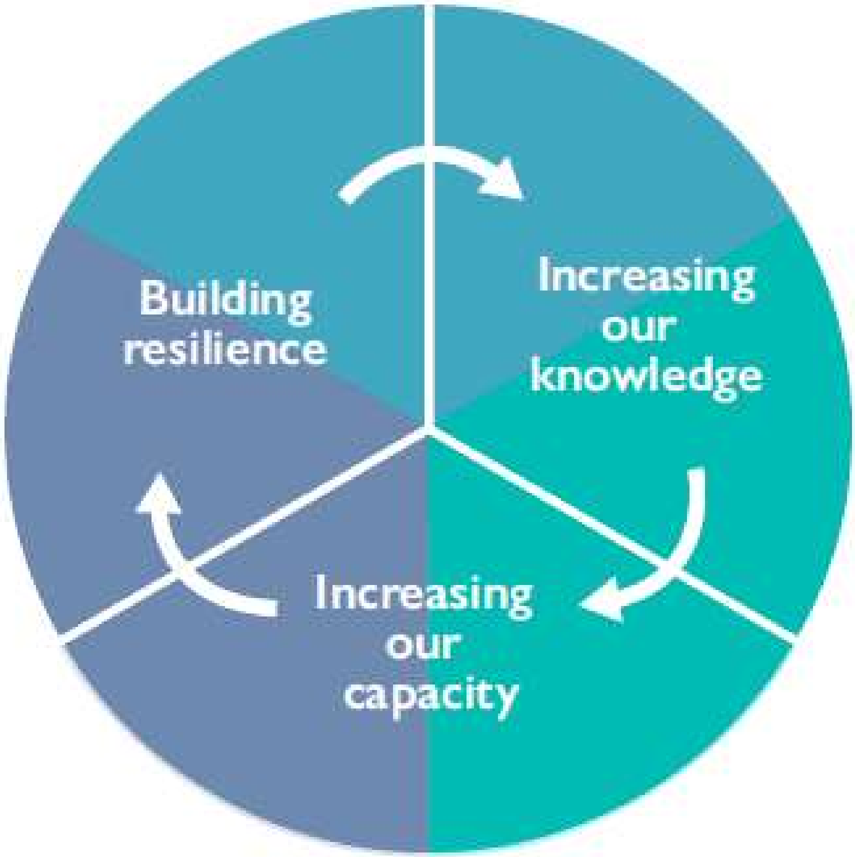
CLIMATE CHANGE ADAPTATION PILOT PROJECT 2020- 21



Produced by

Dyfed Archaeological Trust
For: Cadw

DYFED ARCHAEOLOGICAL TRUST

REPORT NO. 2021-04

EVENT RECORD NO. 125653

CADW PROJECT NO. DAT 162

March 2021

CLIMATE CHANGE ADAPTATION PILOT PROJECT

By

Menna Bell

Ymddiriedolaeth Archaeolegol Dyfed Cyf
Corner House, 6 Stryd Caerfyrddin, Llandeilo,
Sir Gaerfyrddin SA19 6AE
Ffon: Ymholiadau Cyffredinol 01558 823121
Adran Rheoli Treftadaeth 01558 823131
Ebost: info@dyfedarchaeology.org.uk
Gwefan: www.archaeolegdyfed.org.uk

Dyfed Archaeological Trust Limited
Corner House, 6 Carmarthen Street, Llandeilo,
Carmarthenshire SA19 6AE
Tel: General Enquiries 01558 823121
Heritage Management Section 01558 823131
Email: info@dyfedarchaeology.org.uk
*Website: www.*dyfedarchaeology*.org.uk*

Cwmni cyfyngedig (1198990) ynghyd ag elusen gofrestredig (504616) yw'r Ymddiriedolaeth.
The Trust is both a Limited Company (No. 1198990) and a Registered Charity (No. 504616)
CYFARWYDDWR *DIRECTOR: K Murphy BA MIFA*

CLIMATE CHANGE ADAPTATION PILOT PROJECT 2020/21

Client	Cadw
Event Record No	125653
Report No	2021-04
Project Code	DAT 162
Report Prepared By	Menna Bell
Illustrated By	Menna Bell
Report Approved By	K Murphy 25.03.2021

CRYNODEB GWEITHREDOL

Yn 2020-21 ymgymerodd Ymddiriedolaeth Archeolegol Dyfed â phrosiect a fabwysiadodd ddull seiliedig ar GIS i ddarparu adnabyddiaeth a dealltwriaeth glir o fygythiadau ac effeithiau newid hinsawdd ar amgylchedd hanesyddol Cymru fel y nodwyd yn Yr Amgylchedd Hanesyddol a Newid Hinsawdd yng Nghymru: Cynllun Addasu'r Sector *2020. Yr egwyddor lywodraethol oedd y dylai'r asesiad o effeithiau newid hinsoddol ar yr asedau hanesyddol gael ei werthuso yn y lle cyntaf gan ble nad ydyn nhw nid beth ydyn nhw.*

EXECUTUVE SYMMARY

In 2020-21 Dyfed Archaeological Trust undertook at project that adopted a GIS based approach to provide clear identification and understanding of the threats and impacts of climate change on the Welsh historic environment as identified by the Historic Environment and Climate Change in Wales Sector Adaptation Plan *2020. The governing principle was that the assessment of the impacts of climatic change on the historic assets should be evaluated in first instance by where they are not by what they are.*

Climate Change Adaptation Pilot Project 2020/21

TABLE OF CONTENTS

FIGURES

TABLES

1 INTRODUCTION

1.1 Scope of the Project

1.1.1 This report outlines the aims, objectives, methodology and results of the Climate Change Adaptation pilot project. This project was intended to draw upon and take forward, the recommendations outlined in the Historic Environment and Climate Change in Wales Sector Adaptation Plan produced by the Historic Environment Group in February 2020 (HEG, 2020). The plan outlines the issues and impacts of climatic change on the historic environment, emphasises the necessity for adaptation and encourages collaboration and action across all sectors.

1.1.2 It was intended that the four Welsh Archaeological Trusts undertake a pilot project to identify the major threats to the historic environment and the appropriate responses. The project was designed to take a collaborative approach, identifying potential partnerships and information sources, along with a mapping exercise to identify areas of potential impact. DAT's approach to this project leads on from the results of a scoping exercise undertaken by colleagues at the Glamorgan-Gwent Archaeological Trust whose recommendations ranged from a need for further detailed study using spatial mapping to continuing monitoring of the historic environment (Roberts, 2020).

1.1.3 This project attempts to provide a spatial methodology and analysis solution to addressing and implementing the results and headline actions needed to adapt to the impacts of climate change of the historic environment of Wales as identified in the HEG Sector Adaptation Plan and a (HEG, 2020).

1.2 Project aims and objectives

1.2.1 The overall **aims** of this project are:

- To assess the types of risks and impacts of climatic change to the historic environment.
- To identify where these impacts and risk will be active.
- To identify appropriate adaptive techniques and sources of data.

1.2.2 The **objectives** of this project are:

- To identify and consult with relevant organisations to encourage improved data exchange and to examine the potential for partnership working. It will build on established relations with organisations such as local authorities, National Trust and Natural Resources Wales and other organisations involved with management of agriculture, freshwater sources and the coastal zone.
- To identify the major threats and areas of potential impact within south-west Wales.
- To list a number of case studies illustrating adaptation.
- To make recommendations for future work.

1.3 Research Objectives

1.3.1 The project will contribute to many of the research objectives identified within the Research Framework for Wales for all periods. It will contribute to our understanding of climate change and its impacts on the historic environment, and also our understanding of past climatic change and the ways in which humans have adapted to former change (Research Framework for the Archaeology of Wales, 2016).

1.4 Abbreviations

1.4.1 All sites recorded on the regional Historic Environment Record (HER) are identified by their Primary Record Number (PRN) and located by their National Grid Reference (NGR). Sites recorded on the National Monument Record (NMR) held by the Royal Commission on the Ancient and Historical Monuments of Wales (RCAHMW) are identified by their National Primary Record Number (NPRN). Scheduled Monuments (SM) are recorded by a SM number. Altitude is expressed to Ordnance Datum (OD). References to cartographic and documentary evidence and published sources will be given in brackets throughout the text, with full details listed in the sources section at the rear of the report.

1.5 Illustrations

1.5.1 Printed map extracts are not necessarily reproduced to their original scale.

1.6 Timeline

1.6.1 The following timeline (Table 1) is used within this report to give date ranges for the various archaeological periods that may be mentioned within the text.

Period	Approximate date	
Palaeolithic –	*c.*450,000 – 10,000 BC	**Prehistoric**
Mesolithic –	*c.* 10,000 – 4400 BC	
Neolithic –	*c.*4400 – 2300 BC	
Bronze Age –	*c.*2300 – 700 BC	
Iron Age –	*c.*700 BC – AD 43	
Roman (Romano-British) Period –	AD 43 – *c.* AD 410	**Historic**
Post-Roman / Early Medieval Period –	*c.* AD 410 – AD 1086	
Medieval Period –	1086 – 1536	
Post-Medieval Period[1] –	1536 – 1750	
Industrial Period –	1750 – 1899	
Modern –	20th century onwards	

Table 1: Archaeological and Historical Timeline for Wales

[1] *The post-medieval and Industrial periods are combined as the post-medieval period on the Regional Historic Environment Record as held by* Dyfed *Archaeological Trust*

2. CLIMATE CHANGE AND THE WELSH HISTORIC ENVIRONMENT

2.1 Climate Change in Context

2.1.1 The combined effects of climate change are being felt across Wales. Warmer temperatures, rising sea levels, changing rainfall patterns (which can cause either drought or increased risk of flooding events) and more frequent extreme weather events are all examples of the changes taking place. These can result in major impacts upon the historic environment; itself a vulnerable and finite resource. Whilst the short term and more direct impacts are self-evident, the longer term and indirect impacts are more difficult to predict and are less understood.

2.1.2 Projections from the UK Climate Change Risk Assessment 2017 Evidence Report: Summary for Wales predicts the most notable agents of change to be a rise in mean summer temperatures, increasing winter rainfall and rising sea levels (ASC, 2016). The UK Climate Change Projections (UKCP18) climate analysis tool forms part of the Met Office Hadley Centre Climate Change Programme and places these predictions within a 2050 and 2080 range as shown in Figure 1 (Met Office, 2018). The Historic Environments Group's Sector Adaptation Plan (HEG, 2020) used these climate projections as a starting point for assessing future climate change and identifying potential adaptation measures. The plan is designed to be used as a framework for action and to encourage collaboration between key stakeholders, Welsh Ministers, senior decision makers, asset managers and policy makers to:

- ***Increase our knowledge*** *and understanding of the threats and opportunities for the historic environment from change weather and climate in the short, medium and long term.*
- ***Increase our capacity*** *by developing the awareness, skills and tools to manage the impacts of climate change on the historic environment.*
- ***Build the resilience*** *of the historic environment by taking action to adapt and respond to the risks, reduce vulnerability and maximise the benefits.*

2.1.3 The adaptation plan describes the challenges posed by a changing climate on the historic environment. It identifies how we can improve our understanding of the processes involved and how they impact on the physical and cultural aspects of Wales's historic environment. It also discusses ways to build adaptive capacity and increase resilience by delivering adaption actions (HEG, 2020).

2.1.4 Understanding and assessing the risk and impacts of climate change on our historic environment is no easy task. The impacts of climate change on this resource are not only physical but also have economic, social and cultural ramifications, which can be determinative factors of heritage management. The agents and drivers of climatic change are complex and operate within a system of positive and negative feedbacks which incur varied responses from what is a dynamic and multifaceted historic environment. The risks and impacts of climate change can only be measured by a divergent scale; from no change to negative or positive impacts.

2.1.5 The HEG Plan uses the predicted climate change projections and predicted outcomes outlined by the UK Climate Change Risk Assessment 2017 Evidence Report: Summary for Wales to assess the significance of these impacts based on extent, severity and sensitivity on nine broad classes of historic assets. This risk assessment is presented in Table 2 and an explanation of the likely impact summary codes is presented in Table 3.

