1589

Climate Change Adaptation: North-west Wales Pilot Project

Cadw

Ymddiriedolaeth Archaeolegol Gwynedd
Gwynedd Archaeological Trust

Climate Change Adaptation: North-west Wales Pilot Project

Project No. G2639

Report No. 1589

Event PRN 46068

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SUMMARY/ CRYNODEB

Gwynedd Archaeological Trust was grant aided by Cadw to carry out a scoping project to establish climate change priorities within north-west Wales. This is to inform the design of investigative work programmes and arose from the Historic Environment and Climate Change in Wales Sector Adaptation Plan. The scoping project presents Specific Adaptation Response recommendations, leading to potential projects. The recommendations include further detailed risk assessment, spatial mapping, and monitoring.

Derbyniodd Ymddiriedolaeth Archaeolegol Gwynedd gymorth grant gan Cadw i gynnal prosiect cwmpasu er mwyn adnabod blaenoriaethau newid hinsawdd oddi mewn i ffiniau gogledd-orllewin Cymru. Y nod yw cyflwyno gwybodaeth ar gyfer cynllunio rhaglenni gwaith ymchwiliol, ac fe gododd o Gynllun Addasu Sector yr Amgylchedd Hanesyddol a Newid Hinsawdd *yng Nghymru. Mae'r prosiect cwmpasu'n cyflwyno argymhellion Ymateb Addasu Penodol wnaiff arwain at brosiectau posib. Mae'r argymhellion yn cynnwys asesiad risg manwl pellach, mapio gofodol, a monitro.*

1. INTRODUCTION

1.1. Project Background

The combined effects of climate change are being felt across Wales, including warmer temperatures, rising sea levels, changing rainfall patterns, and more frequent extreme weather events. These changes are likely to have significant direct and indirect impacts on the historic environment and landscape character. The Historic Environment Group's *Historic Environment and Climate Change in Wales: Sector Adaptation Plan 2020* (Sector Adaptation Plan) outlines the issues and impacts, and summarises how we can adapt these changes.

The Sector Adaptation Plan (Historic Environment Group 2020, 7) states that:-

'Climate change brings a number of significant challenges for the historic environment. The UK Climate Risk Assessment 2017 Evidence Report: Summary for Wales predicts a rise in mean summer temperatures, changing winter precipitation and sea level rise.

Depending on the type of historic asset, its use (if any) and location, the challenges that these changes present may be physical, economic and/or cultural. For example, all classes of historic asset are at risk from frequent high winds and storm events, including the associated storm surges, damage and erosion. Hotter, drier summers may increase tourism potential and support economic development, but increased visitor numbers can also risk harm to fragile historic assets.

It is also important to recognise that individual risks associated with climate change rarely act in isolation; more often, they interact and amplify other climate and non-climate related risks. For example, buildings and structures that are already poorly maintained are at much greater risk of storm damage. Similarly, veteran trees and historic woodland already stressed by drought are less able to withstand the onslaught of pests, diseases and storms.'

The Sector Adaptation Plan identifies the following headline actions:-

Knowledge: Increase our knowledge and understanding of the threats and opportunities for the historic environment from a changing climate

- Knowledge exchange/collaboration
- Mapping and monitoring of the resource
- Research Priorities

Capacity: Develop the methodologies, tools and guidance to work with others and build adaptive capacity

- Dissemination and promotion
- Collaborative working
- Training and guidance

Resilience: Increase resilience of the historic environment by implementing actions to respond and adapt to the risks

- Taking action

Climate change adaptation is planned to occur in five stages:-

1. Starting
2. Investigating
3. Planning
4. Implementing
5. Monitoring and evaluation

The Sector Adaptation Plan represents the first two stages. The next stage is planning, to include dissemination and publicity, and developing partnerships. To take forward the recommendations outlined in the Sector Adaptation Plan all four Welsh Archaeological Trusts are undertaking pilot projects within their areas to assess the risk of climate change on heritage assets. These projects will identify the major threats to the historic environment and the appropriate responses. The results will feed into the climate change planning process by providing improved baseline data and investigating the challenges posed by climate change adaptation for the historic environment in their relevant areas.

The other nations of Britain are carrying out a similar process of looking at the impact of climate change on their historic assets. Historic Environment Scotland's Climate Action Plan (Historic Environment Scotland) focuses on efforts to reduce future climate change as well as to mitigate its effects through its Carbon Management Plan, sustainable procurement, sustainable travel and sustainable tourism. The Our Place in Time Climate Change Working Group's Guide to Climate Change Impacts on Scotland's Historic Environment (Our Place in Time Climate Change Working Group 2019) considers risk factors and adaptation responses in the same way as the Welsh Adaptation Plan, but with a specific consideration of adaptations that either resist or accept loss of assets through climate change impacts. Where loss is accepted an emphasis is put on recording, excavation and historical research to recover as much information as possible before an asset is lost. Historic England produced a Climate Change Adaptation report in 2016 identifying risks and recommending general adaptations for increasing resilience in the historic environment (Fluck 2016).

1.2. Methodology

This report is the result of a scoping project designed to assess the impacts of climate change on historic asset type, and to identify areas most at risk. From this it provides proposals for further work to investigate the risks in more detail, identify specific sites at highest risk and consider appropriate mitigation. The current report presents baseline data to inform and support further stages of work. Proposals for further work and mitigation measures have been informed by joint working with relevant organisations, such as local authorities, National Trust and Natural Resources Wales (NRW). This has included representation on the Climate Change HEG Sub-group and West Wales Coastal Forum.

This project makes use of landscape types defined by LANDMAP, an all-Wales landscape resource developed by NRW. LANDMAP maps and classifies landscapes, describing their key characteristics, qualities and components. Fourteen key landscape type categories (LMP14) are used for reporting on the potential impacts of climate change on the landscape, as specified in Berry *et al.* 2019 (p152). The landscape types are given in Table 1.

Table 1. LANDMAP LMP14 landscape type categories

Landscape type	**LMP14 code**
Upland (Wooded)	LMP14_1
Upland (Moorland)	LMP14_2
Upland (Rock and Scree)	LMP14_3
Upland (Grassland)	LMP14_4
Upland (Wooded Hills)	LMP14_5
Lowland Valleys (Hedgerow)	LMP14_6
Lowland Valleys (Open)	LMP14_7
Lowland (Wooded and Wetland)	LMP14_8
Coastal Edge	LMP14_9
Developed (Communities)	LMP14_10
Developed (Amenity)	LMP14_11
Developed (Industry)	LMP14_12
Water (Sea)	LMP14_13
Water (Inland)	LMP14_14

The Sector Adaptation Plan (Historic Environment Group 2020) provides an updated risk assessment for nine broad classes of historic asset. This risk assessment for historic assets across Wales is included as Table 2. The impact summary codes in that table are explained in Table 3. In this project the risk assessment has been applied in more detail to historic assets in north-west Wales.

Table 2. Assessment of the likely impacts of climate change on historic assets in Wales (from Historic Environment Group 2020, 8)

Description of climate change	**Warmer mean temperatures**				**Hotter, drier summers**		**Warmer, wetter winters**	**More frequent extreme weather**
Predicted outcome of climate change on environment	**Rise in sea levels**	**Migration and proliferation of pests, diseases and invasive species**	**Longer growing season**	**Changes in lifestyle and leisure patterns**	**Drying out, desiccation, shrinkage and erosion**	**Wild fires**	**More flooding events, increased ground moisture and precipitation**	**Frequent high winds, storms and heat/cold events**
Buildings and settlements	**SL1** **SL2**	**PD1**	**LGS1**	**LEI1** **LEI2**	**DRY1** **DRY4**	**WF1**	**FL1**	**EX1** **EX2**
Marginal and upland		**PD2**	**LGS1**	**LEI1** **LEI2**	**DRY2** **DRY3**	**WF2**	**FL2** **FL3**	**EX1** **EX2**
Marine and coastal	**SL1** **SL2**	**PD2**	**LGS1**	**LEI1** **LEI2**	**DRY2**		**FL1**	**EX1** **EX3**
Rivers, canals, fresh water	**SL1**	**PD2**	**LGS1**	**LEI1** **LEI2**	**DRY1** **DRY2** **DRY3**		**FL1**	**EX1** **EX2**
Farmland		**PD2**	**LGS1**		**DRY2** **DRY3** **DRY4**		**FL2** **FL3**	**EX1** **EX2**
Woodland		**PD2** **PD3**			**DRY2** **DRY3**	**WF2**		**EX1**
Industrial landscapes	**SL1**	**PD2**	**LGS1**	**LEI1** **LEI2**	**DRY1** **DRY2** **DRY3**		**FL2** **FL3**	**EX1**
Designed landscapes, parks and gardens		**PD2** **PD3**	**LGS2**	**LEI1** **LEI2**	**DRY3** **DRY4**	**WF1** **WF2**	**FL1** **FL2** **FL3**	**EX1** **EX2**
Historic landscapes	**SL1** **SL2**	**PD2** **PD3**	**LGS1**	**LEI1**	**DRY3** **DRY4**	**WF1** **WF2**	**FL1** **FL3**	**EX1** **EX2**

Significance of impact:
High negative
Moderate negative
Small negative
Positive
Blank = limited/no impact

Table 3. The impact summary codes used in Table 2 (from Historic Environment Group 2020, 9)

Warmer mean temperatures	
Rise in sea levels	
SL1	Persistent inundation and flooding • Loss of historic settlements and structures. • Impact on heritage related coastal economy, e.g. heritage tourism. • Impact through loss and inundation of coastal archaeology on foreshore and coast edge e.g. ship wrecks, peat deposits and promontory forts. • Impact on coastal industries and installations e.g. tidal mills, fish weirs, salt works, limekilns.
SL2	Impact from management response • Direct and indirect impacts on historic assets and areas, and their settings from increasing or strengthened engineered/physical protections. • Response to managed retreat. • Potential adverse impacts from clean-up operations.
Migration and proliferation of pests, diseases and invasive species (PD)	
PD1	• Increased incidence and severity of fungal and insect attack and the impacts on the health of building fabric, occupants and collections/archives.
PD2	• Proliferation and expansion in range of invasive and non-native (INNS) species. • Change in marine species in response to warmer seas and increased acidification.
PD3	• Loss of species already at threshold of tolerance leading to changes in distinctive character. • Wide range of species susceptible to Phytopthora root rot in some gardens.
Longer growing season (LGS)	
LGS1	• Increased/spreading vegetation cover, obscuring historic assets/accelerating decay of building materials. • Expanding improved pasture and cultivation into uplands, including ploughing fields not recently cultivated. • Introduction of new crops/bio-energy crops and increasing cereals, intensifying farming practices and cultivation techniques that could impact adversely on buried archaeology. • Increased/longer period of maintenance tasks on historic assets. • Introduction of new species altering distinctive historic character
LGS2	• Earlier flowering and later leaf fall potentially increasing visitors.
Changes in lifestyle and leisure patterns (LEI)	
LEI1	• Increased migration from urban centres to historic coastal resorts in response to overheating. • Increasing development/infrastructure pressure on coastal resorts for leisure to satisfy increasing visitor pressure. • Increased visitor pressure on historic coastal, upland, industrial, river and designed landscapes, parks and gardens.
LEI2	• Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration.
Hotter, drier summers	
Drying out, desiccation, shrinkage and erosion (DRY)	
DRY1	Subsidence • Subsidence caused by clay shrinkage to features and structures e.g. buildings, breaches in flood defences, dams and reservoirs, shafts and underground workings, blockages of river courses.
DRY2	Erosion and destabilisation • Erosion of historic assets exposed by the lowering of lake, inland waterways and river levels. • Destabilisation/erosion of earth structures, embankments and cuttings. • Destabilisation of tips and industrial remains leading to landslides and increased potential for pollution. • Increased erosion from impaired pasture growth caused by desiccation. • Increased use of marginal pastures leading to erosion of archaeological remains. • Wind-blown movement of marine sediments, e.g. dunes, exposing historic assets.

