impact at least in the short to medium term prior to replacement planting of exotics becomes established.

Specific gaps in knowledge

Researching papers that deal with the impact of climate change on tree and plant species is beyond the scope of this study, and therefore specifics are not cited here.

Responses to outcome of change

Planting of more warmth-loving trees, shrubs and plants.

Notes and references

Czúcz B, Gálhidy L & Mátyás C, 2011. Present and forecasted xeric climatic limits of beech and sessile oak distribution at low altitudes in Central Europe, *Annals of Forest Science*, 68, 99-108. This study shows that in central Europe with current models of climate change 56%-99% of beech forests and 82%-100% of sessile oak forest might be outside their bioclimatic niche by 2050.

Location Historic parks and gardens

Description of change	Outcome of change	Location	Impact on historic environment assets	Significance of impact
Warmer mean temperatures	Longer growing season	All historic parks and gardens	The character of historic parks and gardens	Moderate positive
	Migration of pests and diseases into Britain	All historic parks and gardens	Trees, shrubs and plants in historic parks and gardens	Moderate negative
Hotter drier summers	Stress on trees and plants	All historic parks and gardens	Trees, shrubs and plants in historic parks and gardens	Moderate negative
More frequent extreme weather events	Frequent high winds/storms	All historic parks and gardens	Mature trees	Moderate negative
			Historic buildings and structures	Small negative

Summary

The impact of climate change on historic parks and gardens is particularly difficult to assess as there are likely to be positives as well as negatives. There can be little doubt that a combination of warmer mean temperatures, hotter drier summers and more frequent, extreme weather events will result in a loss of trees, shrubs and plants, with, in extreme cases, the wholesale loss of some species. This could have a severe short/medium term impact on many parks and gardens, and long term impacts on some. In managed parks and gardens this loss can be off-set by new planting. Where parks and gardens are celebrated for their exotic plants warmer, drier conditions will be an opportunity to enhance character. The most severe negative impact will be in unmanaged historic parks and gardens where no new planting of lost trees and shrubs is likely to take place, resulting in a degradation and eventual loss of character.

9. PEAT, PEATY SOILS AND BLANKET BOGS

Description of change

Hotter drier summers

Outcome of change

Drying out, desiccation and erosion of peats and blanket bog

Location

The high upland of Wales, valley bottom bogs and lowland mires

Impact on historic environment assets

A. Palaeoenvironmental record contained peat
B. Organic artefacts within peat
C. Archaeological sites in and beneath peat deposits
D. Historic landscapes

	Extent	Severity	Sensitivity	Significance of Impact
A	5	-1	5	-25 Moderate negative
B	2	–1	3	-6 Small negative
C	3	–2	3	-18 Moderate negative
D	5	-2	2	-20 Moderate negative

Risk assessment of historic assets

A recent study by the Royal Commission on the Ancient and Historical Monuments of Wales titled 'initial spatial analysis of the impact climate change may have on the historic environment of Wales' demonstrated that there are c.18,000 known archaeological sites (15% of all sites) occupying peaty soils, of which 650 are Scheduled Ancient Monuments. A break-down of these figures shows that the majority of these sites lie in areas which can be defined as having peaty soils. Just seven sites are recorded in raised bogs. Approximately 500 sites and 30 SAMs are recorded in blanket bog. Approximately 600 sites and 27 Scheduled Ancient Monuments lie in wet modified bog and 300 sites and 15 Scheduled Ancient Monuments in dry modified bog. Based on Countryside Council for Wales's Bogs BAPHabitat data.

Note: Erosion of peats and blanket bogs following drying and desiccation will be exacerbated by more frequent storm events. Erosion may also be exacerbated by the stripping of the vegetation cover caused by more frequent fires.

The greatest impact is likely to be on the margins of mires and bogs, with the centres of valley bottom bogs and the high areas of blanket bogs not so severely affected.

A. Peat bogs and blanket bogs are highly vulnerable to change, and hotter, drier summers will have a widespread and severe impact on these peats, with the consequent loss of the palaeoenvironmental record, and the loss of stratigraphic context.