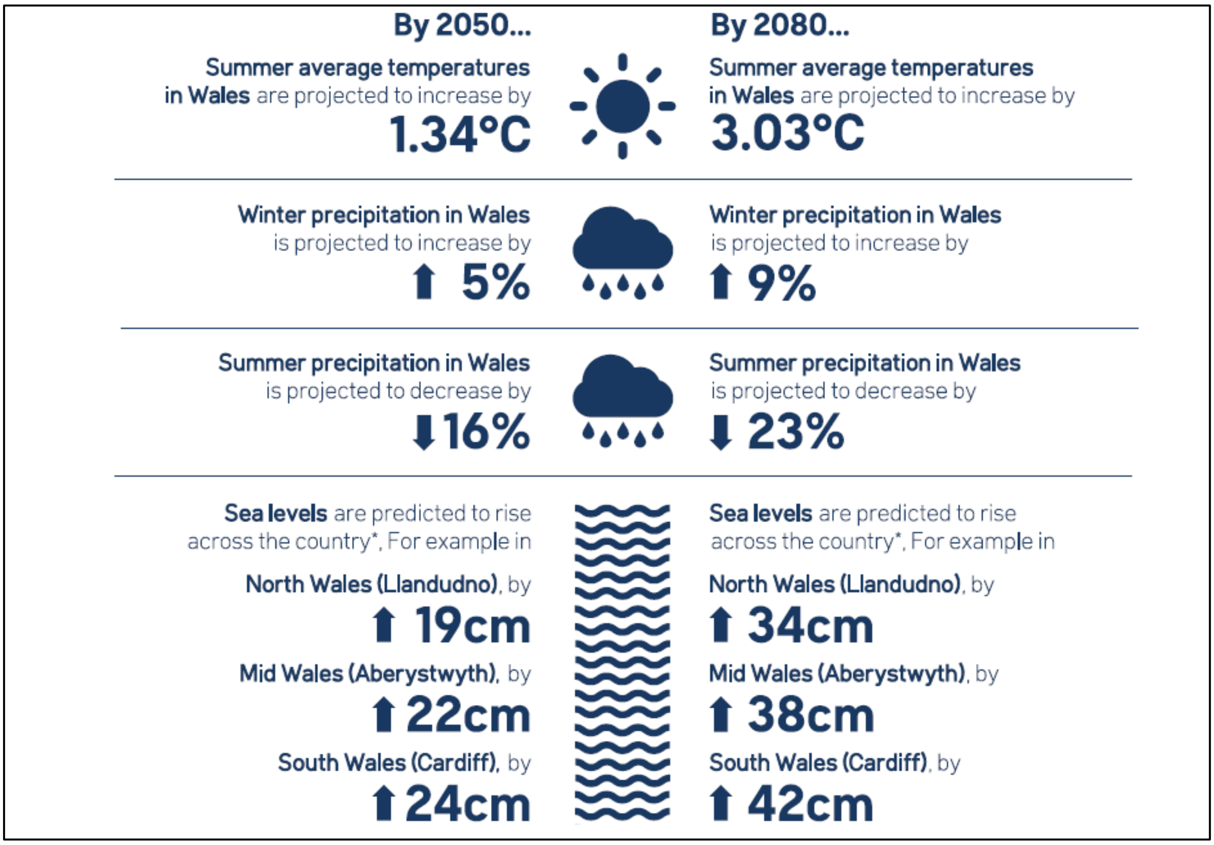


Figure 1: *Climate change predictions by 2050 and 2080.*

2.1.6 The risk assessment summarised the main challenges for Wales' historic environment from climate change as:

- *Historic assets associated with coastal, freshwater, woodland and built environments are at high risk, mostly from more frequent extreme weather, increased flood events, rising sea levels, changes to peaty soils, pests and diseases.*
- *A large number of assets are potentially at moderate risk from a wide range of climate change events. Cumulatively, we should consider these risks to be of high significance. Historic landscapes associated with the nine categories considered in the table are particularly vulnerable as the cumulative loss of historic assets may affect the integrity and survival of the historic landscape as a whole. For example, the loss of hedgerows and boundaries leads to loss of fieldscape which may alter the spatial arrangement, pattern and understanding of vernacular buildings.*
- *If managed well, there may be small positive outcomes arising from a longer growing season, drying out of buildings and the associated reduced humidity, and changing leisure patterns. The discovery of new historic assets in desiccated grassland and crops visible, as parch and cropmarks, may also be a beneficial outcome from drying out. Coastal erosion and the movement of marine sediments may reveal previously unknown sites. The conversion of formal lawns to meadow in response to the longer growing season in designed landscapes may increase species count in the natural environment and have the benefit of reducing mowing and maintenance costs but may have a significant impact on the character of historic parks and gardens.*

Description of climate change	Warmer mean temperatures				Hotter, drier summers		Warmer, wetter winters	More frequent extreme weather
Predicted outcome of climate change of environment	**Rise in sea levels (SL)**	**Migration and proliferation of pests, diseases and invasive species (PD)**	**Longer growing season (LGS)**	**Changes in lifestyle and leisure patterns (LEI)**	**Drying out, desiccation, shrinkage and erosion (DRY)**	**Wild Fires (WF)**	**More flooding events; increased ground moisture and 11recipitation (FL)**	**Frequent high winds, storms and heat/cold events (EX)**
Buildings and settlements	SL1 SL2	PD1	LGS1	LEI1 LEI2	DRY1 DRY4	WF1	FL1	EX1 EX2
Marginal and Upland		PD2	LGS1	LEI1 LEI2	DRY2 DRY3 DRY4	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 DRY4		FL2 FL3	EX1
Designated Parks and Gardens		PD2 PD3	LGS2	LEI1 LEI1	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 = No impact

Table 2: *An assessment of the likely impacts of climate change on historic assets in Wales and their significance (after HEG, 2020).*

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.

Table 3: *The impact summary codes (after HEG, 2020) continued next page.*

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	• 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.

Table 3: *The impact summary codes (after HEG, 2020) continued next page.*

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, 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.

Table 3: *The impact summary codes (after HEG, 2020).*

3. MAPPING CLIMATE CHANGE RISK

3.1. This project adopted a GIS based approach to provide clearer identification and understanding of the threats and impacts of climate change on the Welsh historic environment as identified by the HEG Plan. The governing principle was that the assessment of the impacts of climatic change on the historic assets should be evaluated in first instance by *where* they are not by *what* they are.

3.2 This was possible by using the landscape climate change impact metrics and landscape narratives provided by NRW's 2019 *Landscape and a Changing Climate*[2] report (Berry et al, 2019) of which the geospatial data is freely available to download from the online repository[3]. This report identified and communicated the impacts of the climate change projects of the UK Climate Change Risk Assessment 2017 Evidence Report: Summary for Wales on landscape character and qualities using the LANDMAP[4] Visual & Sensory landscape types. The report collated the 45 LANDMAP Visual & Sensory landscape types into two new classifications: one of 14 landscape classes (LMP14) which was again simplified into 9 classes (LMP09). The LMP14 landscape classes were used for reporting the potential impacts of climate change on landscape character and quality. These landscape types were also

[2] *https://cdn.naturalresources.wales/media/689497/eng-evidence-report-314-landscape-and-changing-climate.pdf*
[3] *https://github.com/robertberryuk/LANDMAP_ClimateChange*
[4] *Natural Resources Wales / LANDMAP - the Welsh landscape baseline*

assessed for risk for 1m+ sea level rise and flooding using NRW's Flood Zones 2 and 3 definitions.[5]

3.3 The summary of the work presented in the report (Berry et al, 2019) is reproduced here:

Summary

The landscape narratives involve description of the character of the LMP14 landscape types utilising relevant literatures, analysis of the LANDMAP areas themselves, and expert knowledge and judgement to describe the relevant characteristics and aspects of the landscape categories.

The climate change narrative involved development of a seven-point scale to assess the likely impact of climate change outcomes on specific elements in the landscape. Elements relate to landform, tree cover, vegetation, field boundaries, surface water, settlements & structures, and archaeological assets. The landscape narratives, relevant literature identifying effects of climate change, and expert judgement were utilised to identify which elements in the landscape would be affected by each particular climate change outcomes, and judgements made about the magnitude and significance of the effects. Results are presented in a set of matrices detailing impacts of each relevant climate change outcome on the landscape elements and summarised in a colour coded matrix to highlight where the largest impacts are expected.

Conclusions

Analysis for the drafting of the landscape narratives has highlighted the need for more detailed spatial analysis that is responsive to often profound historic differences that have shaped habitats and landscape character in upland and lowland areas of Wales. The time-depth of its distinctive farming landscapes, for example, often show marked contrasts from east to west in close association with species diversity and contrasts observed in traditional architecture. Spatial understanding of the development and significance of woodland and wetland areas, and rough pasture which has greatly diminished in extent, is also poorly understood. Whilst 19th century Ordnance Survey maps indicate many areas as parkland, their historic development and character as either species-rich parkland habitats or the degraded remnants of farming or sporting landscapes is also unclear.

Analysis of the climate change impacts identified where the most significant impacts are likely to occur in respect of the LMP14 landscape types. The analysis suggests there are some low-level benefits arising from warmer mean temperatures (e.g. in terms of changes in crops and vegetation growth) but overall impacts will have negative impacts on landscape. Most significant effects will be related to the potential spread of pests, pathogens and diseases, in particular for tree cover and vegetation. Hotter drier summers are also likely to have significant effects on tree cover and vegetation through increasing stress, and lead to reductions in visibility and availability of surface water, especially in upland areas. Wetter winters and more intense storms are likely to create a different set of

[5] *Natural Resources Wales / Flood zones*

problems including soil waterlogging, increased run-off and higher potential for flooding, affecting lowland and coastal edge areas in particular.

The analysis was based on judging the effects of climate change outcomes over the period from 2019 to 2050. The analysis highlights the uncertainties associated with undertaking future predictions, in particular in trying to understand the potential outcomes from synergistic effects of multiple changes on ecological and hydrological systems over large areas covered by the LMP14 landscape types. Predicted impacts are based on judgement and are broad brush in scope. Impacts in any one location will be affected by local conditions and underlying geological, soil and landform characteristics.

Informing Policy

The narratives developed for this project represent an initial attempt to demonstrate how Wales's landscape reflects the interaction of human and natural factors over millennia. This calls for integrated approaches to the development of an evidence base and informing policy responses. Climate change is a 'risk multiplier', the severity of which will be closely linked to long-term and more recent drivers for change. These need to be better understood to inform policy and adaptation strategies, which will extend beyond specific climate change scenarios to mitigation strategies and changing patterns of agriculture, woodland management, habitat conservation, infrastructure, energy generation and sustaining urban and rural communities as they adapt to a changing world.

The climate change narratives condense into a small number of matrices a large amount of information about the effects of climate change on landscape. As such they provide an overview of where impacts are most likely to be significant and the landscape types most likely to be affected. As such the matrix approach offers a means of prioritising response and suggests where support for adaptive change might be required, or most beneficial.

3.4 These LANDMAP narratives identified where the most significant impacts of climate change are likely to occur, relative to the LMP14 landscape types. It provided a spatial baseline from which the findings of the HEG Plan could be practically applied. First, the landscape impact matrices were converted into numerical scores and transcribed into spreadsheet (See Appendix 1). In all instances, any positive change impact scores were outweighed by the negative impacts and consequently the resultant scoring classification provides indicative landscape sensitivity to the projected impacts of climatic change by 2050.

3.5 Individual land class element scores were aggregated to create a total "Land class" impact/ sensitivity score. Archaeology was identified as an element within a land class. To amplify the impacts of climate to the historic environment, an individual archaeology impact score was assigned to each land class. This resulted into impact scores for two variables (See Appendix 1). These scores were then normalised by reclassifying the values into 6 classes where in both variables 6 was equivalent to the highest scores and 1 to the lowest. The reclassified scores were then multiplied to calculate an indicative risk for the historic environment. In this risk equation the land class score was considered the likelihood/susceptibility factor and archaeology score was used as a vulnerability factor. These two factors were multiplied to calculate an overall indicative historic landscape risk score. This classified data was then amended to the original LMP14 polygons. Those polygons with the highest scores indicate those most at risk.

3.6 These classified LANDMAP LMP14 polygons provided a base map onto which data relating to the historic environment data could be overlaid and provided the parameters to search the HER Core records using spatial queries. Spatial queries remove the limitations presented by typologies and syntax, and it is possible to answer questions beginning with "*where*" with or without, discrimination of the attributes of the data being questioned. This was key in overcoming the main challenge presented by the HEG Plan in that the nine broad classes of historic assets it utilised did not correspond with the broad classes or site typologies used in the Welsh Historic Environment Record (HER).