	• Wind-blown contamination/pollution from metal mine sites e.g. tips, settling ponds.
DRY3	Drying out • Lowering of water table causing loss of paleoenvironmental evidence. • Drying out of blanket bog leading to dome collapse or erosion of exposed faces e.g. impact on peat as a paleoenvironmental record. • Changing decay and survival of organic artefacts e.g. trackways, peat processing sites, timber launder systems. • Operating historic water mills at risk from water shortage. • Increased risks to historic assets from irrigation systems on farmland. • Changing use of agricultural land and buildings to cope with water shortages, lack of fodder and poor harvests. • Drying and stress to veteran trees, historic woodland and their contribution to setting.
DRY4	• Exposure of industrial remains buried beneath redeposited peaty sediments e.g. potential prehistoric mining remains, smelting sites.• Discovery of new historic assets in desiccated grassland and crops visible as parch and crop marks.• Improved humidity levels in buildings.
Wild fires (WF)	
WF1	Built • Increased risk of fire in buildings and structures from drier conditions. • Wild fires causing damage to buried and above ground archaeology, buildings and structures.
WF2	Vegetation • Changes in species leading to alterations to the ecology, vegetation and historic landscape character. • Increased risk of erosion and subsequent loss of peat as a paleoenvironmental record resulting from fire damage to surface vegetation and its protective effect.
Warmer, wetter winters	
More flooding events; increased ground moisture and precipitation (FL)	
FL1	Increased erosion, scour and other damage • Damage to historic buildings, settlements, infrastructure and designed features. • Destabilisation and subsidence of archaeology on the coast edge. • Erosion, damage or loss of buried and above ground archaeological remains. • Increased pressure, scour and damage to water-related features e.g. bridges, overtopping of dams. • Potential adverse impact from clean-up operations and modifications e.g. installation of property flood resilience measures.
FL2	Physical and chemical changes • Increased risk of physical (mechanical) damage through the use of agricultural machinery on waterlogged soils, including 'poaching' by livestock near historic assets. • Persistent saturation resulting in chemical changes to buried archaeology.
FL3	Destabilisation and pollution • Inadvertent pollution episodes from flooding and increased precipitation e.g. metal mines. • Destabilisation and subsidence of archaeology on spoil and waste tips, designed features, archaeological deposits and earth structures leading to slippage or collapse. • Potential adverse impact from clean-up operation.
More frequent extreme weather	
Frequent high winds, storms and heat/cold events (EX)	

EX1	Damage from increased precipitation/high wind events • Storm damage to features, historic buildings, settlements and structures above ground. • Wind driven rain and increased humidity with resulting impact on indoor air quality and health of building fabric, occupants and collections/archives. • Increased high-energy flooding events (see FL1, FL2). • Turbulent seas leading to damage/scour to underwater, intertidal and coast-edge archaeology. • Increased sediment transport leading to exposure of historic assets. • Direct impact from storms causing damage to veteran trees and woodland. • Cumulative impacts from multiple events. • Potential adverse impact from clean-up operations and modifications. • Increased maintenance and repair costs.
EX2	Extreme heat/drought and cold events • Potential direct and indirect impacts from extremes and fluctuations affecting physical weathering, exacerbating building material and structural problems e.g. freeze/thaw action, • Increased use of marginal pastures leading to erosion of archaeological remains. • Wind-blown movement of marine sediments, e.g. dunes, exposing historic assets. • Wind-blown contamination/pollution from metal mine sites e.g. tips, settling ponds.
EX2	Extreme heat/drought and cold events • Potential direct and indirect impacts from extremes and fluctuations affecting physical weathering, exacerbating building material and structural problems e.g. freeze/thaw action, shrinkage. • Overheating of buildings and potential for maladaptation e.g. poorly designed air conditioning. • Changing land use to cope with the impacts of extreme and fluctuating weather conditions. • Increased heat and drought impacting on veteran trees and woodland.
EX3	• Discovery of new historic assets following exposure by coastal erosion or movement of sediment.

This initial assessment of the impacts of climatic change on the historic environment assets in north-west Wales was undertaken by using the LANDMAP landscape types and the assessment criteria to assess the risks in this region. The LANDMAP geospatial data was downloaded and used in analyses specific to north-west Wales. The impact assessments on land classes and archaeological assets as given in Berry *et al*. 2019 (118-145) have been converted to numerical scores to enable them to be applied to HER core sites according to the landscape type in which the sites are located (see Appendix I). The impact scores on both the archaeological assets and the land classes were combined through bivariate mapping. The geospatial analysis was carried out using MapInfo with a methodology devised by Menna Bell of Dyfed Archaeological Trust. The full details of this process are included as Appendix II.

The core HER point data have been overlaid on the basemap of risk assessed land classes and classified a risk level according to the land class it is situated within. This provides a baseline at a regional level, which can subsequently be assessed at a site level. MapInfo GIS (versions 19.0 and 16.0) were used to analyse data sets, compare polygon boundaries and extract sub-data sets as required.

1.3. Acknowledgements

The project has been grant aided by Cadw. Thanks to Menna Bell for providing the GIS methodology.

1.4. Copyright

2. SCOPING RESULTS

2.1. Landscape types and risk assessment

Table 4. Area of LANDMAP landscape types within north-west Wales with number of HER core sites recorded for each landscape type

Landscape type	LMP14 code	Area in GAT region (km2)	% of total land	Number of HER core sites
Upland (Wooded)	LMP14_1	250	6.4	2340
Upland (Moorland)	LMP14_2	955	24.6	7714
Upland (Rock and Scree)	LMP14_3	141	3.6	497
Upland (Grassland)	LMP14_4	599	15.5	7504
Upland (Wooded Hills)	LMP14_5	255	6.6	2608
Lowland Valleys (Hedgerow)	LMP14_6	489	12.6	4482
Lowland Valleys (Open)	LMP14_7	852	22.0	7392
Lowland (Wooded and Wetland)	LMP14_8	70	1.8	1013
Coastal Edge	LMP14_9	92	2.4	1005
Developed (Communities)	LMP14_10	100	2.6	5007
Developed (Amenity)	LMP14_11	6	0.2	73
Developed (Industry)	LMP14_12	23	0.6	1566
Water (Sea)	LMP14_13	11	0.3	15
Water (Inland)	LMP14_14	33	0.9	168

Table 4 presents the area of each landscape type within north-west Wales (Figure 1), with the combined upland landscape types covering 56.8% of the region and all the lowland types, including coast edge, totalling 39%. This shows how the region is dominated by the uplands, but Anglesey is largely lowland and the mainland is bisected by the large valleys of the Conwy, Dwyryd and Mawddach rivers. The marine and terrestrial elements of the coast together form 3% of the total area of the region, making this quite a significant element of the region, as the developed categories together only form 3.3%, due to the relatively nonurban nature of this part of Wales. The upland landscape types contain 20663 core HER sites and the lowland types combined contain 13892 sites, so that they have a similar density of sites taking into account the different areas that they cover. The developed areas, unsurprisingly, have a much higher density of sites, with 6646 sites in the much smaller area.

Figure 2 presents the risk scores for landscape types across the region and Figure 3 has the core HER sites imposed on this and graded by risk level. Table 5 presents the results of the risk assessment of historic asset groups as in the Sector Adaptation Plan with proposed adaptation responses where specific threats have been noted as being Moderate or High Negative. The recommendations range from further detailed scoping to spatial mapping, review and assessment projects, and monitoring.

Table 5. Risk assessment of historic asset groupings and adaptation responses in north-west Wales (note: the adaptation response only includes responses directly relevant to the historic environment, which could involve GAT)

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
Settlements (Buildings and Settlements)						
	SL1 Sea level rise leading to persistent inundation and flooding, causing the loss of historic settlements and structures. **High negative** **SL2** Impact from management response to flooding, with direct and indirect impacts from increasing or strengthened engineered/physical protections, response to managed retreat, and from clean-up operations **High negative** **FL1** Damage to historic buildings and settlements by flooding. Potential adverse impact from clean-up operations and modifications e.g. installation of property flood resilience measures. **High negative** **EX1** Storm damage to historic buildings and settlements. Wind driven rain and increased humidity impacting indoor air quality and health of building fabric, occupants and collections/archives. Increased maintenance and repair costs. **High negative** **EX2** Potential direct and indirect impacts from extremes and fluctuations in temperature affecting physical weathering, exacerbating building material and structural problems. Overheating of buildings and potential for maladaptation e.g. poorly designed air conditioning. **High negative** **PD1** Increased incidence and severity of fungal and insect attack and the impacts on the health of building fabric, occupants and collections/archives. **Moderate negative** **LGS1** Increased/spreading vegetation cover, obscuring historic assets/accelerating decay of building materials. Increased/longer period of maintenance tasks on historic assets. **Moderate negative** **LEI1** Rise in temperatures leading to Increased migration from urban centres to historic coastal resorts, increasing development/infrastructure pressure on coastal resorts for leisure, and increased visitor pressure on historic properties. **Moderate negative**	**Knowledge** Participation in established UK and wider climate heritage groups and networks to maximise knowledge and resources, leading to capacity building and more successful adaptation. Establish and implement targeted monitoring regimes on buildings and settlements. Improve understanding of the interacting, cascading and cumulative impacts of climate risk factors on building condition and fabric. **Capacity** Prepare, promote and maintain building and settlement case studies to illustrate examples of adaptation. Provide training and support within and across sectors on the risks and opportunities of climate change for buildings and settlements, and their adaptation. Prepare guidance/advisory notes that increase the knowledge, understanding and resilience of buildings and settlements to climate change e.g. property flood resilience. **Resilience** Develop and implement emergency/adaptation plans for buildings. Undertake programme of urban characterisation to inform management of change in urban areas. Work closely with the all-Wales monuments and listed buildings at risk monitoring work to help prioritise adaptive action.	High: SL1, SL2, FL1, EX1, EX2 Moderate: PD1, LGS1, LEI1, DRY1, WF1	Mapping high risk areas to include potential sea level rise, storm surges and flooding. Identify historic assets within these areas according to their type and significance. Identify areas at risk from wild fires, and carry out appropriate surveys in those areas. Provide case studies and ‘best practice’ guidance. Monitor areas at risk. Identify urban areas at risk of impact. Undertake Urban Historic Landscape Characterisation to aid management	Cadw, RCAHMW, NRW, UAs, AHF, SPAB, IHBC, National Trust, Victorian Society, other national, regional and local societies/groups	HER; NMR; Cadw SM and LB data; Buildings at Risk Registers; Conservation Area data held by UAs; NRW Flood risk data; material held at national and local archives.