B. Peat bogs are highly vulnerable to change, and hotter, drier summers will have a widespread and severe impact on these peats, with some loss of organic artefacts contained within it. But as there is no data on the numbers and character of these artefacts the risk to them is difficult to assess, hence the cautious score of small negative significance.

C. The loss of thinner peat deposits will expose archaeological sites currently sealed and protected by them. Once exposed these sites will be highly vulnerable and hence will be severely affected. Sites within and beneath deeper deposits are likely to remain unaffected.

D. The main impact on historic landscapes will be visual, and assessed as moderately negative, but it could be more severe, with some blanket bog environments becoming favourable for agricultural improvements with longer growing seasons. This is a human response to climate change, rather than a direct result.

Specific gaps in knowledge

Little is known about the nature and quantity of artefacts contained in peat. The number of archaeological sites sealed by peat bogs is unknown.

Responses to outcome of change

Peaty and organic soils are recognised as a carbon store, and therefore their erosion and loss may be addressed through the EU Soil Thematic Strategy, following the vetoing of the proposed EU Soil Directive by some member states.

Notes and references

Royal Commission on the Ancient and Historical Monuments of Wales 'Initial spatial analysis of the impact climate change may have on the historic environment of Wales'.

Moore P D 1988, The Development of moorlands and upland mires, in M Jones (ed.), Archaeology and the Flora of the British Isles, Oxford, 116-122. This paper demonstrates the complex factors that led to the development of blanket bog, these include human factors and natural ones such as climate change, waterlogging, soil changes, microfauna ec.

Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/storms

Location

The high uplands of Wales, valley bottom bogs and lowland mires

Impact on historic environment assets

A. Historic landscapes

B. Archaeological sites and artefacts in and beneath peat deposits.

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-2	5	-20 Moderate negative
B	2	-1	3	-6 Small negative

Risk assessment of historic assets

A. Greater erosion caused by more frequent intense storms will have an impact on the historic landscape, particularly the visual aspect of the landscape. This is likely to be localised rather than widespread.

B. Erosion of peats will expose archaeological sites and artefacts. As with the above this is likely to be localised.

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Location The high upland of Wales, valley bottom bogs and lowland mires

Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Hotter drier summers	Drying out, desiccation and erosion of peats and blanket bog	Palaeoenvironmental record contained peat	-25 Moderate negative
		Organic artefacts within peat	-6 Small negative
		Archaeological sites in and beneath peat deposits	-18 Moderate negative
		Historic landscapes	-20 Moderate negative
More frequent extreme weather	Frequent high winds/storms	Historic landscapes	-20 Moderate negative
		Archaeological sites and artefacts in and beneath peats	-6 Small negative

Summary

Archaeological sites at high altitudes on peats are likely to remain largely unaffected. It is likely that the main impact will be the loss of integrity, particularly in relation to the palaeoenvironmental record, and the potential changes to the historic environment as environments become more favourable for farming.

10. HISTORIC LANDSCAPES

Description of change

Hotter drier summers

Outcome of change

Stress on trees and plants, impact on wetlands

Location

Historic landscapes

Impact on historic environment assets

A. Wetlands and bogs
B. Woodland and forestry
C. Upland Environments

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-3	4	-24 moderate negative
B	1	-2	4	-8 small negative
C	2	-2	4	-16 moderate negative

Risk assessment of historic assets

A. The predicted trend towards hotter, drier summers could result in the drying out and possible erosion of wetland and bog environs such as the historic landscape defined by the large raised bog of Cors Caron in the upper valley of the Afon Teifi. Peat deposits in areas like this contain valuable botanical data and can also preserve water-logged archaeological deposits.

B. Hotter, drier summers could have a visual impact on historic landscapes as summer droughts may lead to widespread tree losses and higher temperatures may result in many species of trees native to more southern climates, such as Walnut and Sweet Chestnut, becoming more popular. Forest fires could be more frequent in dry summers.

C. Hotter, drier summers could threaten upland areas such as the Cambrian Mountains. Drying out of the soil could cause erosion and loss/change of habitat, with the potential for upward migration of habitat squeezing upland landscapes into smaller areas.