3.7 The classified, pan Wales data was then shared with the remaining Welsh Archaeological Trusts as a geospatial dataset for independent analysis using their own GIS platforms. The initial processing and classification of the data was undertaken by the author in the open-source GIS software QGIS. This was then recreated in MapInfo and accompanied by a step-by-step methodology for colleagues to use with their regional HER Core data. This methodology, written by the author is presented in Appendix 2. This data, namely the classified LMP14 polygons, was then subsequently integrated into the Core HER records of all the Welsh Archaeological Trusts to create an initial risk baseline for recorded archaeological assets in the historic environment. All of the Core records and their child tables (eg, site type, period, condition, status etc) are now linked to the classified LMP14 polygons and in addition to these parameters can be queried by land class type, by the land class sensitivity score or individual archaeology score and finally, by the overall historic environment risk score. The overall historic environment risk score is not a true assessment of vulnerability of the historic assets for it does not consider the form or condition of the monument, but it provides a hierarchical way of assessing the vast HER data. It is now possible to undertake a very rapid assessment both a regional and site level. The true vulnerability of an individual assets (and therefore risk) can be assessed individually as a secondary level of analysis using the criteria provided in the HEG 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.

3.8 The results of search queries in the HER can be exported in various formats from csv spreadsheets, pdfs and several GIS formats but most commonly as an ESRI shapefile. For the purpose of this pilot project, automated summary reports based on the overall historic environment risk scores have been scripted so that it is possible export all of the linked Core records either as individual records or as a pivot table.

3.8 An important caveat to state is that the classified data is a result of this modelling methodology. Different processing and classification will produce different results. Indeed, the calculation of the overall historic environment risk may be superfluous to requirements, with the total land class score being a sufficient baseline. As previously mentioned, the data has been integrated into the HER in such a way that users can choose which of the variables by which to evaluate the Core records. The results of both methods of modelling area presented in the following section.

3.9 Finally, it has been possible to roughly correlate the LMP14 and LMP09 landscape classes with the nine historic asset broad classes defined by the HEG Plan (See Table 4). Indeed, some of the associations are a better match than others but it provides another opportunity to directly apply the findings of the HEG Plan with the existing HER data.

3.10 The following figures demonstrate the application of the classified LMP14 polygons in the Core records of the HER.

Map Key:

LOW

MEDIUM

HIGH

HEG Broad class	LMP14 class	LMP09 class
Buildings and settlements	Developed (Communities) Developed (Amenity) Developed (Industry)	Built Land
Marginal and Upland	Upland (Grassland) Upland (Moorland) Upland (Rock and Scree) Upland (Wooded Hills) Upland (Wooded)	Upland (open) Upland (wooden) Upland (moorland)
Marine and Coastal	Coastal Edge Water (Sea)	Coast
Rivers, canals, fresh water	Water (Inland)	Water (inland)
Farmland	Lowland Valleys (Hedgerow) Lowland (Wooded & Wetland) Lowland Valleys (Open)	Lowland (wooded) Lowland (open)
Woodland	Upland (Wooded Hills) Upland (Wooded) Lowland (Wooded & Wetland)	Upland (wooden) Lowland (wooded)
Industrial Landscape	Developed (Industry)	Built Land
Designated Parks and Gardens		
Historic Landscapes		

Table 4: *Table showing the correspondence between the HEG Sector Plan broad classes, LMP14 and LMP09 landscape classes and existing HER broad classes.*

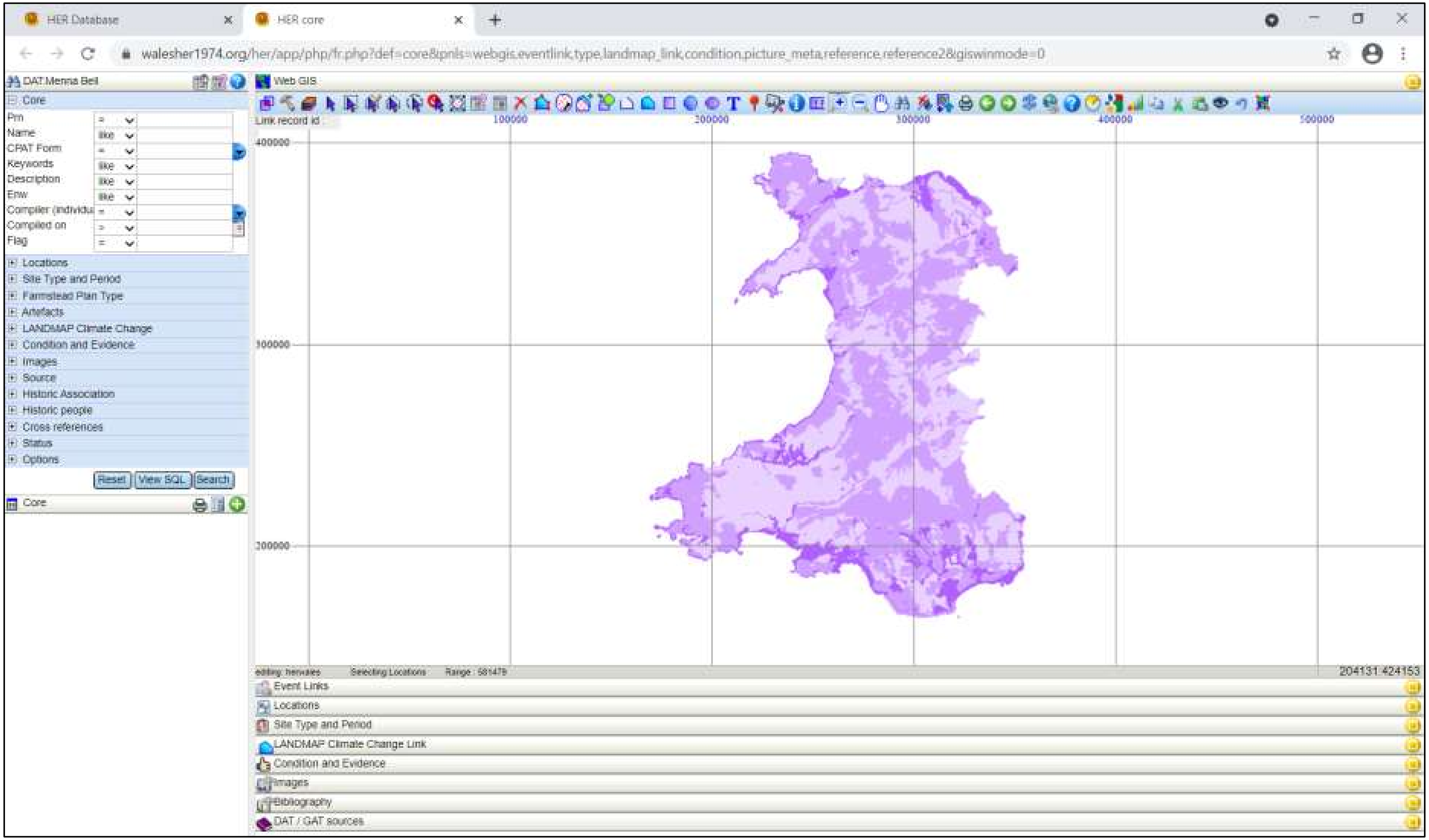


Figure 2: *Overview of the pan Wales classified LMP14 dataset in the GIS interface of the HER Core records*

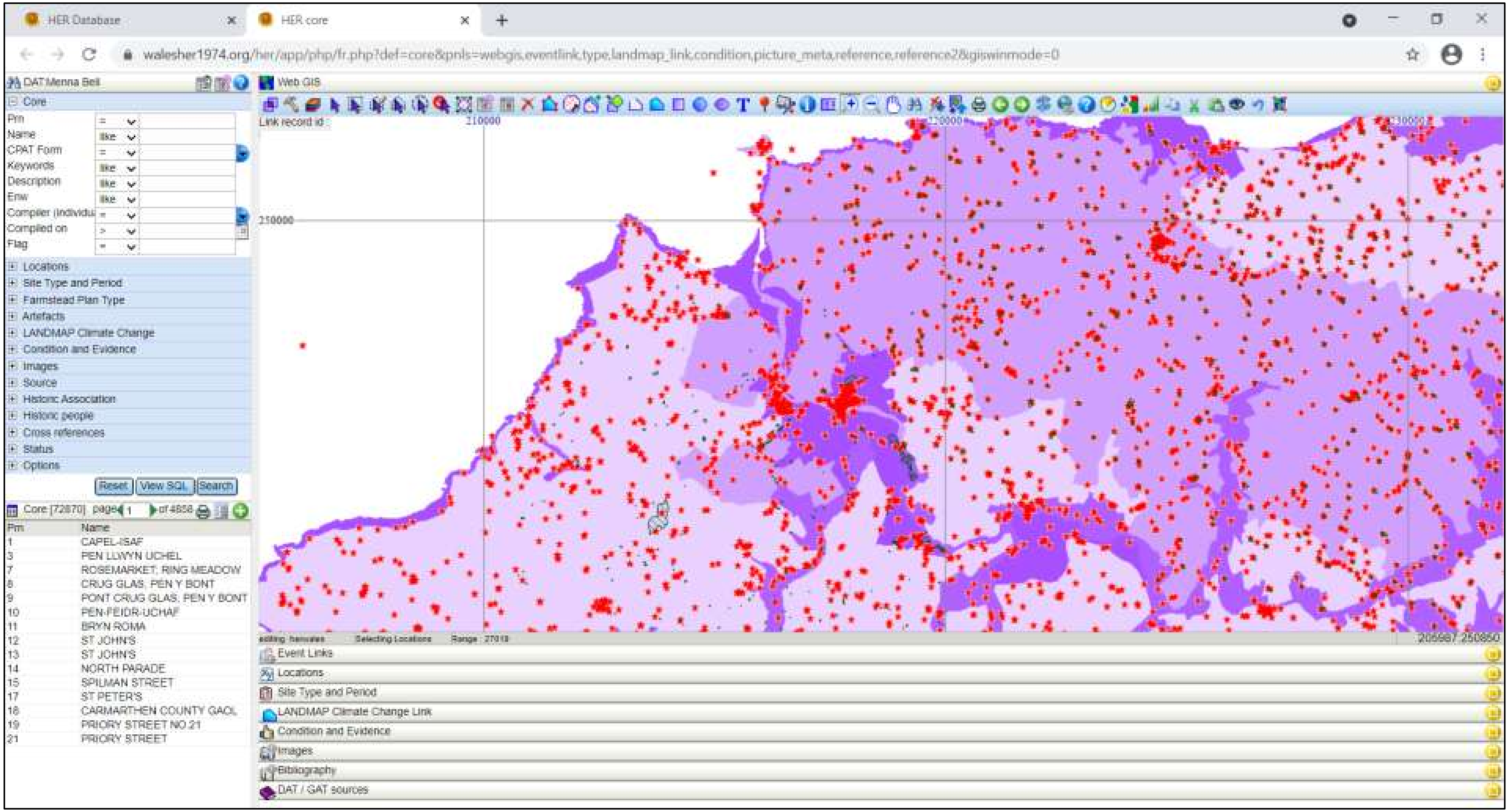


Figure 3: *The map window shows the distribution of Core HER records (red stars) overlaid the LMP14 classified polygons.*