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	DRY1 Subsidence caused by clay shrinkage to features and structures e.g. buildings, breaches in flood defences, dams and reservoirs, shafts and underground workings, blockages of river courses. **Moderate negative** **WF1** Increased risk of fire in buildings and structures from drier conditions. **Moderate negative** **LGS2** Earlier flowering and later leaf fall increasing visitors to historic properties and increasing revenue to be spent on maintenance. **Moderate positive** **LEI2** Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration. **Moderate positive** **DRY4** Improved humidity levels in buildings. **Moderate positive**					
Marginal and upland						
	LGS1 Expanding improved pasture and cultivation into uplands, including ploughing fields not recently cultivated. **High negative** **WF2** Increased wild fires causing erosion and loss of peat as a palaeoenvironmental record. Erosion due to the burning of vegetation cover leading to damage to archaeological monuments and buried deposits. **High negative** **PD2** Proliferation and expansion in range of invasive and non-native (INNS) species. **Moderate negative** **PD3** Loss of species already at threshold of tolerance leading to changes in distinctive character. **Moderate negative** **LEI1** Increased visitor pressure on uplands with potential for general damage to character of the landscape and specific damage to heritage assets. **Moderate negative**	**Knowledge** Carry out spatial mapping work to identify marginal and upland areas at greatest risk and analysis of specific impacts on those assets at greatest risk. Improve our understanding of the proliferation and expansion in the range of invasive and non-native (INNS) species and changing land use that could result in a cumulative loss of landscape character. **Capacity** Prepare case studies to further illustrate climate change risks and adaptation in marginal and upland areas. Prepare guidance/advisory notes to increase our knowledge, understanding and resilience of marginal and upland areas to climate change e.g. land management to reduce the impact of wild fires on buried archaeology and loss of peat as a palaeoenvironmental record.	High: LGS1, WF1 Moderate: PD2, PD3, LEI1, DRY2, DRY3, FL1, FL2, FL3, EX1, EX2	Identify areas most at risk through spatial mapping, and monitor condition of landscapes/assets. Undertake Historic Landscape Characterisation to aid management. Work with NRW, NT and LA's to identify impact from improving works to raised or blanket bogs. Monitor condition and record/survey/excavate sites at risk.	NRW; RCAHMW; National Trust; Carneddau Landscape Partnership; Country Landowners Association; various commoners and graziers associations; NFU Cymru; FUW	HER; NMR; Cadw SM and LB data. NRW Flood risk data; data on blanket bog from NRW's GWC_NRW_Sensitive Habitats data. Other relevant available data on peat/peat bogs: including 'Unified Peat Map of Wales' (https://lle.gov.wales/catalogue/item/UnifiedPeat/?lang=en), Forestry Commission survey of Peats, Lowland Peatland Survey (NRW) and Phase 1 habitat peats (NRW). Carneddau Landscape Partnership LiDAR data and sites. CHERISH Project data SNPA Lost Farmsteads project, Ardudwy SNPA/ University of Sheffield early fields

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	DRY2 Erosion and destabilisation from drier conditions leading to increased erosion from impaired pasture growth and increased use of marginal pastures resulting in the erosion of archaeological remains. Wind-blown movement of marine sediments, e.g. dunes, exposing historic assets. **Moderate negative** **DRY3** Lowering of water table and drying out and erosion of blanket bog and lowland peat deposits causing loss of palaeoenvironmental evidence. Changing decay and survival of organic artefacts. Changing landuse to cope with water shortages. .**Moderate negative** **FL1** Increased flooding of upland streams causing erosion, damage or loss of buried and above ground archaeological remains. **Moderate negative** **FL2** Increased risk of physical (mechanical) damage through the use of agricultural machinery on waterlogged soils, including 'poaching' by livestock near historic assets. Persistent saturation resulting in chemical changes to buried archaeology. **Moderate negative** **FL3** Destabilisation and subsidence of archaeology deposits and earth structures leading to slippage or collapse. **Moderate negative** **EX1** Storm damage to features and structures above ground. **Moderate negative** **EX2** Changing landuse to cope with the impacts of extreme and fluctuating weather conditions. **Moderate negative** **SL1** Coastal erosion leading to the loss of coastal peat and lake deposits containing palaeoenvironmental evidence. **Small negative** **LEI2** Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration. **Moderate positive** **DRY4** Discovery of archaeological sites from beneath drying and eroding peat.	**Resilience** Work with agricultural advisors to limit adaptations that have potential to damage historic assets e.g. deeper root crops. Survey vulnerable areas where drying and shrinkage of peat affects historic assets. Establish stakeholder/community groups able to monitor and record assets and respond to significant events such as wild fires.				research

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	Small positive **EX3** Flooding and storm damage causing erosion leading to the discovery of buried archaeological remains. **Small positive**					
Marine and coastal						
	SL1 Loss of heritage assets to flooding and coastal erosion. Impact on heritage related coastal economy, e.g. heritage tourism. Impact through loss and inundation of coastal archaeology on foreshore and coast edge e.g. ship wrecks, peat deposits and promontory forts. Impact on coastal industries and installations e.g. tidal mills, fish weirs, salt works, limekilns. **High negative** **SL2** Impact on historic assets and areas from management response to sea level rise, including building defences and from clean-up operations. **High negative** **LEI1** Rise in temperatures leading to Increased migration from urban centres to the coast, increasing development/infrastructure pressure on the coast for leisure, and increased visitor pressure on the coast and marine environment. **High negative** **FL1** Increased pressure, scour and damage to water-related features at mouths of rivers. Potential adverse impact from clean-up operations after flooding. **High negative** **EX1** Storm damage to coastal features and buildings, and archaeological remains above and below. Turbulent seas leading to damage/scour to underwater, intertidal and coast-edge archaeology. Increased sediment transport leading to exposure of historic assets. Potential adverse impact from clean-up operations and modifications. Increased maintenance and repair costs to coastal features and infrastructure. **High negative** **PD2** Threats to wrecks and coastal structures from change in marine species in response to warmer seas and increased acidification. **Moderate negative** **PD3** Loss of species already at threshold of tolerance leading to changes in distinctive character of coastlands and potentially threats to landscape features such as dunes. **Moderate negative**	**Knowledge** Carry out spatial mapping work to identify historic assets at greatest risk. Improve understanding of the impacts of acidification of seawater and changing marine species on wrecks and timber structures in marine environments. **Capacity** Work with local and national authorities to ensure the historic environment is included within management of the coastal zone policy statements, plans and codes. Provide support and training for historic environment practitioners wishing to specialise in the impacts of climate change and adaptation of historic assets. **Resilience** Prepare and implement emergency/adaptation plans for sites at risk from erosion. Survey or excavate sites at risk. Establish stakeholder/community groups able to monitor and record assets and respond to significant events such as wild fires.	High: SL1, SL2, LEI1, FL1, EX1 Moderate: PD2, PD3, LGS1, DRY2	Use spatial mapping techniques to identify areas of impact from sea level rise and storm surges. Identify sites in those areas and monitor condition. Undertake characterisation surveys of coastal resorts to aid planning decisions. Monitor exposure or burial of shipwrecks, and survey/record as necessary. Monitor movement of sediments, which can expose vulnerable sites, or erode others. Work with volunteers to monitor erosion and record sites at risk.	RCAHMW, NRW	HER; NMR; Cadw SM and LB data NMR Maritime Heritage Assets (http://lle.gov.wales/catalogue/item/NationalMonumentsRecordOfWalesMaritimeHeritageAssets) NRW Flood risk data. CHERISH Project data

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	LGS1 Expanding improved pasture and cultivation into coastal areas not recently cultivated due to the introduction of new crops/bio-energy crops and increasing cereals, intensifying farming practices and cultivation techniques. **Moderate negative** **DRY2** Wind-blown movement of marine sediments, e.g. dunes, exposing historic assets to damage. **Moderate negative** **LEI2** Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration. **Moderate positive** **EX3** Discovery of new historic assets following exposure by coastal erosion or movement of sediment; particularly important for understanding prehistoric coastal settlement. **Moderate positive**					
Rivers, canals, fresh water						
	FL1 Increased flooding leading to damage of buildings, features, infrastructure and buried archaeology along water courses. Potential adverse impact from clean-up operations and modifications such as flood defences. **High negative** **SL1** Rise in sea level and storm surges exacerbating risk of flooding and damage to historic assets from overflowing rivers and coastal erosion at river mouths. **Moderate negative** **SL2** Damage to historic assets at river mouths from the construction of coastal defences against sea level rise. **Moderate negative** **PD2** Proliferation and expansion in range of invasive and non-native (INNS) species. **Moderate negative** **PD3** Loss of species already at threshold of tolerance leading to changes in distinctive character and potentially exposing river banks to erosion. **Moderate negative**	**Knowledge** Carry out spatial mapping work to identify assets at greatest risk from flood events and increased scour, using evidence including the flood zone mapping. Improve understanding of the interacting, cascading and cumulative impacts of climate risk factors on building condition and fabric. **Capacity** Work with relevant authorities to ensure the historic environment is taken fully into account when planning improved flood defences. Develop advice and guidance on the maintenance and repair of historic buildings and structures to increase their resilience, and on post-flood clean-up operations. **Resilience** Prepare and implement emergency/adaptation plans for sites at	High: FL1 Moderate: SL1, SL2; PD2, PD3, LGS1, LEI1, DRY1, DRY2, DRY3; EX1, EX2	Use spatial mapping techniques to identify areas at risk from erosion or flooding. Undertake assessments of river catchment areas. Make recommendations for further work. Work with relevant authorities such as NRW and LA's to ensure remedial action does not impact significantly on the historic environment.	NRW; Canals and Rivers Trust; Local Authorities; River Boards.	HER; NMR; Cadw SM and LB data Canals and Rivers Trust, NRW Flood risk data

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	LGS1 Increased/spreading vegetation cover, obscuring historic assets/accelerating decay of building materials, especially along canals. Potentially also causing the choking of canals or canalised streams and water channels. Expanding cultivation into uplands would increase run-off into rivers, potentially increasing both flooding and sedimentation. **Moderate negative** **LEI1** Increased visitor pressure could impact on river and lake landscapes and features located in these areas. Increase in visitor use could lead to development along rivers, especially at river mouths, and by lakes. **Moderate negative** **DRY1** Subsidence caused by clay shrinkage to features and structures e.g. dams, reservoirs and river banks, blockages of river courses. **Moderate negative** **DRY2** Erosion of historic assets exposed by the lowering of lake, inland waterways and river levels. Destabilisation/erosion of earth structures, embankments and cuttings. **Moderate negative** **DRY3** Operating historic water mills at risk from water shortage. **Moderate negative** **EX1** Storm damage to historic structures along water courses, resulting in increased maintenance and repair costs. **Moderate negative** **EX2** Potential direct and indirect impact from extreme and fluctuating weather conditions affecting the physical weathering of building materials and exacerbating structural problems. **Moderate negative** **LEI2** Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration. **Moderate positive** **EX3** Discovery of new historic assets by erosion of the banks of rivers and streams. **Moderate positive**	risk from flooding. Survey or excavate sites at risk. Establish stakeholder and community groups to help monitor and respond to the risks and their impacts.				
Farmland						
	LGS1 Introduction of new crops/bio-energy crops and increasing cereals, intensifying	**Knowledge** Carry out spatial mapping work to	Moderate: LGS1, LEI1, DRY2,	Monitor selection of buried archaeology sites looking at	NRW; National Trust; NFU Wales; FUW;	HER; NMR; Cadw SM and LB data

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	farming practices and cultivation techniques that could impact adversely on buried archaeology. **Moderate negative** **LEI1** Increased tourism could lead to the unsympathetic reuse of agricultural buildings for tourists or the development of new buildings and facilities on farms. **Moderate negative** **DRY2** Increased erosion from impaired pasture growth caused by desiccation. Increased use of marginal pastures leading to erosion of archaeological remains. **Moderate negative** **DRY3** Increased risks to historic assets from irrigation systems on farmland. Changing use of agricultural land and buildings to cope with water shortages, lack of fodder and poor harvests. **Moderate negative** **FL2** Increased risk of physical (mechanical) damage through the use of agricultural machinery on waterlogged soils, including 'poaching' by livestock near historic assets. **Moderate negative** **FL3** Destabilisation and subsidence of archaeology or designed features, archaeological deposits and earth structures leading to slippage or collapse. **Moderate negative** **EX2** Changing land use to cope with the impacts of extreme and fluctuating weather conditions. **Moderate negative** **DRY4** Discovery of new historic assets in desiccated grassland and crops visible as parch and crop marks. **Moderate positive**	identify farmland assets at greatest risk. Resource aerial reconnaissance programmes and the capacity to react swiftly to weather events for the enhancement of the National Monuments Record of Wales and historic environment records of Wales. **Capacity** Provide training and support within and across sectors on the impacts of climate change and adaptation of the historic environment. Prepare updated best-practice agri-environment and historic environment guidance to encompass climate change risks and recognition that adaptation will be a continuous process. Convey how stable, well-managed grass swards can be beneficial to archaeological sites and promote this where appropriate. **Resilience** Support climate change adaptation through the new sustainable farming scheme for Wales. Encourage the re-planting of fieldscape trees and gaps in hedgerows where they form a key component of the historic landscape to reduce the impact of disease and storm losses.	DRY3, FL2, FL3, EX2	erosion, changing agricultural practices, drying out. Work with RCAHMW aerial programme to identify new sites in times of drought. Work with relevant authorities/organisations to produce guidance on the management of farmland and the historic environment.	Country Landowners' Association	NRW Flood risk data
Woodland						