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Some species will be affected to greater extent than others which, in natural woodland ecosystems, will change the competitive advantage of one species over another and hence change the appearance of our woodlands. Small-leaved lime, once a major component in our woodland, may make a comeback. Predictions are that although current 'native' species will not disappear, their distribution will change significantly (Hellis Tree Consultants)

Description of change

More frequent extreme weather events

Outcome of change

Frequent high winds/storms

Location

Historic landscapes

Impact on historic environment assets

A. Historic buildings and archaeological monuments
B. Woodland and forestry.

	Extent	Severity	Sensitivity	Significance of Impact
A	4	-2	4	-32 high negative
B	2	-2	3	-12 moderate negative

Risk assessment of historic assets

A. Potential increases in, and intensity of, rainfall may threaten the continued stability and weather resilience of many historic buildings. Archaeological monuments may come under an increased threat from erosion, flooding and windthrow.
B. Areas of woodland and forestry will be damaged by an increased frequency of storms and high winds (The Friends of the Earth, 2005). Forestry and woodland can define a historic landscape, such as the Tywi Forest, Ceredigion, and Canaston & Minwear Woods in Pembrokeshire.

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Forests cover 12% of Wales (Friends of the Earth, 2005)

Description of change

Warmer mean temperatures

Outcome of change

Rise in sea levels; Longer growing season; Migration of pests and diseases into Britain

Location

Historic landscapes

Impact on historic environment assets

A. The character of historic landscapes

	Extent	Severity	Sensitivity	Significance of Impact
A	3	-2	4	- 24 moderate negative

Risk assessment of historic assets

A. A global increase in mean temperatures will result in a rise in sea levels. Historic landscapes that lie on the coast or adjacent to major waterways will be affected, with the inundation of low-lying ground, changes in habitat potentially leading to changes in land use, and possible displacement of population and disruption to communities.

B. Warmer temperatures will lead to a longer growing season. Potentially this could affect the character of certain historic landscapes as different plant species may begin to thrive. Possibly habitat such as heath and moorland will be changed. Heather is slow-growing and could be forced out by bracken and grasses, which grow much faster when it's warmer. Additionally, a longer growing season may result in a change in farming practices, with more/different crops that flourish in warmer regions being grown (e.g. establishment of vineyards), possibly affecting the landscape character.

C. It is possible that an increase and spread of vegetation such as bracken will have a visual impact on historic landscapes. Relict field systems, which often comprise earthworks, may become obscured and existing boundaries may be altered to accommodate new farming practices

D. The potential migration of pests and diseases into Britain could have a devastating effect on specific species of trees and plants, resulting in a change of character of an area. This has already been witnessed in the late 1960s/70s with Dutch Elm disease, spread by the elm bark beetle, killing over 25 million trees in the UK. The Woodland Trust (2011) notes that Britain's native woodland is dominated by a few key tree species, which makes it particularly vulnerable to the threat of non-native pests and diseases.

Specific gaps in knowledge

It is problematic to predict with any accuracy what the impact of warmer mean temperatures on historic landscapes may be. Some changes will be widespread, some very localised.

Responses to outcome of change

Notes and references

Farmers are already diversifying their crop varieties in parts of southern England. One farm in Devon has planted 300 trees including almonds, walnuts and sharon fruits. And in 2005 the UK's first commercial harvest of apricots was grown at a farm in Kent and sold in a national supermarket. Grapes have been grown in the UK for some time, but the number of vineyards could increase as the climate warms. (sciencemuseum.org.uk)

Location Historic landscapes			
Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Warmer mean temperatures	Rise in sea levels	Waterside landscapes such as coastland, estuaries and river valleys	Moderate negative
	Longer growing season	Farmland and upland areas	Moderate negative
	Migration of pests and diseases into Britain	Areas of woodland and forestry	Moderate negative
Hotter drier summers	Drying out, desiccation and erosion of wetlands	Wetland habitats, such as blanket bog, and upland areas.	Moderate – great negative
	Stress on some trees and plants	Native woodland	Moderate negative
Warmer, wetter winters/wetter summers	More flooding events	Historic towns and cities and areas of woodland.	Moderate negative
More frequent extreme weather	Frequent high winds and storms	Historic buildings, areas of woodland and forestry and archaeological monuments	Moderate negative