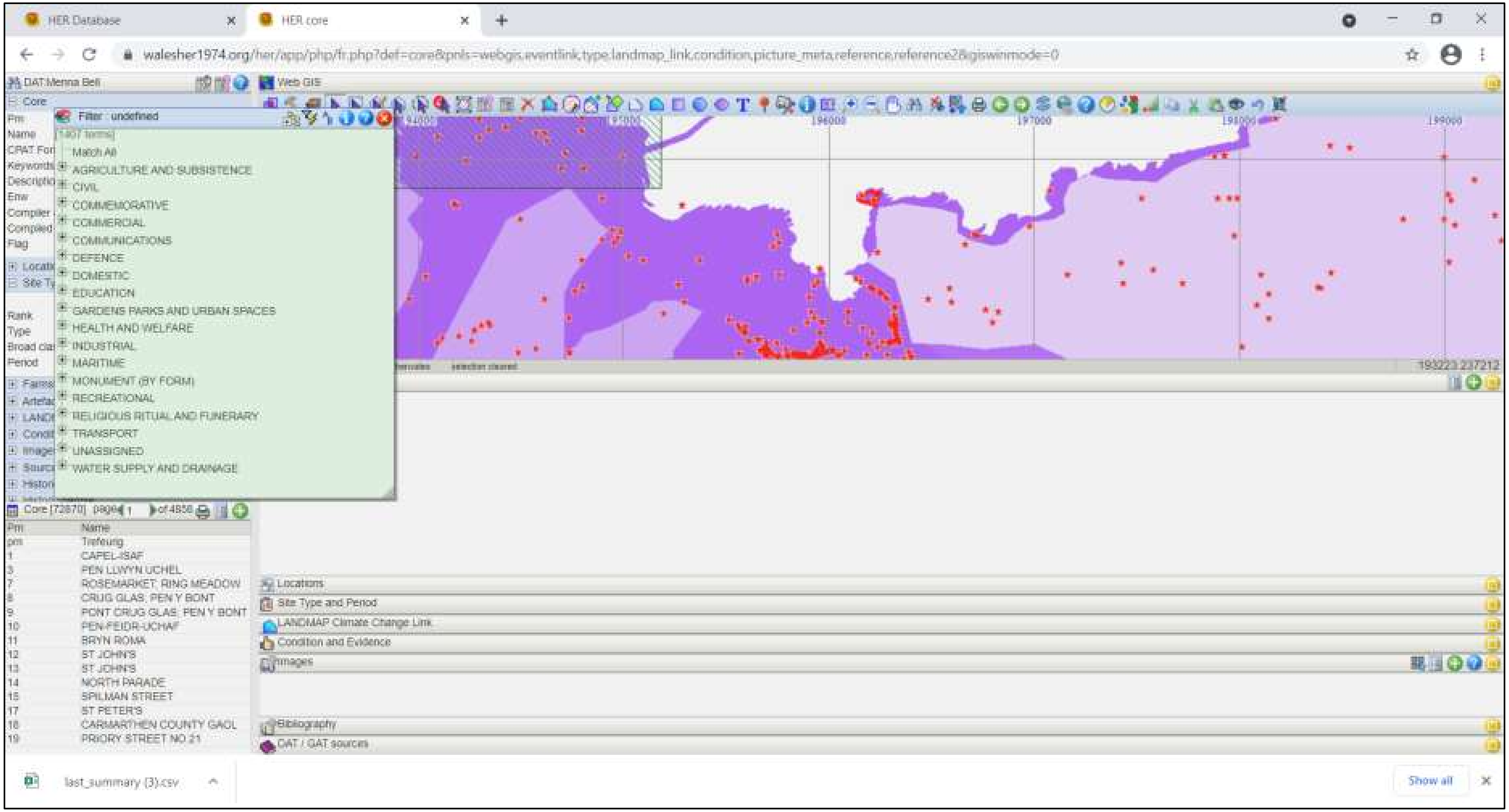


Figure 4: *The dropdown list shows an extract of the site type broad classes in used the HER.*

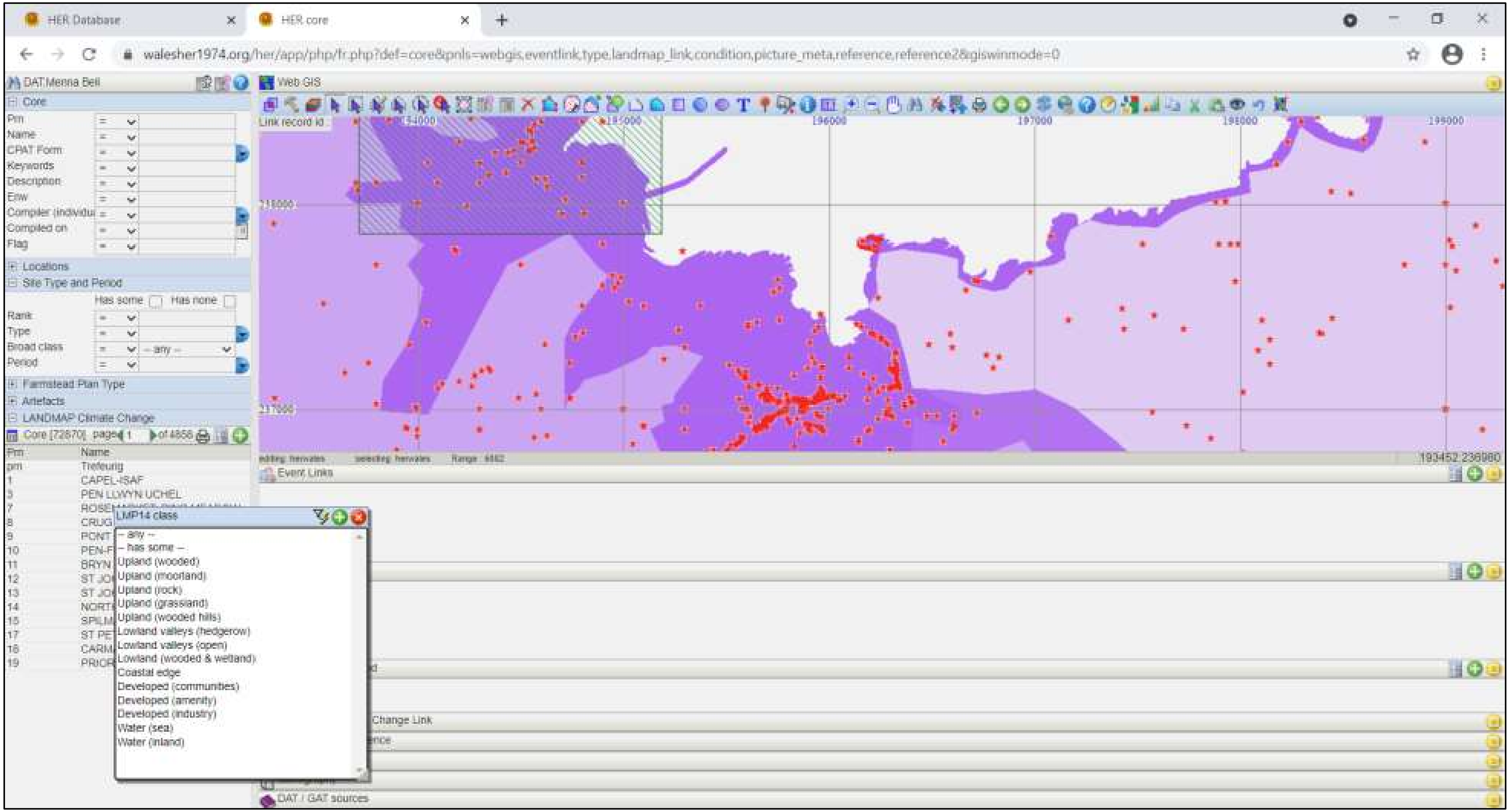


Figure 5: *The pop-up window shows the LMP14 landscape classes search options.*

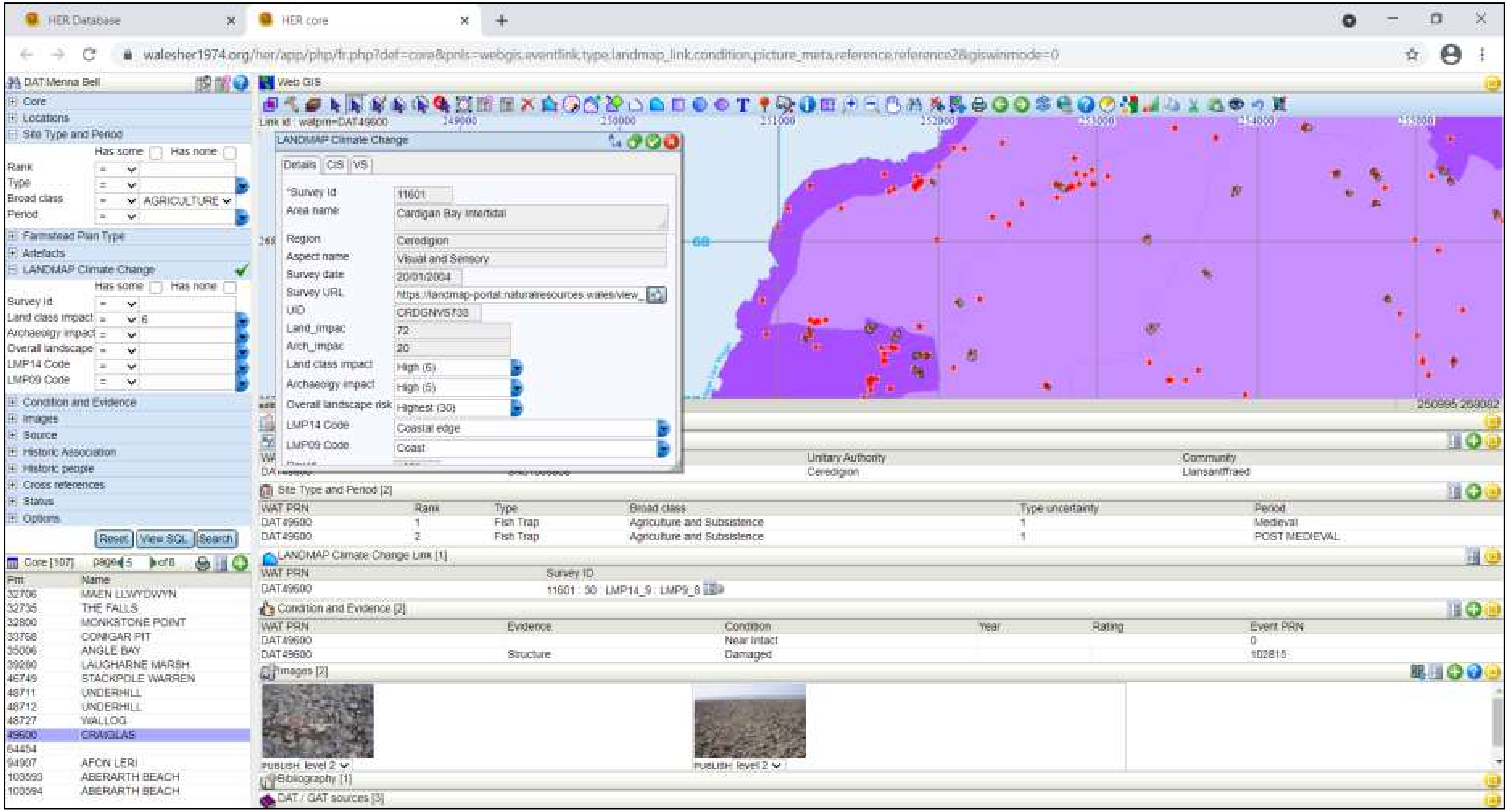


Figure 6: *This screenshot shows the result of a query for records with a Broad class of "Agriculture and Subsistence" which are located within a High Sensitivity ("6") land class. The highlighted example is for PRN46900 Fish Traps located within the Cardigan Bay Intertidal area; LMP14 Coastal edge.*

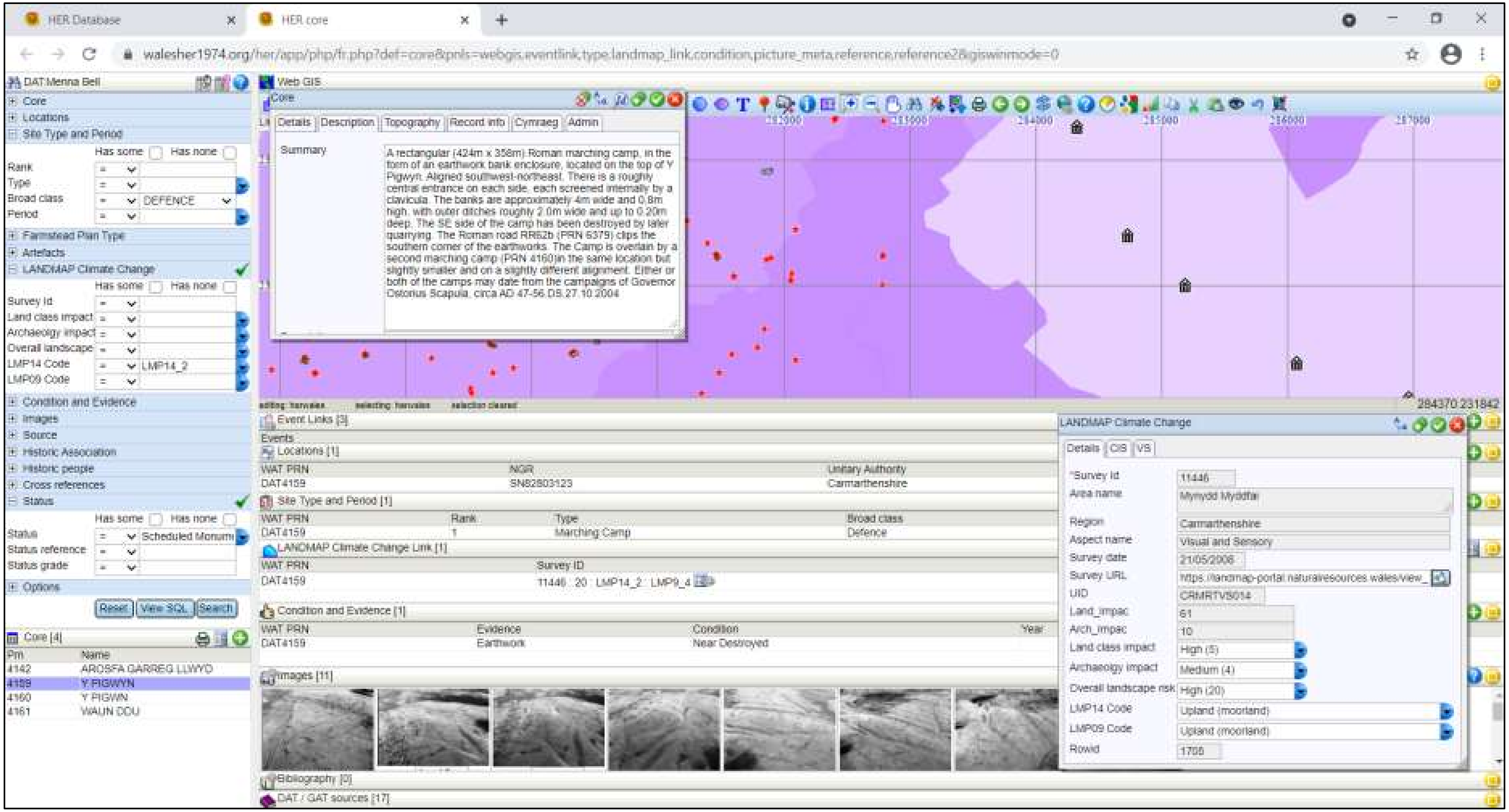


Figure 7: *This screenshot shows the result of a query for records of scheduled monuments, with a Defence Broad class located in Upland (moorland) LMP14 land class.*