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	PD2 Proliferation and expansion in range of pests, pathogens and invasive and non-native (INNS) species. **High negative** **PD3** Changes in the distribution of tree species and loss of species already at their threshold of tolerance. **High negative** **LGS1** Introduction of new species altering distinctive historic character. **Moderate negative** **LEI1** Increased visitor pressure on designed woodland landscapes. **Moderate negative** **DRY2** Destabilisation/erosion of earth structures and embankments. Change of use of woodlands leading to change of woodland character and threat to archaeological remains. **Moderate negative** **DRY3** Changing use of agricultural land and buildings to cope with water shortages, lack of fodder and poor harvests. Drying and stress to veteran trees, historic woodland and their contribution to setting. **Moderate negative** **WF2** Wild fires leading to alterations in the ecology, vegetation and historic landscape character. **Moderate negative** **FL3** Destabilisation of soil, especially on steeper slopes, leading to loss of trees and potentially associated archaeology or structures. **Moderate negative** **EX1** Storm damage to veteran trees and woodland. Changes in the frequency and magnitude of high winds causing more damage from wind blow affecting built and buried archaeology. **Moderate negative** **EX2** Increased heat and drought impacting on veteran trees and woodland. **Moderate negative** **LGS2**	**Knowledge** Improve understanding of the positive and negative effects of a longer growing season on the maintenance and management of the historic environment. Increase our understanding of the threats and opportunities from a changing climate to new woodland planting by using UKCP18 projections. **Capacity** Promote best-practice guidance on making woodlands more resilient. www.naturalresources.wales/guidance-and- advice/environmental-topics/woodland-management/planning-for-the-future/making-woodlands-more-resilient/?lang=en **Resilience** Management to increase the tree species composition and genetic diversity to improve woodland resilience to climate change. The Woodlands for Wales strategy advocates increased use of low impact silvicultural systems (LISS) to diversify the structure of our woodlands and their ability to adapt to changing conditions, offering potential benefits for historic assets such as earthworks and structures within woodlands. Encourage and implement new planting regimes where trees and hedgerows form a key component of the historic environment to reduce the impact of the spread of disease and increased storminess.	High: PD2, PD3 Moderate: LGS1, LEI1, DRY2, DRY3, WF2, FL3, EX1, EX2	Undertake selective surveys within ancient woodland, looking in particular for sites associated with former woodland practices, but also earthworks. Continue to work with NRW to monitor new forest areas, and areas to be clear felled and replanted. Work with NRW to produce guidance on forest management and the historic environment.	NRW; Coed Cadw/Woodland Trust	HER; NMR; Cadw SM and LB data Relevant NRW data

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	Earlier flowering and later leaf fall potentially increasing visitors. **Moderate positive** **LEI2** Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration. **Moderate positive**					
Industrial landscapes						
	SL1 Impact of sea level rise on coastal industries and installations e.g. tidal mills, fish weirs, salt works, limekilns. **Moderate negative** **SL2** Impact from management response to sea level rise on remains of coastal industries. **Moderate negative** **PD2** Proliferation and expansion in range of invasive and non- native (INNS) species obscuring sites. **Moderate negative** **LEI1** Impact of development due to increased leisure use on industrial landscapes. **Moderate negative** **DRY1** Subsidence caused by clay shrinkage to features and structures e.g. buildings, shafts and underground workings. **Moderate negative** **DRY2** De-stabilisation of tips and industrial remains leading to landslides and increased potential for pollution. Wind-blown contamination and pollution from metal mine sites, tips and settling ponds. **Moderate negative** **DRY3** Changing decay and survival of organic artefacts e.g. trackways, peat processing sites, timber launder systems. Operating historic water mills at risk from water shortage. **Moderate negative** **FL1**	**Knowledge** Improve baseline data, particularly those underrepresented in the record, such as underground remains. Improve understanding of the interacting and cascading relationships, and cumulative impacts of climate risk factors on pollution from historic metal mining. **Capacity** Prepare case studies to further illustrate climate change risks and adaptation in industrial landscapes. Prepare guidance/advisory notes that increase the knowledge, understanding and resilience of industrial landscapes to climate change. **Resilience** Work closely with Natural Resources Wales during remediation schemes to record and, where possible, conserve archaeological remains.	Moderate: SL1, SL2, PD2, LEI1, DRY1, DRY2, DRY3, FL1, FL2, FL3, EX1	Provide advice on managing former industrial sites, in particular where remedial action is required to deal with pollution, tip destabilisation, clearance of upstanding remains. Map industrial features on Historic Environment Record, including underground features. Provide guidance notes for management of former industrial remains. .	RCAHMW; Cadw; NRW; National Museum of Wales	HER; NMR; Cadw SM and LB data NRW Flood risk data, British Geological Survey

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	Flooding leading to erosion, damage or loss of buildings, water-related features, buried and above ground archaeological remains. **Moderate negative** **FL2** Persistent saturation resulting in chemical changes to buried archaeology. **Moderate negative** **FL3** Inadvertent pollution episodes from flooding and increased precipitation e.g. metal mines. Destabilisation and subsidence of archaeology on spoil and waste tips, and earth structures leading to slippage or collapse. **Moderate negative** **EX1** Storm damage to features, historic buildings, and structures above ground. Turbulent seas leading to damage/scour to underwater, intertidal and coast-edge industrial structures. Increased maintenance and repair costs. **Moderate negative** **LEI2** Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration. **Moderate positive** **DRY4** Exposure of industrial remains buried beneath redeposited peaty sediments leading to the discovery of prehistoric mining remains, smelting sites, etc. **Moderate positive**					
Designed landscapes, parks and gardens						
	PD3 Loss of species already at threshold of tolerance leading to changes in distinctive character. Wide range of species susceptible to Phytophthora in some gardens. **High negative** **PD2** Proliferation and expansion in range of invasive and non-native (INNS) species. **Moderate negative** **LGS1** Increased/longer period of maintenance tasks on historic assets. Introduction of new species altering distinctive historic character. **Moderate negative** **LEI1** Increased visitor pressure on designed landscapes, and parks and gardens. **Moderate negative**	**Knowledge** Carry out spatial mapping work to identify parks and gardens at greatest risk and analysis of specific impacts on those at greatest risk. Improve our understanding of the proliferation and expansion in the range of invasive and non-native (INNS) species. Improve our understanding of the consequences of changing growing conditions for the maintenance and management of sites and landscapes. **Capacity** Provide guidance for post-damage clean up.	High: PD3 Moderate: PD2, LGS1, LEI1, DRY2, DRY3, WF2, FL1, FL2, FL3, EX1, EX2	Undertake spatial mapping work to identify designed landscapes not included within the Register. Monitor and undertake surveys of a selection of sites, working with other organisation such as NT, WHGT to record changes in species, and management of infrastructure. The latter to take account of potential flooding risk.	Cadw; NRW; National Trust; Historic Gardens Trust	HER; NMR; Cadw SM and LB data Cadw's Historic park and garden data, NRW Flood risk data.

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	DRY2 Erosion of historic assets exposed by the lowering of ornamental lake levels. Destabilisation/erosion of earth structures, embankments and cuttings. **Moderate negative** **DRY3** Drying and stress to veteran trees, historic woodlands and their contribution to setting. **Moderate negative** **WF2** Risk to gardens of increased wild fires. **Moderate negative** **FL1** Erosion, damage or loss of garden features, structures, buildings, and buried and above ground archaeological remains. Destabilisation and subsidence. **Moderate negative** **FL2** Increased risk of physical (mechanical) damage through the use of agricultural machinery on waterlogged soils including 'poaching' by livestock near historic assets. **Moderate negative** **FL3** Inadvertent pollution episodes from flooding and increased precipitation. Potential adverse impact from clean-up operations. **Moderate negative** **EX1** Storm damage to features, buildings, and structures above ground. Direct impact from storms causing damage to veteran trees and woodland. **Moderate negative** **EX2** Increased heat and drought impacting on veteran trees and woodland. **Moderate negative** **LGS2** Earlier flowering and later leaf fall potentially increasing visitors. **Moderate positive** **LEI2** Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration. **Moderate positive**	Promote best-practice guidance to encourage management practices which are beneficial to designed landscapes. **Resilience** Prepare and implement emergency/adaptation plans for vulnerable sites. Management to increase the tree species composition and genetic diversity to improve woodland resilience to climate change. Encourage and implement new planting regimes where trees form a key component of the designed landscape to reduce the impact of the spread of disease and increased storminess.				
Historic landscapes						

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	SL1 Changes to coastal historic settlements and landscapes from erosion, storm surges and flooding. **Moderate negative** **SL2** Direct and indirect impact on historic coastal landscapes from increasing or strengthened engineered/physical protections. **Moderate negative** **PD2** Proliferation and expansion in range of invasive and non-native (INNS) species. **Moderate negative** **PD3** Loss of species already at threshold of tolerance leading to changes in distinctive character. Loss of species susceptible to Phytopthora and other diseases. **Moderate negative** **LGS1** Increased/spreading vegetation cover and introduction of new species altering distinctive historic character. Changes in farming practice altering landscape character. **Moderate negative** **LEI1** Increased visitor pressure on historic landscapes. **Moderate negative** **DRY3** Drying out and deterioration of blanket bog changing landscape character. Drying and stress to veteran trees and historic woodland. Changing land use to cope with water shortages, lack of fodder and poor harvests. **Moderate negative** **WF1** Increased fire risk in upland and woodland environments leading to risk of deterioration of landscape. **Moderate negative** **WF2** Changes in species leading to alterations to the ecology, vegetation and historic landscape character. **Moderate negative** **FL1** Increased flooding, soil erosion and landslips in altering historic landscapes. **Moderate negative** **FL3** Potential adverse impact from clean-up operations.	**Knowledge** Carry out spatial mapping work to identify historic landscapes at greatest risk and analysis of specific impacts on those at greatest risk. Improve our understanding of the proliferation and expansion in the range of invasive and non-native (INNS) species. Improve our understanding of the consequences of changing growing conditions for the maintenance and management of sites and landscapes. **Capacity** Provide guidance for post-damage clean up. Promote best-practice guidance to encourage management practices which are beneficial to historic landscapes. **Resilience** Prepare and implement emergency/adaptation plans for vulnerable sites. Management to increase the tree species composition and genetic diversity to improve woodland resilience to climate change. Encourage and implement new planting regimes where trees form a key component of the historic landscape to reduce the impact of the spread of disease and increased storminess.	Moderate: SL1, SL2, PD2, PD3, LGS1, LEI1, DRY3, WF1, WF2, FL1, FL3, EX1, EX2	Identify landscapes at risk as part of a spatial mapping programme. Carry out surveys, in particular characterisation surveys, to identify the significance and character of an area. Monitor these at appropriate intervals.	Cadw; NRW	HER; NMR; Cadw SM and LB data; NRW Flood risk data.

Historic Asset Grouping	Impacts with Summary Code and Significance	Example Adaptation Responses (Knowledge, Capacity, Resilience)	Specific Threats	Specific Adaptation Responses (potential projects)	Potential Partner Organisations	Heritage Resources
	Moderate negative **EX1** The historic character of wooded landscapes and individual trees in parkland landscapes, fieldscapes and hedgerows are at risk from storm damage pests and diseases inducing stress, dieback and loss. **Moderate negative** **EX2** Increased heat and drought impacting on veteran trees and woodland. The deterioration of traditional rural buildings may be accelerated by climate change. **Moderate negative** **LGS2** Earlier flowering and later leaf fall potentially increasing visitors. **Moderate positive** **LEI2** Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration. **Moderate positive**					

2.2. Potential Projects as initial Specific Adaptation Response

The above analysis provides an initial overview of the potential risk from climate change to the historic environment in north-west Wales. More detailed spatial analysis is required to assess the risks in specific areas. The impacts of climate change will be affected by local conditions and underlying geological, soil and landform characteristics. A study of how these relate to historic assets will improve the understanding of the significance of the impacts. Bringing in map regression and historical and archaeological information to study the development of current landscape character would give a context to future changes and may help identify sites at risk. This could include agricultural developments leading to changing farming landscapes and the development or decline of woodlands, wetlands, rough pasture and parklands.

The actual risk to individual sites in the areas most at risk needs to be assessed. The current work provides a basis for this, but could be enhanced by using other data, such as that from NRW's October 2020 Flood Risk Assessment and detailed information from historic environment data.