Summary

The impact of climate change on historic landscapes, although difficult to forecast accurately, is likely to be largely negative in nature. Coastal areas are particularly vulnerable as the effects of erosion and land loss are already being felt. These effects will become progressively noticeable as sea levels continue to rise and affect not just the coast but also areas of landscape subject to fluvial flooding, leading to possible changes in habitat. Woodland and forestry are under threat from most projected climate change scenarios, whether from disease and pests introduced by warmer temperatures or damage caused by high winds and storms. Similarly, upland environments are vulnerable to both hotter, drier conditions and the possible upward migration of habitat as growing conditions change.

These impacts may force changes in the characterisation of particular historic landscapes, some wholesale and long-term where habitats are changed or lost, some very localised or short-term where individual sites or monuments are lost or damaged.

Urban environments may also be affected, with the increased flooding of settlements being, perhaps, the most obvious problem. In the most dramatic scenario there could potentially be an enforced displacement of communities. In such an event, the impact on the character of the landscape is difficult to assess.

11. HISTORIC ASSETS IN SAND DUNES

Description of change

More frequent extreme weather

Outcome of change

Frequent high winds/storms

Location

Sand dunes

Impact on historic environment assets

A. Historic assets and deposits

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-1	2	-4 small negative

Risk assessment of historic assets

A. An increase in the frequency of intense storms and high winds could cause the retreat and reshaping of dune-scapes, possibly exposing any archaeology preserved below. Once exposed, such deposits can become vulnerable to further erosion.

Specific gaps in knowledge

Responses to outcome of change

Notes and references

Description of change

Warmer mean temperatures

Outcome of change

Rise in sea levels

Location

Sand dunes

Impact on historic environment assets

A. Historic assets and deposits

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-2	2	-8 small negative

Risk assessment of historic assets

A. The rate of coastal dune-scape erosion is predicted to increase with a rise in sea levels, possibly leading to a direct impact onto the archaeological resources that they currently cover and help to preserve. The extent of any impact is difficult to forecast as dunes are adaptable, responsive environments – “it is probable that adjacent dune systems will react in different ways” (RWG. Carter, *Near-future sea level impacts on coastal dune landscapes,* 1991)

Specific gaps in knowledge

The dynamic, responsive nature of sand dunes makes it almost impossible to predict how changes in the climate will affect them.

Responses to outcome of change

Notes and references

“The extent of frontal dune erosion may increase in the next century as a result of increased storminess and sea level rise, and this may have negative impacts on the extent of some dune habitats and the effectiveness of dune systems as flood defences. However, the consequences of such changes will vary from location to location” (Joint Defra/ Environment Agency R&D Technical Report FD1302/TR, 2007)

Location Sand dunes			
Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Warmer mean temperatures	Rise in sea levels	Historic assets and deposits	Moderate negative
More frequent extreme weather	Frequent high winds/ storms	Historic assets and deposits	Small negative

Summary

The adaptive, dynamic nature of sand dune habitats makes any prediction as to how they might respond to climate change problematic. However, in general terms, it is thought that a rise in sea levels and an increase in the frequency of intense storms and gales will result in changes to dune-scapes. There are extensive areas of sand dunes around the Welsh coast including one of the largest dune systems in Europe, where the medieval town of Kenfig lies buried. The sand currently serves to help preserve the underlying archaeology from erosion and will be vulnerable if/when it becomes exposed.
No general predictions can be made for all dune systems – impacts caused by climate change will be highly localised , with adjacent dunes not necessarily reacting in the same way.

Analysis by the Royal Commission on the Ancient and Historical Monuments of Wales shows that lying within Countryside Council for Wales's Coastal Sand Dunes LBAPHabitat there are: 71 scheduled ancient monuments, 647 listed buildings, 1666 sites recorded on the Historic Environment Records and 1617 sites recorded on the National Monument Record.