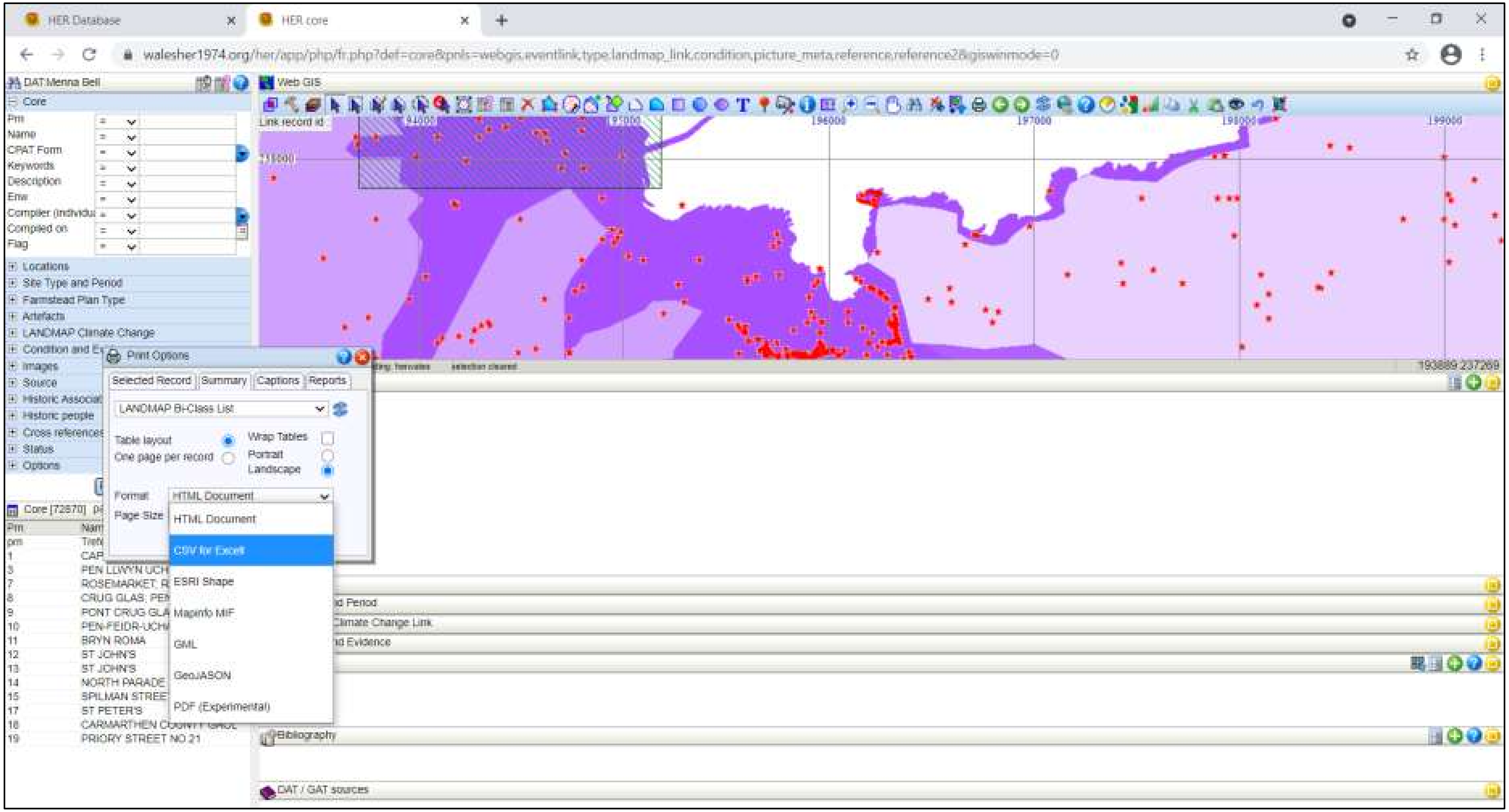


Figure 8: *A summary of the overall landscape risk for Core PRNs can be exported in various spatial and non-spatial formats.*

4. RESULTS

4.1 The key characteristics of the LMP14 land class narratives align with those attributes described in the National Landscape Character Areas of Wales[6] and the 48 individual landscape areas thereof. The spatial analysis undertaken during this project revealed that the most prevalent LMP14 land class in Dyfed is that of "Lowland valleys (hedgerow") which has a total area coverage of the 27.46%. This is followed by a close second and third of "Upland (grassland)" (21.70%) and "Lowland valleys (open)" (20.9%) respectively. These land classes comprise over 70% of the landscapes in Dyfed. Perhaps unsurprisingly, these land classes also contain the greatest number of Core HER records (See Figure 9).

4.2 The LMP14 landscape narratives for these land classes are reproduced here (after Berry et al, 2019):

Lowland valleys (hedgerow) = 27.46% total Dyfed Area Coverage

This landscape type of valleys and rolling lowlands comprises 15.03% of the area of Wales covered by LANDMAP. It is defined by the strong presence of hedgerows and hedgerow trees, often associated with a mosaic of farmland and small-scale woodlands occupying between 20 and 50% of its land area.

• Patterns of enclosure define this landscape, developing from a varied pattern of dispersed and more rarely village-based settlement. This can range from patterns of irregular 17th century and earlier fields, fields enclosed from medieval strip fields around settlements and 18th-19th century planned enclosures of former common land. This farmed landscape, and the layouts of farmsteads with barns and other buildings, reflect the past importance of mixed agriculture.

• Most of this area is enclosed by a mixture of boundaries (42.1%), followed by hedgerows with trees (30.5%) and managed hedges (15.29%) – the latter tending to result from 19th century enclosure. Gorse and thorn hedges are more common nearer the coast. It has after Lowland (open) landscapes the second-highest proportion of hedgebanks (cloddau) of any of the landscape types, at 9.4% of land area and concentrated in the south-west.

• The sense of enclosure is enhanced by a strong presence of ancient woodland – often sessile oak with ash, hazel on drier land, willow and alder carr in wetter areas, 18-19th century plantations and some post-1919 softwood plantations.

• Parkland is another strong characteristic of this and to a lesser degree the Lowland (open) landscape character type, particularly in east and south Wales.

• The field patterns in these landscapes lend a strong patchwork character and sense of place in a settled pastoral and tree-rich landscape, enhanced by the seasonal colours of older, mixed deciduous woodland and mixed-species hedgerows. There has been a significant decline in botanical diversity of both permanent and temporary pasture, now managed intensively for maximum productivity of often ryegrass-dominated swards.

Upland (grassland) = 21.70% total Dyfed Area Coverage

This landscape type comprises 23.17% of the area of Wales covered by LANDMAP. This type includes upland valleys, hillsides, lower plateaux and scarps where

[6] Natural Resources Wales / National Landscape Character Areas (NLCA)

grazing land is more than 50% of land use, some parts being internationally and nationally valued for nature conservation.

• These are open, sparsely-settled upland landscapes with isolated farmsteads and hamlets, interspersed with deserted settlements, prehistoric monuments (concentrated in unenclosed land) and in some areas by historic mineral mines marked in the landscape by their spoil heaps.

• A distinctive characteristic of this landscape type is the lower incidence of woodland (typically under 20% of land area) and relative lack of hedgerow trees, although low scrub and bracken are common on valley sides (the ffridd), along with some patches of exposed rock – either loose boulders, slates or scree.

• Some substantial blocks of post-1919 plantations, areas of ancient woodland, intermixed with pre-18th century enclosed fields, and some smaller non-native 18th-19th century plantations. Some parkland, although much less common than in lowland areas.

• Farms developed on both acid-based and loamy soils, historically used for growing crops as well as growing grass but now mostly permanent pastures (for sheep with limited suckler cows) interspersed with wet rush pasture).

• This landscape type is now more strongly enclosed than other upland types (96.7% of land area), enabling the cultivation of crops as well as mostly by a mixture of boundaries (33.7%), managed hedges (20.62%), hedgerows with trees (11.6%), stone walls (10.5%) and fences. In some places these boundaries have been replaced or supplemented by post and wire fences, while fields on lower slopes are bounded by once-dense hawthorn hedges which would traditionally have been laid in order to create sheep-proof barriers. Hedgerows are more common in eastern areas of Wales, as are timber-framed buildings.

• Remaining inland and coastal grazed commons, heath and moor are valuable habitats due to enclosures and post-1940 agricultural improvement.

These are expansive and panoramic landscapes with often little to interrupt the view and often dark night-time skies. Traditional farmsteads and houses, mostly of 19th century date, make a fundamental contribution to the character of these landscapes. The ruins of buildings convey a sense of the difficulties that rural communities faced in these areas. In some locations the historic remains of former mining and quarrying activity add texture and colour to the landscape through changes in landform and vegetation cover.

Lowland valley (open) = 20.94% total Dyfed Area Coverage

This landscape type comprises 16.59% of the area of Wales covered by LANDMAP. It is a pastoral landscape of farms and fields in a rolling or flat lowland landscape, defined by its relative lack of hedgerow trees and a lower proportion of woodland (under 20% of land area) than in other lowland landscape types.

• Rural communities developed in village-based (mostly in South West Wales) and a predominantly dispersed settlement pattern of farmsteads and hamlets, working fields enclosed from the medieval period that tended to become larger than in other lowland landscapes.

• Patterns of fields and farmstead architecture testify to a varied farming economy. Courtyard farms including threshing barns developed in tandem with the 18th-20th century enlargement of fields with straight thorn boundaries, bringing organised regularity to parts of the landscape and enabling intensive modern agriculture which contributes to its sense of openness.

• This landscape type is mostly enclosed by a mixture of boundaries (42.1%, including stone walls), managed hedges (35.17%) and hedgerows with trees (7.5%). Many hedges are thorn hedges resulting from 19th century improvement and enclosure. It has the highest proportion of hedgebanks (cloddau) of any of the landscape types, at 10% of land area and concentrated in the south-west.

• Parkland is another characteristic of this landscape character type, and areas of historic commons and rough grazing are very rare and significant as habitats.

• These are open landscapes with a strong sense of their relationship to other landscape types - of coastal edges, the sea, up valleys and to historic houses and farmsteads and their associated modern agricultural barns and buildings.