Each Heritage Asset Group is considered below, and potential projects are proposed as specific adaptation responses. In all cases long term projects are required to cover the whole region in sufficient detail and priority areas, groups of sites or specific classes of sites will have to be identified. See Figures 1, 2 and 3.

Settlements (Buildings and Settlements)
Covered by landscape types LMP14_10 to 12, which total 128 km^2 (3.3% of north-west Wales).
6646 HER core sites fall within these landscape types.

Specific Adaptation Response (potential projects)

Further risk assessment of buildings

Buildings are a large group of assets, some in current use, some ruined, with a wide range of uses. This variety means that risks within this group are also very varied. Further analysis is required to assess these varied risks. NRW floodzone data should be used to look more closely at the flooding risk to buildings and contour data can be used to assess the exposure and storm risk. Condition fields in the HER core data can be used to assess the condition of the buildings and how this might impact their risk. A more detailed investigation could take place of buildings on the Buildings at Risk Registers to assess risk on the level of individual buildings.

Work would concentrate on mapping high risk areas to include potential sea level rise, storm surges and flooding, and identify historic assets within these areas according to their type and significance. Areas at risk from wild fires would also be identified, and appropriate surveys would be carried out in those areas.

Urban Historic Landscape Characterisation

The risks applicable to settlements are the sum of the risks to the buildings that compose those settlements but also additional risks to infrastructure and character. The study of flood risk to buildings would also provide information about the physical risks to settlements, but an assessment of flooding and other risks to the character of settlements is also required. Existing Urban Historic Landscape Characterisations could be used to inform an assessment of risks on specific settlements. Where these are not available Conservation Areas and concentrations of listed buildings and scheduled sites could be used to identify areas of settlements that should be prioritised for urban HLC and subsequent risk assessment, recommendations for adaptations and monitoring.

Monitoring

Monitor threats and changes to asset condition, and take remedial action where necessary. Escalate to priority where evidence indicates impacts are becoming cumulative.

Marginal and upland
Upland is covered by landscape types LMP14_1 to 5, which total 2199 km^2 (56.8% of north-west Wales), and marginal land is also covered by LMP14_8, which adds an additional 70 km^2 (1.8% of north-west Wales).
21676 HER core sites fall within these landscape types.
This the largest landscape type by far in north-west Wales. While the mountain summits and rocky areas have relatively few historic assets, overall the uplands are as rich in historic assets as the lowlands. Although the uplands are marginal today they were extensively used in the past for agriculture, industry, settlement and ritual

purposes, and know historic assets are likely to be a significant under-representation of actual surviving archaeological remains.

Specific Adaptation Response (potential projects)

Further risk assessment of sites

A more detailed landscape assessment of the risks to different classes of site within these landscape types would improve on the baseline assessment. Sites include built structures, earthworks, buried remains and underground features, all of which have very different risks, as well as being in a wide variety of locations with varying risks. Some areas with a high number of known sites, especially scheduled sites, could be taken as examples and assessed in more detail to investigate the specific factors involved and suggest adaptations, which might be more widely applied.

Spatial mapping

Spatial mapping using aerial photographs and LiDAR would identify landscapes most at risk as well as potentially identifying previously unknown sites and estimating the real risk to unknown archaeological resource. This is a large scale project but would be greatly enhanced by the high resolution LiDAR of the whole Carneddau Range produced for the Carneddau Landscape Partnership and the project of using volunteers to analyse this data for new sites. On a smaller scale the CHERISH Project has produced high resolution LiDAR for Ynys Enlli/Bardsey Island and has analysed that and ground truthed potential sites.

Undertake Historic Landscape Characterisation could be undertaken to aid management.

Blanket bog and lowland peat

Blanket bog and lowland peats are historic assets in their own right for the palaeoenvironmental information they contain, but may also contain or cover other assets. The value of the information preserved in a bog can be related to its position in relation to other sites, e. g. those close to prehistoric settlement may preserve evidence of prehistoric agriculture and be of greater value than ones isolated from human activity. Studying sites around blanket bogs could identify the most valuable bogs and those of the highest priority to protect from an archaeological point of view. The Unified Peat Map of Wales (https://lle.gov.wales/catalogue/item/UnifiedPeat/?lang=en) could be used to investigate the relationship between peat deposits and HER core sites.

Monitoring

Monitor threats and changes to asset condition, and take remedial action where necessary. Escalate to priority where evidence indicates impacts are becoming cumulative.

Marine and coastal

Covered by landscape types LMP14_9 and 13, which total 103 km^2 (3% of north-west Wales).
1020 HER core sites fall within these landscape types.
This landscape type is most at risk from climate change impacts.

Specific Adaptation Response (potential projects)

Further risk assessment of sites

The coastline is varied with varied risks and the nature of the historic assets on the coast are varied. More detailed risk assessment is required to identify the sites at greatest risk and enable adaptation responses to be proposed for these.

Spatial mapping

Identification of zones of risk based on distance from the coast edge and potentially on geology could be used to identify erosion risk. This could be used to identify sites at highest risk of erosion. Confirmation of current erosion and potential for future erosion could be established by rapid field visits to sites identified as being at highest risk.

Characterisation

Undertake characterisation surveys of coastal resorts to aid planning decisions.

Intertidal zone assessment

Various projects have previously recorded sites in the intertidal zone (e.g. GAT intertidal peats and fish weir projects, NMR Maritime Heritage Assets

(http://lle.gov.wales/catalogue/item/NationalMonumentsRecordOfWalesMaritimeHeritageAssets)). These sites could be compared in detail to impact risks and selected sites might be visited to confirm current levels of erosion.

Monitoring
Monitor threats and changes to asset condition, and take remedial action where necessary. Escalate to priority where evidence indicates impacts are becoming cumulative.

Monitor exposure or burial of shipwrecks, and survey/record as necessary, and monitor movement of sediments, which can expose vulnerable sites, or erode others. Work with volunteers to monitor erosion and record sites at risk.

Rivers, canals, fresh water
Covered by landscape types LMP14_14, which totals 33 km^2 (0.9% of north-west Wales).
168 HER core sites fall within this landscape types, but this cannot include all sites in or on the banks of all rivers and streams across the region, which must be much more numerous.
There are very few canals in north-west Wales, but there are canalised sections of rivers and streams, as well as natural rivers, lakes and ponds, many of which have been used for industry and transport.

Specific Adaptation Response (potential projects)

Mapping of associated sites
Sites associated with rivers and canals are poorly represented within the Historic Environment Record. It is important, therefore, to undertake assessments of river catchment areas in order to identify features in advance of remedial works, flooding, drainage etc, and to make recommendations for further work.

Further risk assessment of sites
Simple proximity to rivers is inadequate to determine the risk from flooding or erosion as the position and height of the asset above the river level is as important as its proximity. More detailed analysis is necessary to identify sites at highest risk. This is a large project as there are a significant number of rivers and streams in north-west Wales. Site visits to selected sites would establish the current erosion level.

Work with relevant authorities
Work with relevant authorities such as NRW and LA's to ensure remedial action does not impact significantly on the historic environment.

Monitoring
Monitor threats and changes to asset condition, and take remedial action where necessary. Escalate to priority where evidence indicates impacts are becoming cumulative.

Farmland
Covered is generally covered by landscape types LMP14_6 and 7, which total 1342 km^2 (34.6% of north-west Wales), though some of the coast edge (LMP14_9) is also farmed and grazing takes place over most of the uplands.
11874 HER core sites fall within landscape types LMP14_6 and 7. Much of this land is on flood plains and at high risk from flooding.

Specific Adaptation Response (potential projects)
Further risk assessment of sites
This land is often particularly prone to flooding and a detailed comparison with NRW Floodzone data is needed. This will identify sites particularly at risk from flooding and the types of sites that are at risk. Site visits to selected sites would establish the current erosion level. As very large areas are being covered this would be done in smaller, more manageable areas.

Spatial mapping
Mapping using LANDMAP data (historic landscape, visual and sensory, etc. and other relevant habitat/environmental data), aerial photographs, LiDAR etc. to identify changes in farming practice and areas subject to drought or flooding, and to compare these to historic assets to identify sites most at risk.

Landscape characterisation
Undertaking landscape characterisation will identify, and contribute to an understanding of, fieldscapes, settlement patterns, and communication routes. The baseline data will allow monitoring of change to be undertaken.

Guidance
Work with relevant authorities/organisations to produce guidance on the management of farmland and the historic environment.

Monitoring
Monitor threats and changes to asset condition, and take remedial action where necessary. Escalate to priority where evidence indicates impacts are becoming cumulative.

Monitor selection of buried archaeology sites looking at erosion, changing agricultural practices, drying out. Work with RCAHMW aerial programme to identify new sites in times of drought.

Woodland
Covered by landscape types LMP14_1, 5 and 8, which total 574 km^2 (15% of north-west Wales).
5961 HER core sites fall within these landscape types.
Woodland covers a surprisingly large proportion of north-west Wales, which is often considered to be a largely unwooded region. The largest areas of woodland or forest are recent confer plantations but the smaller pockets of native woodland are of high historic and landscape value, as well as containing HER core sites relating to their use or preceding their development.

Specific Adaptation Response (potential projects)

Further risk assessment of sites
The nature of sites within woodlands needs to be investigated and the risks relating to these assessed. Adaptation responses suggested for the sites may conflict with those for the woodlands themselves and vice versa, so these issues need to be considered and balanced.

Undertake selective surveys within ancient woodland, looking in particular for sites associated with former woodland practices, but also earthworks.

Spatial mapping
The nature and historic value of woodlands under threat needs to be explored using LANDMAP data and other relevant habitat/environmental data, aerial photographs, historic maps etc. Different types of woodland will be impacted in different ways by climate change and will require different adaptation responses.

Guidance
Work with NRW to produce guidance on forest management and the historic environment.

Monitoring
Monitor threats and changes to asset condition, and take remedial action where necessary. Continue to work with NRW to monitor new forest areas, and areas to be clear felled and replanted.

Industrial landscapes
Covered by landscape type LMP14_12, which totals 23 km^2 (0.6% of north-west Wales).
1566 HER core sites fall within this landscape type. This landscape type includes some but not all of the large quarries and does not include all the very numerous small scale industrial workings in the uplands and elsewhere. Large sections of Snowdonia can be argued a being industrial landscapes, although they are now commonly seen as being largely natural.

Specific Adaptation Response (potential projects)

Further risk assessment of sites
The nature of sites within industrial landscapes needs to be investigated and the risks relating to these assessed. Upstanding buildings, buried remains and underground features all have very different risk factors.

Spatial mapping

The current data does not adequately map historic industrial landscapes. Using LANDMAP data, historic environment data, aerial photographs, historic maps etc to map these landscapes would contribute significantly to assessing their risk. Previous work such as the Gwynedd Metal Mines Survey has provided some historical context and locational information but not polygons defining areas. Detailed mapping would allow the comparison of industrial landscapes with spatial climate change risk factors.

Guidance
Provide advice on managing former industrial sites, in particular where remedial action is required to deal with pollution, tip destabilisation, clearance of upstanding remains. Provide guidance notes for management of former industrial remains.

Monitoring
Monitor threats and changes to asset condition, and take remedial action where necessary.

Designed landscapes, parks and gardens
Parks and gardens are not covered by the LMP14 landscape types and these areas are generally included within the lowland landscape types. The Register of Landscapes, Parks and Gardens of Special Historic Interest in Wales (Cadw 1998) has 56 parks and gardens in the GAT region.
999 HER core sites fall within registered parks and gardens.

Specific Adaptation Response (potential projects)

Further risk assessment of sites
Further detailed analysis of parks and gardens in relation to drought, flooding and coastal erosion risks is necessary as well as a consideration of the types of sites within these areas and the risks relevant to these.

Spatial mapping
Undertake spatial mapping work to identify designed landscapes not included within the Register, and surveys of a selection of sites.

Monitoring
Monitor threats and changes to asset condition, and take remedial action where necessary. Work with other organisation such as NT, WHGT to record changes in species, and management of infrastructure; the latter to take account of potential flooding risk.

Historic landscapes
There are 16 Registered Historic Landscapes in the GAT region covering 1266 km^2.
19610 HER core sites fall within these landscapes. These landscapes are covered by several of the LMP14 landscape types discussed above but historic landscapes should be considered as a priority, as they include some of the best historic assets.