12. ARCHAEOLOGICAL SITES IN UPLAND ENVIRONMENTS, EXCLUDING PEAT BOGS

Description of change

Warmer wetter winters/wetter summers

Outcome of change

More frequent high winds/storms

Location

Upland environments excluding bogs and peat deposits

Impact on historic environment assets

A. Increase in erosion on upstanding archaeological sites in an upland environment

	Extent	Severity	Sensitivity	Significance of Impact
A	2	-2	4	-8 Small negative

Risk assessment of historic assets

A. Uplands are environmentally sensitive areas, with rates of erosion and climate in a fine balance. The introduction of more frequent storms associated with intense periods of high rainfall is likely to cause more intense localised erosion. As some of the best examples of upstanding archaeological sites are located in the uplands, these will suffer erosion as a result of more frequent storms.

Specific gaps in knowledge

The biggest threat to archaeological sites located on upland environments has been land improvement and forestry. Threats caused by natural agencies have received little attention.

Responses to outcome of change

Notes and references

Description of change

Warmer mean temperatures

Outcome of change

Longer growing season

Location

Upland environments excluding bogs and peat deposits

Impact on historic environment assets

A. Land improvement on and around archaeological sites on upland margins.
B. Scrubbing-up of archaeological sites on upland margins.
C. Historic landscapes of upland Wales

	Extent	Severity	Sensitivity	Significance of Impact
A	3	-3	3	-27 moderate negative
B	2	-1	2	-4 small negative
C	3	-3	3	-27 moderate negative

Risk assessment of historic assets

A. Many of Wales's best preserved archaeological sites occupy a zone between the upper limits of farmland and the high uplands. A longer growing season provides the potential for the pushing back of the current limits of farmland into this zone, accompanied by ploughing of previously unploughed land, and drainage schemes, resulting in damage to upstanding archaeological sites. This is clearly a human response to climate change rather than as a direct consequence of it. It is not possible to quantify the number of sites that may be affected.
B. Where land is not improved, then the longer growing season may allow for scrub and tree growth on archaeological sites, possibly leading to root and other damage, and obscuring the remains.
C. As with A, any change is likely to be the result of human intervention. Pushing back the current limits of farmland onto marginal land will have a profound impact on the historic landscape, changing the character of vast tracts of upland fringe Wales.

Specific gaps in knowledge

Responses to outcome of change

A longer growing season only provides the potential for pushing back the limits of farmland onto marginal land. Whether it happens or not will depend on economic and political factors, such as participation on agri-environment schemes, or changes to the CAP.

Notes and references

Location Upland environments excluding bogs and peat deposits			
Description of change	**Outcome of change**	**Impact on historic environment assets**	**Significance of impact**
Warmer mean temperatures	Longer growing season	Land improvement on and around archaeological sites on upland margins.	-27 moderate negative
		Scrubbing-up of archaeological sits on upland margins.	-4 small negative
		Historic landscapes of upland Wales	-27 moderate negative
Warmer wetter winters/wetter summers	More frequent high winds/storms	Increase in erosion on upstanding archaeological sites in an upland environment	-8 small negative

Summary

The biggest impact on archaeological sites and historic landscapes in the uplands will be as a result of warmer mean temperatures. This in itself will not have a big impact on archaeological sites - scrubbing-up on archaeological sites is assessed as small negative – but the human response in the form of land improvements could have a substantial impact, and has been assessed as high negative on both individual sites and on historic landscapes. Other impacts, such as more frequent storms are likely to have just a local impact, and so are assessed as a small negative.

7. Constraints on Knowledge

Some specific constraints on knowledge are noted in the Risk Assessment Matrices; these are summarised below. Generic constraints on knowledge result from:

- The quality of data on the historic environment.
- The imprecision of the climate change variables and scenarios.
- The coarseness of the data used for impact predictions.
- The character of local topography and local environments.
- The regional and local character of historic environment assets.

The quality of data on the historic environment varies considerably according to a wide range of factors, including: type of historic asset, land-use, and location. For example, the Risk Assessment has indicated that archaeological sites sealed by blanket bogs will be exposed and so making them vulnerable to erosion, but we have very little information on quantity or character of these sites.

The imprecision of the climate change variables and scenarios is briefly discussed in earlier sections of this report.