4.3 The results of the *overall landscape risk* assessment undertaken by the author revealed that the land classes most at risk to the impacts of warmer mean temperatures, hotter, drier summers, warmer, wetter winters and more frequent extreme weather by 2050 are:

- **Coastal edge** (2.17% Area coverage)
- **Upland (moorland)** (7.68% Area coverage)
- **Lowland (wooded & wetland)** (4.47% Area coverage)

4.4 At the time of writing the distribution of Core HER records within land classes of High, Medium and Low overall landscape risk scores was:

- High = 13.86%
- Medium = 31.95%
- Low = 54.19%

4.5 The results for the *landscape sensitivity* based on the findings of Berry et al, 2019 revealed that the land classes most at risk of these climatic changes are:

- **Lowland (wooded & Wetland)** (4.47% Area coverage)
- **Coastal edge** (2.17% Area coverage)
- **Developed (communities)** (1.88% Area coverage)

4.6 The distribution of Core HER records within land classes of High, Medium and Low landscape sensitivity scores was:

- High = 19.15%
- Medium = 39.03%
- Low = 41.81%

4.7 The results of this modelling are presented in Figures 10 and 11, and the landscape narratives and predicted outcomes of change to these land classes owing to the impacts of warmer mean temperatures, hotter, direr summers, warmer, wetter winters and more frequent extreme weather by 2050 are presented in Table 5.

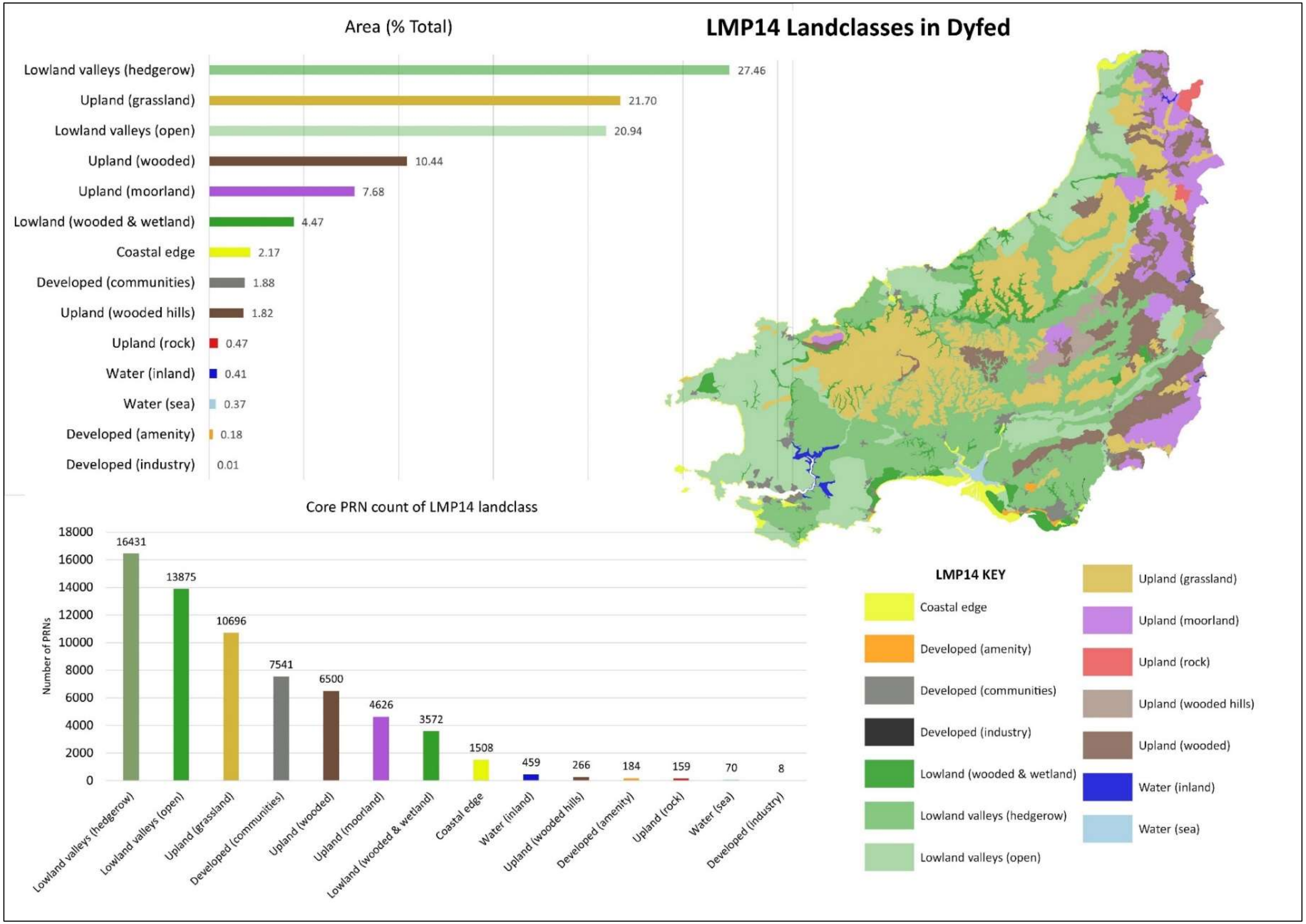


Figure 9: *Area coverage and number of Core PRN records of the LMP14 land classes in Dyfed.*

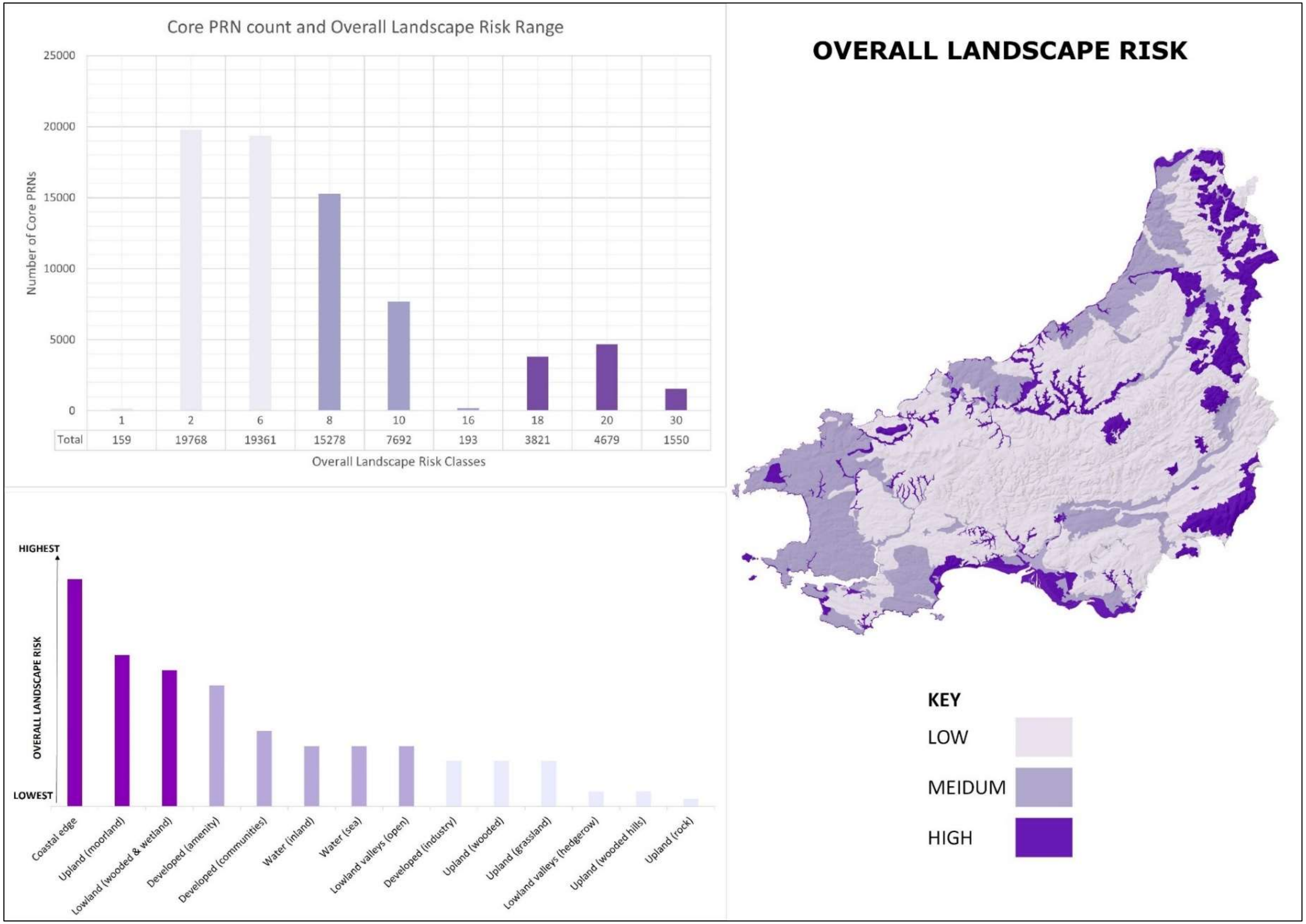


Figure 10: *The results of the overall landscape risk analysis*

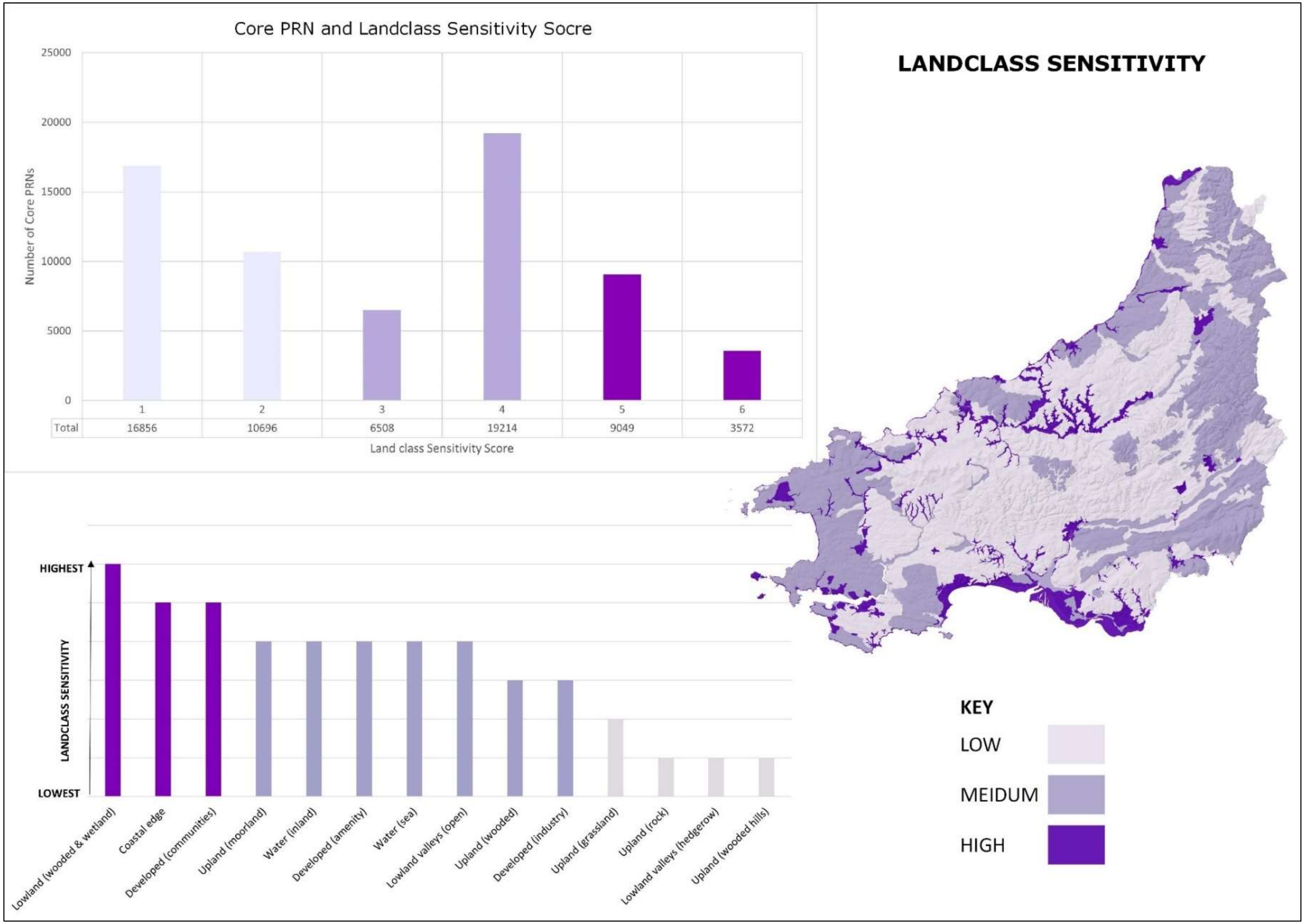


Figure 11: *The results of the Land class sensitivity analysis based on the assessment undertaken by Berry et al, 2019*.