Specific Adaptation Response (potential projects)

Further risk assessment of sites
An assessment similar to that undertaken in the current report needs to take place for historic landscapes, allowing the comparison of landscape types and risks to sites within these areas. Flooding data can be used to create more detailed risk assessments within these landscapes and analyses of the types of sites they contain will highlight specific types of sites most at risk. Much of this work will be carried out under recommendations for other Historic Asset Groups but the results need to be applied to each historic landscape as a whole and the risks to each landscape need to be considered.

Spatial mapping
Identify landscapes at risk as part of a spatial mapping programme. Carry out surveys, in particular characterisation surveys, to identify the significance and character of an area.

Monitoring
Monitor threats and changes to asset condition, and take remedial action where necessary.

3. POTENTIAL CASE STUDIES

Case studies of the application of adaptation responses can inform the application of similar responses to other historic assets and landscapes. Identifying case studies will involve working with a range of organisations which are carrying out climate change adaptation responses and studying the impact on the historic asset groupings. Below are suggestions for potential case studies and pointers to identify future case studies. More suitable case studies are likely to emerge as climate change effects continue, and mitigation responses are developed and acted upon.

Table 6. Table of Case Studies

Historic Asset Grouping	Case Studies (Potential)
Buildings and settlements	
	Flood alleviation schemes normally have an archaeological element, including desk-based assessments, watching briefs and occasionally further works, e.g. Conwy Valley flood alleviation scheme (project code G1877) or the Beaumaris flood alleviation scheme (project code G2347). The impact of a past or future scheme on historic assets and the historic environment could be studied.
Marginal and upland	
	Between 2012 and 2015 Snowdonia National Park Authority and NRW restored over 33 hectares of peatland at Rhyd Ddu, Beddgelert (https://www.snowdonia.gov.wales/looking-after/projects/peatland-restoration-in-snowdonia). SNPA is the lead partner of the Welsh Peatlands Project, which ended in 2020 (https://www.snowdonia.gov.wales/looking-after/welsh-peatlands-project; https://www.iucn-uk-peatlandprogramme.org/news/working-together-future-welsh-peatlands), which has tackled peat erosion on the Carneddau Mountains. SNPA is also eradicating rhododendron in various places, including Nant Gwynant, the Mawddach Estuary and Llanymawddwy (https://www.snowdonia.gov.wales/looking-after/projects/rhododendron-management). NRW is involved in restoration of peatlands in both uplands and lowlands as part of the National Peatlands Action Program (https://naturalresources.wales/about-us/strategies-and-plans/national-peatland-action-programme/?lang=en). This work is generally not closely linked to archaeological investigation or recording, but an area being restored could be taken as a case study and the impact on heritage assets could be considered. Alltwen, Dwygyfylchi suffered a serious fire in 2016. This exposed the hillfort and a survey was carried out to record the earthworks while they were clearly visible and to record erosion by visitors (project code G2490). In 2020 vegetation was only just returning to a level where it offered some protection to the archaeology.
Marine and coastal	
	Fairbourne - managed retreat in the face of rising sea levels but with some temporary works being done to the sea defences with potential impacts on the Second World War defence system on the beach. Examples of protected and unprotected coasts and the impact on the heritage assets.

	Marine mapping of wrecks with sonar by Bangor University, Centre for Applied Marine Sciences and RCAHMW to study WWI and WWII submarine wrecks. CHERISH Project on Ynys Enlli.
Rivers, canals, fresh water	
	Work with Cyngor Gwynedd Council during their on-going works associated with the Afon Gwyrfai Catchment Area to study the effects of climate change adaptations on the river system.
Farmland	
	Aerial photographs taken by Toby Driver of RCAHMW during the drought of 2018 revealed a large number of new sites and added information to known sites. Tomen y Mur motte – SNPA work to increase water retention to protect the grass that covers the motte
Woodland	
	Identify a site where storm damage has impacted archaeological remains and investigate the impact of the damage and its repair.
Industrial landscapes	
	Nomination of Slate Industry of North Wales as World Heritage Site. Impact of climate change on the proposed World Heritage Site. Impact of increased tourist numbers on the industrial landscape of Snowdon, with potential for discrete information points (such as History Points QR codes) to inform visitors about the landscape.
Designed landscapes, parks and gardens	
	Plas Cadnant garden has recently had extensive rebuilding following flooding and storm damage. National Trust are tackling climate change issues across their properties, including a marine source heat pump to heat Plas Newydd (https://www.nationaltrust.org.uk/features/plas-newydd-mansion).

4. REFERENCES

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APPENDIX I: ASSESSMENT OF IMPACTS OF CLIMATE CHANGE ON LAND CLASSES

Assessment of impacts of climate change on land classes as defined by NRW (after Berry *et al*. 2019, 118-145), with assessments converted to numerical scores

	Warmer mean temperatures			**Hotter, drier summers**			**Warmer, wetter winters**	**More frequent extreme weather**		
Land class	**Rise in sea levels (SL)**	**Migration and proliferation of pests, diseases and invasive species (PD)**	**Longer growing season (LGS)**	**Stress on some trees and plants**	**Drying out, desiccation, shrinkage and erosion (DRY)**	**Wild Fires (WF)**	**More flooding events; increased ground moisture and precipitation (FL)**	**Frequent high winds, storms and heat/cold events (EX)**	**Total Archaeology Impact Score (Archaeological Assets)**	**Total Impact Score**
Coastal Edge									**20**	**75**
Landform	**6**						**4**	**4**		
Field boundaries										
Tree Cover										
Vegetation	**6**						**5**			
Surface water	**6**							**5**		
Settlement and Structures	**6**						**5**	**5**		
Archaeological Assets	**6**				**4**		**5**	**5**		
Water (Inland)										
Landform							**4**		**4**	**52**
Field boundaries										
Tree Cover										
Vegetation			**4**	**5**			**4**			
Surface water			**4**		**6**		**5**	**4**		
Settlement and Structures			**4**				**4**	**4**		
Archaeological Assets					**4**					
Water (Sea)									**4**	**55**
Landform	**6**						**6**	**6**		
Field boundaries										

Tree Cover										
Vegetation		**5**	**3**				**4**	**5**		
Surface water	**4**	**4**					**4**	**4**		
Settlement and Structures										
Archaeological Assets								**4**		
Developed (Communities)									**4**	**68**
Landform										
Field boundaries										
Tree Cover		**5**	**3**	**5**				**4**		
Vegetation		**4**	**3**	**5**			**4**			
Surface water					**4**		**5**			
Settlement and Structures	**5**	**4**			**4**		**5**	**4**		
Archaeological Assets					**4**					
Developed (Industry and Infrastructure)									**4**	**44**
Landform								**4**		
Field boundaries										
Tree Cover										
Vegetation		**4**	**3**	**4**						
Surface water			**4**	**4**			**4**	**5**		
Settlement and Structures							**4**	**4**		
Archaeological Assets								**4**		
Developed (Amenity)									**9**	**60**
Landform	**4**						**4**			
Field boundaries										
Tree Cover		**5**		**5**				**4**		
Vegetation		**4**	**3**	**5**				**4**		
Surface water					**5**					
Settlement and Structures					**4**			**4**		
Archaeological Assets	**5**						**4**			

Lowland (Wood and Wetland)										
Landform							**4**		**8**	**73**
Field boundaries		**4**		**4**	**4**					
Tree Cover		**5**	**3**	**5**	**5**		**4**	**4**		
Vegetation		**4**	**3**	**4**	**4**		**4**			
Surface water					**4**					
Settlement and Structures										
Archaeological Assets					**4**		**4**			
Lowland Valleys (Hedgerow)									**4**	**24**
Landform										
Field boundaries		**4**	**3**	**4**			**4**			
Tree Cover										
Vegetation			**2**	**4**						
Surface water										
Settlement and Structures							**-1**			
Archaeological Assets					**4**					
Lowland Valleys (Open)									**4**	**56**
Landform										
Field boundaries		**5**								
Tree Cover		**5**	**3**	**5**		**5**				
Vegetation		**4**	**3**	**4**		**4**				
Surface water					**4**		**5**			
Settlement and Structures							**5**			
Archaeological Assets					**4**					
Upland (Grassland)									**8**	**42**
Landform										
Field boundaries		**5**	**4**	**5**						
Tree Cover										
Vegetation			**4**	**4**	**4**	**4**				
Surface water				**4**						

Settlement and Structures										
Archaeological Assets			**4**		**4**					
Upland (Rock and Scree)									**0**	**25**
Landform			**3**		**4**			**4**		
Field boundaries										
Tree Cover										
Vegetation			**5**	**5**						
Surface water					**4**					
Settlement and Structures										
Archaeological Assets										
Upland (Wooded Hills)									**1**	**30**
Landform										
Field boundaries										
Tree Cover		**6**	**3**	**5**		**6**	**1**	**5**		
Vegetation			**3**							
Surface water										
Settlement and Structures										
Archaeological Assets					**1**					
Upland (Wooded)									**4**	**45**
Landform										
Field boundaries										
Tree Cover		**5**	**2**	**2**		**5**	**4**	**5**		
Vegetation		**4**	**3**	**3**		**4**				
Surface water					**4**					
Settlement and Structures										
Archaeological Assets					**4**					
Upland (Moorland)									**10**	**61**
Landform					**4**					
Field boundaries										
Tree Cover		**4**	**4**	**5**						

Vegetation		**5**	**5**	**6**	**6**	**6**				
Surface water					**6**					
Settlement and Structures										
Archaeological Assets					**5**	**5**				

Impact Ranking

6 - High Negative

5 - Moderate Negative

4 - Low Negative

0 - No Change

3 - Low Positive

2 - Moderate Positive

1 - High Positive

APPENDIX II: DETAILED METHODOLOGY FOR MAPINFO SPATIAL MODELLING

Below are the instructions produced by Menna Bell of Dyfed Archaeological Trust for extracting and modelling the relevant data. These are practical instructions but are included here as a record of the modelling used to produce the data and figures included in the report.

Detailed Methodology for MapInfo Spatial Modelling

By Menna Bell

GIS software: MapInfo Pro 2019

The following methodology has been undertaken in MapInfo Pro 2019 but all of the steps and processing should be possible in earlier versions.

Premise of the methodology:

- Assessment of the impacts of climatic change on the historic environment assets should be evaluated in first instance by ***where*** they are not by ***what*** they are.
- This is possible by using the landscape climate change impact metrics as provided by NRW's 2019 Report 314 Landscape and a Changing Climate: https://cdn.naturalresources.wales/media/689497/eng-evidence-report-314-landscape-and-changing-climate.pdf of which the geospatial data is freely available to download from the online repository: https://github.com/robertberryuk/LANDMAP_ClimateChange This report categories Wales into 14 land classes against which the impacts of climatic change have been evaluated and risk quantified.
- The LANDMAP impact assessments have been converted to numerical scores and transcribed into spreadsheet *DAT_162_Climate_Change_Impacts_Rescore*. These scores provide the basis for the risk classification. In all instances, any positive change impact scores are outweighed by the negative impacts and consequently the resultant scoring classification indicates the severity of the negative impacts of climatic change.
- The risk assessed land classes provide the basemap onto which data relating to the historic environment data can be overlaid. As an initial baseline, Core HER point data has been classified a risk level according to the land class it is situated within. This has created a very rapid impact baseline at a regional level which can then be assessed at a site level. The true vulnerability (and therefore risk) can be assessed individually as a secondary level of analysis using the criteria provided in the HEG 2020 *Historic Environment and Climate Change* Sector Adaptation Plan. Other historic environment data such as Registered Historic Landscapes, Parks and gardens, Listed Buildings, Scheduled Monuments and maritime assets recorded by the RCAHMW can also be assessed in this way. The same is applicable to blanket bogs and woodland.
- Data from NRW's October 2020 Flood Risk Assessment has been used for it supersedes NRW's Flood Zone 3 data used in both the LANDMAP and HEG assessments. This latest flooding data quantifies the risk of flooding from sea, rivers, surface water and small water courses as being "High", "Medium" or "Low" and also considers flood defence schemes. This data intersects with the historic environment data and requires a dedicated study to identify the risk and implications at a site level using this baseline data.
- Finally, the results from this methodology are a product of the way in which the data has been handled and modelled. Different classification process will result in slightly different models. Regardless, the application of spatial modelling provides an opportunity to create consistent and repeatable processes for rapid assessment of a large amount of multifaceted data.
- This methodology has enabled the rapid assessment and production of a coherent baseline from which to evaluate the risk and impacts of climate change at a national, regional and site level analysis:

Data requirements

- LANDMAP LMP14 polygons
- WAT boundary polygon
- WAT HER Core points
- NRW Flood Risk Assessment polygons: http://lle.gov.wales/catalogue/item/FloodRiskAssessmentWales/?lang=en
- "WATs_Climate_Change_Adaptation_MapInfo_function_syntax" text file
- "DAT_162_Climate_Change_Impacts_Rescore" and "DAT_162_Climate_Change_LMP14_Impact_Scores" Excel spreadsheets

STEP 1

Open a new workspace in MapInfo. All the images in this methodology show DAT data, but in reality, it will be your WAT data.