One of the issues concerning the coarseness of data used for impact predictions is highlighted by the Environment Agency's flood risk analysis. It is possible that may historic assets assessed at being at risk according to the Environment Agency's data may lie marginally outside the flood risk zone. This emphasises the need for more precise data and more local studies.

Climate change variables and scenarios are modelled at a national level: local topography and environment are not factored into the models. Local factors are likely to have an impact, but currently there is no research into how much impact.

The examination of the regional and local character of historic assets and how climate change may impact on them is beyond the scope of this study. Some assets, such as earthwork archaeological sites are reasonably homogeneous across the country, but others, such as historic buildings, vary greatly in terms of style, materials, function and date, and will be impacted differently according to differently climate change outcomes.

Regionality is an issue that has not been studied in relation to climate change.

Specific Constraints on Knowledge

Sites on farmland

Little research into the impact of chemicals on buried archaeology

Historic Assets on the foreshore

The impact of an increased frequency in extreme weather on foreshore sites is difficult to quantify as it could affect widespread areas and/or be very localised, and be influenced by topographical factors. The impact will also vary according to the archaeological site-type.

Forestry and Woodland

The extent and effect of migrating pests and diseases is difficult to predict. It seems likely that areas of forestry comprising a single species are more vulnerable than mixed woodland, although even a single diseased tree can pose a threat to archaeological sites in the immediate vicinity.

All historic buildings

The number of historic buildings at potential risk from clay drying and shrinkage within Wales is currently not known, although clay deposits appear to be mainly confined to areas of South Wales. It is difficult to make any general predictions regarding the impact of climate change on historic buildings as each is unique, with its own strengths and weaknesses.

Historic Assets on Floodplains and Valley Bottoms

Analysis indicates that over 5000 listed buildings and many historic settlements lie in area susceptible to flooding. This is based on coarse modelling. Detailed modelling of all historic settlements potentially at risk of flooding is required. Studies by the Centre of Catchment and Coastal Research, University of Aberystwyth, including a study of the Towy Valley, Carmarthenshire, has demonstrated that changes in climate over the past 40 years are not evidenced in rivers geomorphological/sedimentary records in Wales, demonstrating that, to date, climate change has not resulted in increased flooding events. Does this mean that the climate change models are incorrect, or that flooding events are not evidenced in the record?

Historic Parks and Gardens

An assessment of this change on individual parks and gardens is required. There is a substantial body of evidence concerned with the spread of diseases and pests as a result of climate change and their impact on agriculture and on specific species, but no scientific research on their impact on designed landscapes.

Researching papers that deal with the impact of climate change on tree and plant species is beyond the scope of this study, and therefore specifics are not cited here.

Peat, peaty soils and blanket bog

Little is known about the nature and quantity of artefacts contained in peat. The number of archaeological sites sealed by peat bogs is unknown.

Historic landscapes

It is difficult to predict with any accuracy what the impact of warmer mean temperatures on historic landscapes may be. Some changes will be widespread, some very localised, and they will vary according to prevailing economic, political and social conditions.

Historic assets in sand dunes

The dynamic, responsive nature of sand dunes makes it almost impossible to predict how changes in the climate will affect them.

Archaeological sites in upland environments excluding peat bogs

The biggest threats to archaeological sites located on upland environments have been land improvement and forestry. Threats caused by natural agencies have received little attention.

8. Recommendations

This report is concerned with the direct impacts of climate change on the historic environment. It is recommended that a report considering the adaptive responses to climate change, mitigation to reduce the threat of climate change and opportunities offered by climate change on the historic environment is commissioned.

More local/regional studies and thematic studies are required on issues such as: historic settlements at risk of flooding; sea level rise and the impact on the historic environment; regional historic building types and the threat of climate change, the impact on climate change on historic parks and gardens; climate change and the historic environment of the Welsh uplands.

The Glastir agri-environment scheme (including the New Woodland Creation Scheme) has the potential to mitigate some of the impacts of climate change on the historic landscape, and therefore greater cognisance of the possible impacts of climate change on the historic environment should be taken with formulating Glastir management plans.

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