Table 5: *Landscape narratives and predicted outcomes of climatic change by 2050 (Berry et al, 2019) of the most at risk land classes in Dyfed according to the results of this spatial analysis.*

	Landscape Narrative	**Outcomes of change**	**Summary of Landscape change**
Coastal edge	The coastal edge landscape type – 2.45% of the area of Wales covered by LANDMAP - comprises great variety from the inter-tidal zone (beaches, mud and rocks) and small islands, dunes, coastal wild land, cliffs and cliff tops. The rocky headlands and cliffs showcase geological formations. • Characteristic features are the remains of anti-invasion defences, fishing, maritime trade, features from relict industrial mineral mining and quarrying, coastal navigation (lighthouses, daymarks and coastguard houses) and sea defences - including timber groynes and breastwork defences, and more recent beach nourishment and rock beach structures. • Settlement is sparse. Some areas marked by nearby development; 20th century housing and amenity land, mostly golf courses and caravan sites. • Only a very small proportion (11.7%) of this landscape type is enclosed, mostly with stone walls (9.05% of land area) and sometimes with fences (1.73%). Some use of headlands and dunes for rough grazing. Tree cover is also sparse, prevailing winds can create a distinctive windblown tree profile. • Rough grazing has conserved extensive areas of medieval and earlier archaeology, which extends also into the inter-tidal zone, including fossil forests exposed on beach areas affected by the rise in sea levels around 6,000 years ago. • These landscapes have distinct sense of the birdlife and vegetation from coastal heaths, dunes and gorse scrub and their associated colours that are particular to these areas. Often impressive rock faces, screes and shingle. • There is widespread access, including via coastal tracks and paths, to these landscapes and their valued panoramic views, sense of remoteness and wildness. • They are frequently associated with low levels of light pollution and landscapes of outstanding or high importance for their scenic quality and character and highly valued seascapes often part of a designated Heritage Coast, National Park or AONB, generally associated with attractive views.	The most significant changes are likely to be caused by sea level rise, compounded by warmer wetter winters (leading to more flooding in winter months) and more frequent and intense storms (again causing flooding, and storm surges with negative impacts on low lying areas). • Sea level rise is likely to have a significant impact on coastal edge landform, vegetation and habitat, archaeological assets, transport and settlement. The coastline shape is likely to alter with loss of salt-water marshes and inundation of low-lying land, particularly in estuarine areas. Overall there will be a loss of land and erosion is likely to increase, although the level of accretion may also increase in some places. • Salt water intrusion will impact the coastal vegetation and land use, damaging agricultural land and protected natural habitat with losses of up to 2,300 ha of Natura designated coastal habitat by 2100. Fresh water aquifers in coastal areas may also be affected by salt water intrusion. • Sea level rise and storm surges will threaten coastal settlements and road/rail transport links, which may require stronger flood defence systems (e.g. higher, more extensive, and/or new embankments) for protection. • Archaeological sites and ancient landscapes along the coast edge, either in low-lying locations or on exposed cliffs, will be at risk of damage and loss due to coastal erosion and increased storm events.	The coastal edge is at significant risk of a wide variety of changes. The shape of the coastline may alter along with loss of some specific landscape features such as sand dunes and salt marsh in some areas. • The coastline may become less diverse as a result of specific plant communities (e.g. salt marsh, dunes) with a reduction in the areal extent of low-lying coastal edge. Some coastal freshwater habitats may be lost, reducing diversity across the landscape. • Flood protection structures such as embankments may become more visible, and storm damage on settlements, transport structures, and on archaeological assets more frequent and visible.

	Landscape Narrative	Outcomes of change	Summary of Landscape change
Upland (Moorland)	This landscape type - 14.4% of the area of Wales covered by LANDMAP - comprises upland moorland, hillside & scarp slopes moorland and hill and lower plateau moorland. • Largely open and unenclosed landscapes resulting from centuries of use as grazing and resources for surrounding communities, sustaining rich layers of archaeology and habitats. Variety in upland moorland is evident, from the very dry, rocky limestone pavements in southern parts of Brecon Beacons, the deep peaty heather-clad hags of Y Berwyn, in contrast to the long tussocky grasslands and bogs of the Cambrian Mountains. • Extensive tracts of upland and high ground with an upland moorland character, frequently associated with extensive views, open horizons and skylines. Notably tranquil with a sense of remoteness and exposure, associated with low levels of night time light pollution. Good seasonal colour and contrast from heather, bracken and semi natural vegetation which lends a sense of wildness to the landscape. • Large-scale Forestry Commission plantations, contrasting with moorland vegetation, date from after 1919, otherwise sparse tree cover with the exception of historic woodland in valleys retaining evidence of timber and fuel exploitation. • Extensive traces of prehistoric archaeology, relict industrial mineral mining, quarrying and 20th century military activity. • Sparse settlements are mostly confined to moorland fringes, including smallholdings and medieval and later farms with stone-built traditional architecture. Only 28.3% of this landscape type is enclosed, mostly by drystone walls (2-.6% of the landscape type). • Upland Moorland retains some of the best evidence for prehistoric settlement and land use in Wales. • Large-scale and regular patterns of enclosures, sometimes associated with the establishment of new farms in the late 18th and 19th centuries. • Extensive evidence for transportation, stock rearing, shelter and summer pastures, in the form of droveways, tracks 'braiding out' to open moors and remains of 'hafods' or summer farms. • Decline in traditional use of moorland by surrounding communities has resulted in scrub and vegetation growth, which threatens the significant ecological interest of upland moorlands. The traditional use of upland moorland has declined since the 19th century, as its use as amenity land and forestry has increased.	The most significant changes are likely to be caused by hotter, drier summers altering surface water conditions and leading to changes in plant communities. Warmer mean temperatures are also likely to increase the length of the growing season and potentially increase threats from invasive species. • Warmer temperatures will create more favourable conditions for grasses and shrubby vegetation to grow at higher elevations, leading to possible upward movement of the moorland line. • Some invasive species (such as rhododendron) may extend their range to higher elevations in upland western areas under warmer conditions. Warmer, wetter, winters may lead to the spread of fungi. • Increased stress on trees (plantations) in exposed areas due to low or infrequent summer rainfall. • Drying out of peatbogs and reduced summer rainfall will cause changes in upland vegetation such as loss of mosses and peat forming species. Coarse grass species are likely to increase but bare ground may develop where peat is exposed to wind and water erosion, and the surface too friable for vegetation to take hold. • Destabilised surfaces following erosion or wildfire, increased risk of wildfire with parched vegetation and combustible dry material • Drying out of wetlands, peatland boggy ground and reduced surface water, although effects may be localised and dependent on rainfall pattern through the summer months. Erosion of peat post desiccation, leaving features like peat hags in the landscape • Upland streams may dry up in summer as the regulating nature of upland vegetation is reduced/altered. • Where peat dries out carbon-based archaeological remains that have been preserved by the waterlogged conditions (e.g. buried archaeology, paleo-environmental records), are at risk from drying out and more rapid destruction and erosion. Although these are not always visible in the landscape they represent potential loss of a cultural asset.	• The moorland edge may rise in elevation potentially changing scenic quality at a local level. • Changes in vegetation will blur the moorland line; colour may alter slightly, become greener with softer texture, or added colour from expanding flowering invasive species (gorse, rhododendron). • Post-wildfire ephemeral visual changes (mosaics or patches of blackened or bare soil, possibly leading to exposed geology where re-vegetation slow or fails and peat is eroded, i.e. some potential for change in landform in exposed places/aspects). • Less surface water will be visible as a feature in the landscape.

	Landscape Narrative	Outcomes of change	Summary of Landscape change
Lowland (wooded & wetland)	This landscape type comprises 2.37% of the area of Wales covered by LANDMAP. It is defined by having a higher proportion (typically over 50%) of woodland and wetland than other types of lowland landscapes. There are significant (designated and non-designated) vegetation and plant communities in these areas providing diverse texture from a variety of land cover elements including pasture, wetland and woodland. Some woodlands and wetlands are protected because of the diversity of native and rare species. • Settlement is mostly dispersed, and includes 19th century smallholdings and their small-scale fields which developed around and within drained wetland and common pastures. • These settlements farmed unenclosed and enclosed land, surviving areas of wet grassland and other rough grazing habitats now being very rare. 85.5% of this landscape type is enclosed, much of this being of 18th century or earlier date. Dominant boundary types are hedges with trees (30% of land area), mixed boundaries including stone walls (16.7%, stone-walled enclosures taking 5.3% of land area) and managed hedges (14.8%). Hedgebanks (cloddau) take 2.8% of land area and are concentrated in the south-west. • Forestry Commission plantations, contrasting with ancient woodland and 18th-19th century mixed-species plantations, date from after 1919. • Older woodland and wetland is often evident as an intricate network following the tranquil pastoral and wooded valley sides of watercourses. Enclosed land with its historic hedgerows, copses and blocks of woodland provide a framework for visual appreciation of historic settlements, houses and farmsteads. • These characteristics combine to bring a sense of unity, time depth and pattern in the landscapes with recognisable local character, diversity and texture. Scenic quality is generally higher where associated with species diversity and good design and well-integrated in the landscape in size and scale.	The most significant changes are likely to be caused by hotter drier summers and effects of pests and disease on tree cover and hedgerow species from generally warmer mean temperatures. Warmer, wetter winters may lead to increased water logging of soils, higher river levels and more frequent flooding. • The landscape is diverse with river channels, wetlands, woodland (native species, and conifer plantation), small areas of arable land, permanent pasture, valley floor and sides. • Water quality may decline in summer months as low flows and increased water temperature will impact on aquatic ecosystems making them potentially less effective at delivering services such as filtering water and storage. • Surface water may be less apparent in summer months, with lower flows in river channels and temporary ponds disappearing, while water will be more in evidence in winter with more waterlogged soils and potential for more frequent flood events. • Some reduction or loss of tree species (Sitka Spruce, beech, larch, ash) may occur as a result of pests and disease, drought, and or winter waterlogging of the root zone. Only relatively small reductions in woodland area are anticipated, in favoured sites planting may increase due to improved growing conditions making woodland more economically favourable. • Trees are likely to bud earlier in the spring and remain in leaf longer in the autumn. • Higher risk of storm damage, particularly in exposed locations, and windthrow. • Vegetation composition of woodland may alter, though this may only be apparent at certain times of year (e.g. reduction in springtime flowering plants. • Hedgerows may decrease in extent and species composition as a result of pests, disease, and stress from drier conditions. • Where soil desiccation occurs, buried archaeological remains may be exposed and at risk of rapid deterioration. New archaeological assets may be revealed by soil parching.	Little change from the current situation, although extent of woodland might decline in area with the loss of some species, which may alter texture and colour of the landscape slightly. Also potential for increase in woodland area for favoured species benefitting from warmer conditions. • There may be a reduction in hedgerows and loss of some hedgerow trees (e.g. Ash) and an increase in post and wire fencing. • Most changes will be subtle and relate to changes in species composition and water quality. • Greening may occur earlier in spring. • Increased flooding may alter river channels and leave sediment deposits more frequently.