Load the LANDMAP "LANDMAP_VS_Climate" shape file, MapInfo will convert this to a MapInfo table and will prompt you to save it. I suggest that you create a dedicated directory for this project and prefix everything with the WAT project code. Save your workspace with the same prefix.

STEP 2

Open and overlay your WAT boundary polygon.

STEP 3
Using the "Boundary Select" tool, click on all polygons within the WAT boundary layer (this is selecting all the LANDMAP polygons which are located within the WAT Boundary layer).

STEP 4
Click on the LANDMAP layer in the layers explorer panel, right click and select "Browse table". If the selected rows don't show immediately, scroll through the table to see what has been selected and check the "Region" field to make sure they correspond to your area.

STEP 5
Go to "Save Copy As" and select "Selection" from the list of tables.

STEP 6
Save the table, prefixed with the WAT project code in your dedicated directory.

STEP 7
Open this new table into your workspace.
Save the workspace.

STEP 8
Now that the clipped LANDMAP table we must alter the table structure to accommodate the impact scoring.
Make sure that the table is *editable.* In the "Table" ribbon, click on "Table" in the Maintenance tab and click on "Modify Structure".

STEP 9
In the following popup select the LANDMAP table.

STEP 10
You will now see the table structure of the layer showing the attribute fields. Scroll to the end the list which should end in "lmp09_d_s". Click "Add Field" and in turn, add the following 5 fields making sure that their types are Integers:
Arch_Impact, Land_Impact, Var1_Class, Var2_Class, Bi_Class

STEP 11
Browse the table to check that the new fields have been added. Unlike the image below, all of the new cells will contain "0". If they don't at this stage make sure that the field type is an integer, not character.

STEP 12
You are now going to need to refer to the "DAT_162_Climate_Change_Impacts_Rescore" and "DAT_162_Climate_Change_LMP14_Impact_Score" spreadsheets. Open these on a 2nd screen if you have one, it'll be easier to refer back to.
In the first spreadsheet, the 14 LANDMAP land classes are broken down into individual tabs and the impacts from the LANDMAP report have been converted into a 0 to 6 score. A total impact score for the land class has been calculated and an Archaeology impact score per land class has also been calculated based on the evaluation in the report. Both of these totals need to be considered later on in this methodology. The second spread sheet is a summary for those total scores with the LMP14 land code for easier reference.
The remaining processes of this methodology are based on these scores and it is the same for each WAT. These scores can be changed but it must be applied to all the WAT data for a coherent analysis. If these scores are changed then, the condition processing expression syntax in the following steps will also have to be changed accordingly.

STEP 13
It is possible to populate the new fields in the LANDMAP layer with the Archaeology and Land class impact scores using the global column updates tool found in the "Edit" tab of the "Table" ribbon.
Make sure that the LANDMAP layer is editable.
When the "Update Column" popup opens select the LANDMAP table as the table to update and scroll down the list to select the "Arch_Impact" field as the column to update. Select the LANDMAP table as the "Get Value" variable.
In the "Value" box click on "Assist".

STEP 14
Open the "WATs_Climate_Change_Adaptation_Mapinto_function_syntax_ text file (it should open in Notepad).
We are going to use the MapInfo Con() function to populate the cells. Copy and paste the syntax text for "Arch_Impact" column into the Expression box. Click on "Verify" to make sure that the syntax is correct. Any missing characters will stop it from working. If it's all ok, click "ok" in both popups. Repeat this process with the "Land_Impact" column using the syntax provided in the text file. Be careful when copying and pasting, make you are using the correct syntax for each column.
Once completed you can check by browsing the LANDMAP table to see if the columns have been updated.

STEP 15

Now that these fields have been populated it is possible to classify this data to create the thematic mapping show the risk impacts in a traffic light colour scheme.
In the "Map" ribbon, click on the "Add Theme" icon in the "Content" tab.

STEP 16
Select "Ranges" in the popup and the highlighted template.

STEP 17
Select the LANDMAP table and the "Arch_Impact" field

STEP 18
The default setting for this tool is to classify values into 5 ranges, we want 6 ranges. Click on the "Ranges". In the following popup change the number of ranges to 6 and the classifying method to "Natural Break". Click on "Recalc" to reclassify the values. Click ok

STEP 19
You may want to change the colours of the ranges; especially the pink one to orange. To do this click on "Styles" and click on the pink polygon. Change the fill colour to orange and click ok.

STEP 20
Clicking "ok" a final time so bring you back to the Map window showing your classified thematic map.

STEP 21
In this version of MapInfo you can click on the "Ranges by Arch_Impact" in the layer explorer panel and it will change the ribbon to the "Theme" ribbon. You can change the field it's classifying and indeed the method of classification, the number of ranges and symbology from this ribbon. To see the map using the "Land_Impact" values simply select that as the Field value.

STEP 22
In this methodology, the aim is to map a bivariate map which is showing the results of both the Archaeology and Land class impact scores. We could of course assess them individually, or ignore one for the other. But as you can see from the mapping so far, the resultant maps look quite different and that will impact our assessment. However, it is possible to make use of both these scores and see how they correlate. Put simply, where are the land classes with the highest archaeology impact score and land class score? The schematic demonstrates this principle:

STEP 23
Before we can begin this process, we must normalise our data. This is what "Var1_Class" and "Var2_Class" fields are for. We need to reclassify the values in the "Arch_Impact" and "Land_Impact" columns in to 6 classes. I have chosen to use 1 to 6 as the ranges where in both variables 6 is equivalent to the highest scores and 1 is lowest. In other examples of bivariate maps that I have seen, it often that the two variables are of different types i.e. integer and string (text) but because of the way MapInfo generates thematic maps based on ranges I've had to do it using integers for both variables. So in reference of the schematic in the previous steps, where "C3" would be highest scores from both variables, our result is going to be a number (the multiplication of the two values).

The scoring and ranges should be:

Arch_Impact score Ranges	**Var1_Class**	**Land_Impact score Ranges**	**Var2_Class**
20 to 20	6	72 to 73	6
10 to 20	5	68 to 72	5
9 to 10	4	52 to 68	4
8 to 9	3	44 to 52	3
4 to 8	2	42 to 44	2
0 to 4	1	24 to 42	1

Refer to the "DAT_162_Climate_Change_LMP14_Impact_Scores" to see how this tallies with the land classes and the two variable total scores.
The reclassifying process is based on the ranges produced in steps 20 and 21 (and shown in the above table). Populating the "Var1_Class" and "Var2_Class" columns used the same condition processing as before (make sure that the table is editable!):

STEP 24
Copy and paste the syntax text in the text file for each field into the expression box in turn:

STEP 25
You can browse the table to check the values in these fields.

STEP 26

We now need to calculate the bivariate values. It's only possible to map one field at a time so we need to create a 3rd field to do this. This is what the "Bi_class" field is for. This is simply multiplying one variable by the other.
Copy the following text into the "Value" box in the "Update Column" box:

STEP 27
Check the table in the browser to see the values. Sort columns as you wish and refer back to the spreadsheets and range tables to make sense of it.
SAVE THE LANDMAP TABLE.

STEP 28
You are now able to produce a thematic map using the "Bi_Class" field, 6 ranges and "Natural Break" method as before. You may have to alter the style as before too. Click on the "Save theme" icon to save your final map.

STEP 29
You then should have something that looks like this. As you have saved the theme it would be easy to create print layouts from this.
SAVE YOUR WORKSPACE
It is possible to change this to 3 ranges to create a broad "High", "Medium" and "Low" risk map such as this:

STEP 30
Now that we have our classified base map it is possible to overlay our historic environment data, beginning with the HER Core point data.
This will need to be clipped and saved as a local table as in the previous steps (3 to 6).

STEP 31
This clipped data ought to fall within the WAT boundary removing outliers.

STEP 32
Working on the principle that risk in the first instance should be attributed to the historic environment assets based on *where* they are not *what* they are then we must filter using the Land class Bi_Class scores which are unique. The results of the Bi_Class scoring are:

Bi_Class Score	Risk level
30	Highest
20	
18	
16	
10	
8	
6	
2	
1	Level

In effect, we have now created 9 point risk score which we could utilise and present in different ways. Certainly, 9 classes are easy to reduce to 3 where by values from 1 to 6 would be "Low", 8 to 16 would be "Moderate" and 18 to 30 would be "High" for example. Doing that would reduce the resolution of our assessment however.
For the purpose of this methodology, we will be sticking to 9 and using these to capture the HER points. Each HER point is going to fall into one of these 9 classes, which as we have seen, can include a number of land class types. But to do that we need to disaggregate the LANDMAP table into these 9 risk scores and therefore individual tables to allow us to capture the point data.

STEP 33
The easiest way to filter the LANDMAP table into the 9 Bi_Class values is to use SQL querying. Click on the "SQL" icon in the Map ribbon and open the SQL tool.

STEP 34
The SQL tool dialogue box will open on the right hand side of the map. Add an * next to "Select" if there isn't one. Choose the LANDMAP table you've been using for the "From" option. For the "WHERE" operator type in Bi_Class=30
Turn off the visibility of the LANDMAP table in the layers panel.
At the bottom of that dialogue is a tiny map icon. Make sure to click on this and then click on the "Run" icon. This should then return the result as a named "Query" (in your case, it should be "Query 1") both as a browser table and as a polygonal layer in your layers panel.

STEP 35
What should now appear as those polygons which satisfy this SQL query.

STEP 36

You can browse this new layer to check that the Bi_class values are correct.

STEP 37
You must now save this query. I suggest that at this point you create a new folder in your directory into which to save this table. There will be 8 other tables that join it.

STEP 38
Save the new table with the WAT project code prefix and include the Bi_Class value.

STEP 39
You must now repeat this process for the remaining 8 classes, simply by changing the Bi_Class value in the SQL query:

STEP 40
At the end of this process you should now have 9 separate polygonal tables which you can turn off and on freely and alter the style to correspond to the traffic light colouring used in previous sections.
SAVE YOUR WORKSPACE

STEP 41
Now we have 9 individual polygonal layers to clip the HER point data. Start with the highest Bi_Class layer and turn off all other layers.

STEP 42
Load the HER Core point data from the table we created in step 30.

STEP 43
We need to create a layer which contains *both* the HER Core point table attributes and the LMP14_Bi_Class table attributes. The benefit of this being that we can click on a HER point and see all the LANDMAP attribute data too. We have also merged the natural and historic environment data.
This is done by using an SQL spatial query and join, which is handily all rolled into one tool in MapInfo called “Select By Location” in the Map ribbon.

STEP 44
In the popup box that follows select objects from the HER Core points layer and compare them with objects in your LMP14 Bi_Class 30 layer. The relationship is “within”.

STEP 45
The selected HER points will now become highlighted in the map window but these aren’t the final results.

STEP 46
You must go to the “Save Copy As” icon and save the “Selection” from the list of tables. I suggest that you make a new folder in the directory to accommodate these new tables. 8 more will follow.

STEP 47
Open this new table in your workspace.
SAVE THE WORKSPACE

STEP 48
Browse the table to see that data. Hopefully, you will see that the attributes from the LMP14 table has been joined to the end of the HER Core points table.

STEP 49
Alter the symbology to your preference. I went for points and coloured them to match the Bi_class colour.

STEP 50
Repeat this process for the remaining 8 LMP14 Bi_class tables, building up your layers as you go.

STEP 51
The resultant classified HER point data should then look something like this (you may have to invert the order of the layers in the layers panel to improve the visibility of the points; highest to lowest Bi_classes).

STEP 52
This classified data provides us with a baseline from which to apply further study. We can now assess risk of the historic environment at a site level.

FIGURES

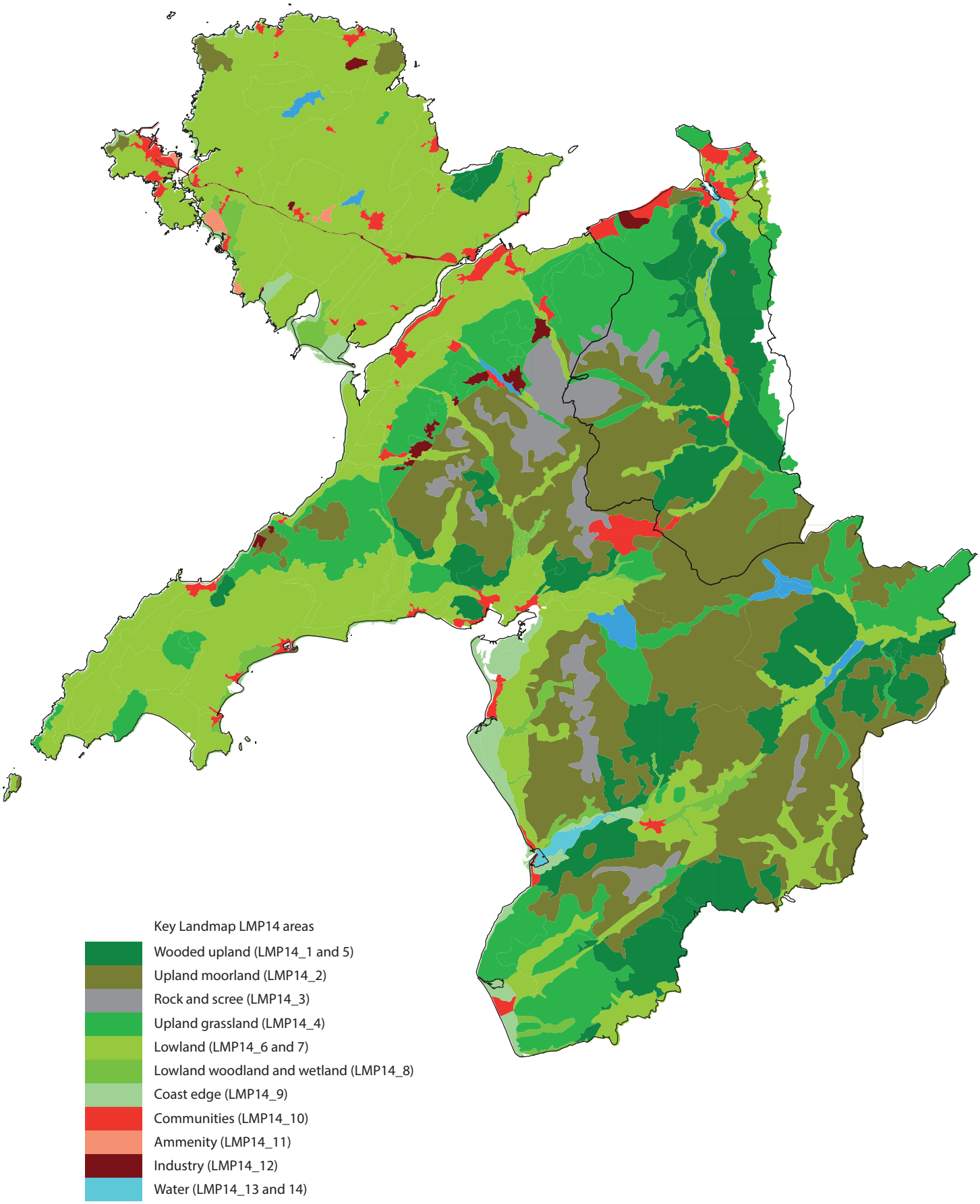

Figure 1. LANDMAP LMP_14 landscape types in north-west Wales

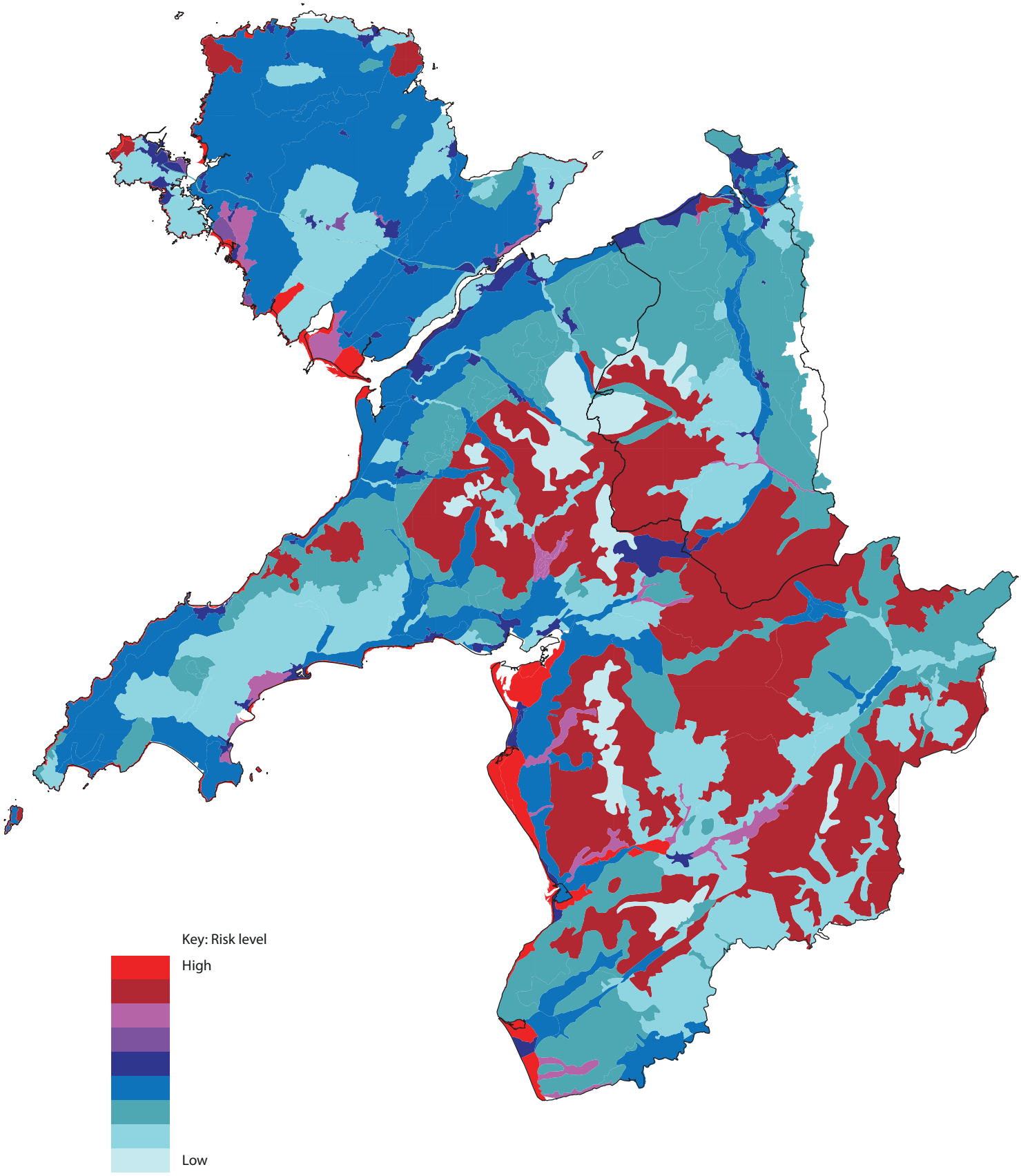

Figure 2. Land areas categorised by risk from climate change impacts calculated from archaeological impact and landscape impact scores

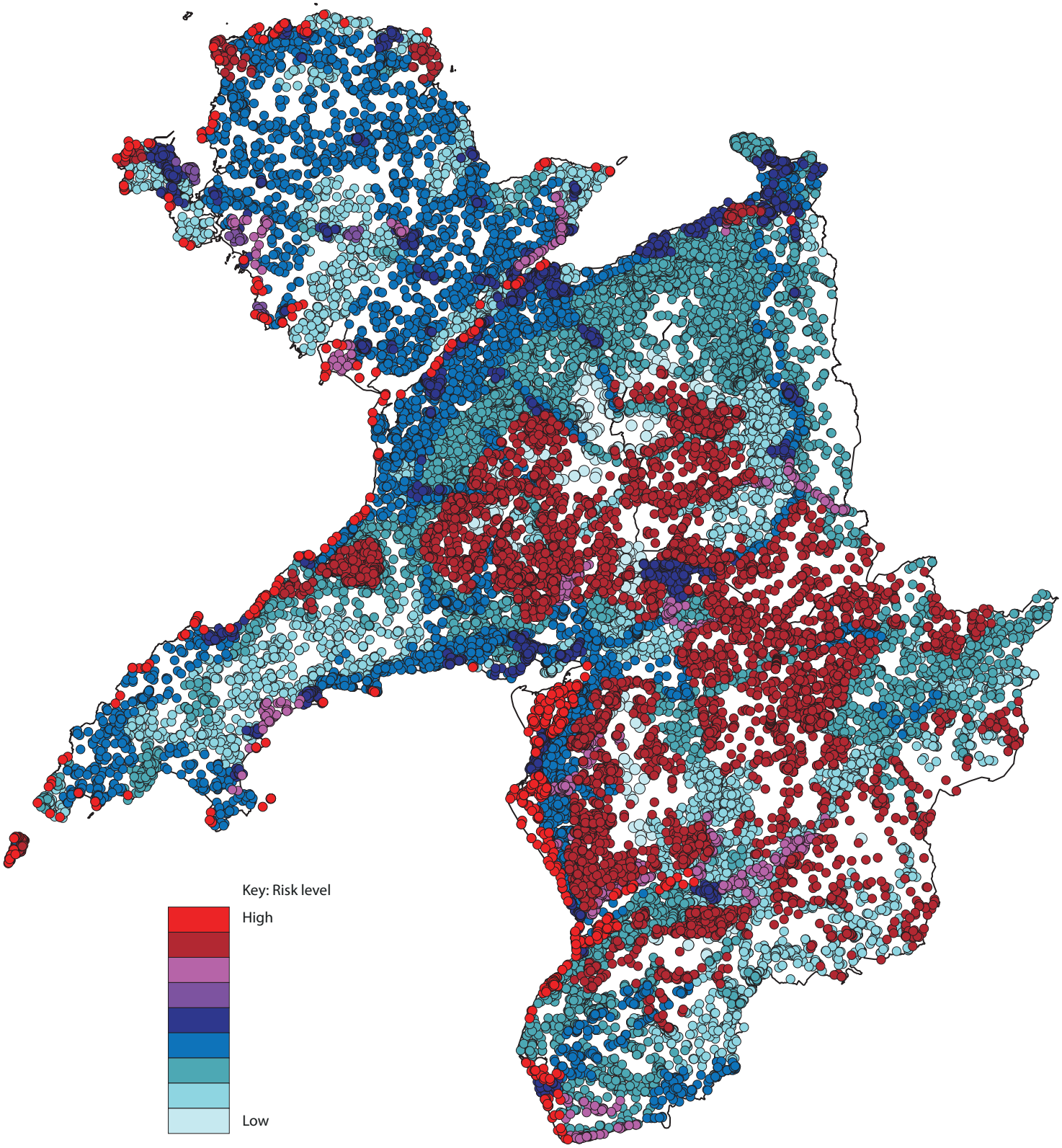

Figure 3. HER core sites categorised by risk from climate change impacts

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