	Landscape Narrative	Outcomes of change	Summary of Landscape change
Developed (Communities)	Developed (communities) – 4.47% of the area of Wales covered by LANDMAP - includes urban communities, villages and other rural settlement exceeding 15 houses in size. Two-thirds of the population (just below 2 million) live in urban areas and a third in rural areas, 11% of the total living in Village, Hamlet and Isolated Dwellings Sparse area types which cover more than half of Wales's land area (Rural Urban Definitions, 2011). **Urban areas:** • 81% of Wales's population of 2.5 million lives in towns and cities. Urban areas with populations exceeding 10, 000 are concentrated around the industries and coal fields of north-east Wales, along the resorts of the north Wales coast, around the ports of Pembroke and Milford Haven and in both ports and industrial centres of south Wales (eastwards of Swansea) including the valleys and their associated former coal fields extending inland. • Small market towns and ports are also a strong characteristic of Wales. Of the 81 identified (Wales Rural Observatory 2007), over 75% have populations of 1-5, 000 with five settlements (Aberystwyth. Milford Haven, Bangor, Carmarthen and Abergavenny) accounting for a fifth of the population resident in this category. These typically retain strongly characteristic historic settlement cores, 19th and 20th century growth being comparatively modest, although recent decades have seen some significant expansions of the coastal towns inland. • Built environment. Historic urban areas in Wales are dominated by their 19th century building stock, often hiding the cores of earlier buildings in historic cores or in chains of industrial settlements absorbed by later growth. These include market buildings, often built-in materials reflecting the underlying geology and standing out in the landscape due to undulating topography. • Open spaces in urban areas and towns provide an important contrast and break from the built environment. Parkland, gardens, wooded areas and open space retained within the expansion of urban areas includes urban river corridors and woodland, industrial-era transport infrastructure (such as the Lower Swansea Valley and the Taff Trail in Cardiff, which was a tramroad linked to Merthyr Tydfil), formal parks, golf courses and playing fields. Deprived areas are noticeably lower in tree cover. • Analysis for Natural Resources Wales of tree cover in Wales' towns and cities (https://naturalresources.wales/about-us/what-we-do/green-spaces/urban-trees/?lang=en) has shown that – whilst private residential gardens take up 35% of their land area – densities are extremely low in area of high-density housing and affected by neighbouring landscape character (being low in Coastal Edge landscapes and high in Upland (Wooded) area.	The most significant changes are likely to be caused by warmer mean temperatures raising the potential risk from pests and disease; hotter drier summers putting additional stress on vegetation and trees, and increased potential for flood and storm damage during winter months. • Urban landscapes may alter as a result of climate change in both direct and indirect ways. Direct impacts such as warmer mean temperatures may increase pests and disease in vegetation and trees, causing a decline in quality or loss. Indirect impacts may result in changes to species mix of trees and plants utilised in open spaces, parts and streets. • Heat island effects are likely to exacerbate summer temperatures of urban environments putting additional stress on trees and vegetation. In addition rapid run off and limited percolation of water into the soil is likely to lead to drier soils and additional stress on trees/vegetation. • Settlements in areas with high clay content in soils may experience additional subsidence of buildings during summer months. • Structures and settlement near coastal areas will be at higher risk of damage from flooding and wetter winters. • Historic structures likely to be impacted by more severe weather conditions, in particular impacts to building fabric from: wetting/drying, freeze/thaw, storm damage, pests and fungal infestations of buildings, overflowing gutters and water management. • Water bodies (Lakes, streams, ponds, rivers) will have lower flows or dry up during summer months. Water bodies will exhibit increased water temperatures. Waterlogging may occur in winter months due to wetter conditions, and water quality may decline where combined sewers cannot manage additional flows.	Less green vegetation visible during summer months although longer growing season may mean earlier greening of tree canopy in spring and extended autumn foliage. • Less surface water visible, more susceptible to algal blooms and ecosystem impacts from quality decline. • More potential from damage to buildings from more intense storms and floods, particularly in coastal areas.

	Landscape Narrative	Outcomes of change	Summary of Landscape change
	• Busy roads and increased light pollution – concentrated in these urban areas and along their linking transport routes - can reduce tranquillity. **Rural areas**: Built land in rural areas is strongly characterised by dispersed settlement intermixed with fields enclosed from the medieval period, and unenclosed land which is now a fraction of its former extent: • About two in eight of the population lives in 'less sparse' rural areas and one in eight in sparsely-populated rural areas that characterise most of rural Wales. • Medieval villages with their strip fields are concentrated in the coastal and lowland vale areas with more fertile land and historic Anglo-Norman influence. Many villages, often linear in their form, were established along the new and improved road transport network that developed in the late 18th and 19th centuries. • Low densities of scattered or dispersed settlement dominate Wales, higher densities being found in historic rural industrial areas and in some of the areas where squatter settlements developed along and within commons in the 16th-19th centuries. • The traditional domestic and farmstead architecture of rural settlements makes a fundamental contribution to the distinctive quality of the Welsh landscape and how it is experienced. • Medieval parish churches are often sited next to an historic manor or plas, another common feature being chapels associated with the influence of Calvinistic Methodism.		

5. CONCULSIONS

5.1 This project adopted a GIS based approach to provide clearer identification and understanding of the threats and impacts of climate change on the Welsh historic environment as identified by the HEG Plan. The governing principle was that the assessment of the impacts of climatic change on the historic assets should be evaluated in first instance by *where* they are not by *what* they are.

5.2 This was possible by using the landscape climate change impact metrics and landscape narratives provided by NRW's 2019 *Landscape and a Changing Climate*[7] report (Berry et al, 2019) of which the geospatial data is freely available to download from the online repository[8]. This report identified and communicated the impacts of the climate change projects of the UK Climate Change Risk Assessment 2017 Evidence Report: Summary for Wales on landscape character and qualities using the LANDMAP[9] Visual & Sensory landscape types. The report collated the 45 LANDMAP Visual & Sensory landscape types into two new classifications: one of 14 landscape classes (LMP14) which was again simplified into 9 classes (LMP09). The LMP14 landscape classes were used for reporting the potential impacts of climate change on landscape character and quality.

5.3 The spatial analysis undertaken during this project revealed that the most prevalent LMP14 land class in Dyfed is that of "Lowland valleys (hedgerow") which has a total area coverage of the 27.46%. This is followed by a close second and third of "Upland (grassland)" (21.70%) and "Lowland valleys (open)" (20.9%) respectively. These land classes comprise over 70% of the landscapes in Dyfed.

5.4 Data from the LMP14 landscape types were classified by two slightly different modelling methods for identifying the most vulnerable land classes to the impacts of climatic change. Overall landscape risk and landscape sensitivity scores were calculated, and those highest scoring land classes were revealed to be most vulnerable. This data, namely the classified LMP14 polygons, was then subsequently integrated into the Core HER records of all the Welsh Archaeological Trusts to create an initial risk baseline for recorded archaeological assets in the historic environment. All of the Core records and their child tables (eg, site type, period, condition, status etc) are now linked to the classified LMP14 polygons and in addition to these parameters can be queried by both methods of spatial modelling.

5.5 The overall historic environment risk score is not a true assessment of vulnerability of the historic assets for it does not consider the form or condition of the monument, but it provides a hierarchical way of assessing the vast HER data. It is now possible to undertake a very rapid assessment both a regional and site level. The true vulnerability of an individual assets (and therefore risk) can be assessed individually as a secondary level of analysis using the criteria provided in the HEG Plan. Other historic environment data such as Registered Historic Landscapes, Parks and gardens, Listed Buildings, Scheduled Monuments and maritime assets

[7] https://cdn.naturalresources.wales/media/689497/eng-evidence-report-314-landscape-and-changing-climate.pdf
[8] https://github.com/robertberryuk/LANDMAP_ClimateChange
[9] Natural Resources Wales / LANDMAP - the Welsh landscape baseline

recorded by the RCAHMW can also be assessed in this way. The same is applicable to blanket bogs and woodland.

5.6 The results of search queries in the HER can be exported in various formats from csv spreadsheets, pdfs and several GIS formats but most commonly as an ESRI shapefile.

5.7 The results of the *overall landscape risk* assessment undertaken revealed that the land classes in Dyfed most at risk to the impacts of warmer mean temperatures, hotter, direr summers, warmer, wetter winters and more frequent extreme weather by 2050 are:

- **Coastal edge** (2.17% Area coverage)
- **Upland (moorland)** (7.68% Area coverage)
- **Lowland (wooded & wetland)** (4.47% Area coverage)

5.8 At the time of writing the distribution of DAT Core HER records within land classes of High, Medium and Low overall landscape risk scores was:

- High = 13.86%
- Medium = 31.95%
- Low = 54.19%

5.8 The results for the *landscape sensitivity* based directly on the findings of Berry et al, 2019 revealed that the land classes most at risk of these climatic changes are:

- **Lowland (wooded & Wetland)** (4.47% Area coverage)
- **Coastal edge** (2.17% Area coverage)
- **Developed (communities)** (1.88% Area coverage)

5.9 The distribution of DAT Core HER records within land classes of High, Medium and Low landscape sensitivity scores was:

- High = 19.15%
- Medium = 39.03%
- Low = 41.81%

5.10 Coastal edge and Lowland (wooded & wetland) land classes are consistently in highest scoring classes in both modelling. Whilst the first is unsurprisingly, the latter highlights the vulnerability of the somewhat juxtaposed living elements of the historic landscape and their priority as valuable assets in both the natural and historic environments. The modelling also revealed Upper (moorland) and Developed (Communities) classes as vulnerable. These results are consistent with that summarised in the HEG Plan. These four land classes and their broadly equivalent historic assets broad classes defined by the HEG Plan have been collated in Table 6 and presented in Figures 12 and 13.

5.11 This project has demonstrated how spatial modelling can quickly produce a baseline dataset to evaluate the risks of climatic change on the historic environment at a national, regional and site scale. However, different processing and classification of the data will produce slightly different results. Irrespective of the methodology undertaken, spatial modelling allows for a rapid coherent and repeatable processing and evaluation of the data and removes anecdotal or subjective sampling. Moreover, this project has harnessed the capacity of the HER as powerful geospatial database and solution to negotiating problems associated with the classification and typologies of the historic environment.

5.12 The project has also provided a means to practically apply the findings of the Historic Environment and Climate Change in Wales Sector Adaptation Plan (HEG, 2020) to the HER, thus enabling heritage managers to fully utilise this key guidance. It also enables a more holistic approach to the natural and historic environments.

5.13 In October 2020 the Welsh Government published its latest strategy for managing coastal erosion and flooding[10] which included a flood risk assessment which superseded the previous Flood Zone 2 and Flood Zone 3 data used in the LANDMAP Landscape and a Changing Climate project by Berry et al, 2019. This latest flood data identified a risk of flooding which has not previously been identified. Therefore, the results of this project are not representative of for flood risk.

5.14 Finally, it must be stated that this project is by no means and exhaustive or expert spatial analysis of the data and it does not claim to be authoritative. Any faults with the data during the process of the modelling are those incurred by the author and are not derivative from the original source of the data. This undertaking has principally been a means of using spatial modelling as a means of fulfilling the aims and objectives of the project.

[10] *https://gov.wales/sites/default/files/publications/2020-10/the-national-strategy-for-flood-and-coastal-erosion-risk-management-in-wales_0.pdf*

***Table 6**: Types of impacts and examples of adaptive strategies identified for the historic asset broad classes identified in the HEG Plan and the LMP14 land class equivalents.*

Marine & Coastal (LMP14 Coastal Edge)
Risks include:
SL1 Submergence or loss of historic assets and landscapes through sea level rise. Negative impact on tourism following closure/damage to historic assets.
SL2 Potential adverse impacts from clean-up operations and flood protection measures.
PD2 Change in marine species in response to warmer seas and increased acidification.
LGS1 Introduction of new species altering the distinctive historic character of the marine and coastal environment.
LEI1 Increased pressure for development and infrastructure in coastal resorts because of migration from urban centres and increased visitor numbers.
DRY2 Increased movement of sand dunes leading to exposure and damage of formerly buried deposits.
FL1 Prolonged heavy rain leading to landslips.
EX1 Storm damage to historic assets and erosion of coastal edge from wind and wave action. Potential adverse impact from clean-up operations and modifications.
Opportunities include:
LEI2 Increase in visitor numbers to coastal resorts and heritage tourism, including conservation-led regeneration.
EX3 Discovery of new sites following exposure by coastal erosion or movement of sediment.
Example adaptation actions:
Knowledge
2.1 Carry out spatial mapping work to identify historic assets at greatest risk.
3.1 Improve understanding of the impacts of acidification of seawater and changing marine species on wrecks and timber structures in marine environments.
Marginal and Upland (LMP14 Upland (Moorland)
Risks include:
PD2 Proliferation and expansion in range of invasive and non-native (INNS) species.
LGS1 Warmer mean temperatures leading to longer growing seasons and the expansion of improved pasture and cultivation into the uplands having a negative impact on historic assets above and below ground.
LEI1 Warmer mean temperatures leading to increased visitor pressure on historic upland areas.
DRY2 Conditions too dry for the growth of lowland mire, making historic assets increasingly vulnerable to degradation.
DRY3 Drying out and erosion of peats and peaty soils, threatening a large proportion of Wales's significant archaeological remains and paleoenvironmental resource. The loss of the organic content of peaty soils transforming the types of vegetation and changing the historic character of peatland. Changing land use to cope with water shortages, lack of fodder and poor harvests.
WF2 Hotter, drier summers leading to increased risk of erosion and subsequent loss of peat as a paleoenvironmental record resulting from fire damage to surface vegetation and its protective effect.
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.
FL3 Destabilisation and subsidence of archaeological deposits and earth structures leading to slippage or collapse.
EX1 Storm damage to features and structures above ground.
EX2 Impacts of extreme and fluctuating temperatures affecting the physical weathering characteristics of building materials. Changing land use to cope with the impacts of extreme and fluctuating weather conditions.
Opportunities include:
LEI2 Potential opportunities from increasing visitors and heritage tourism, including conservation-led regeneration.
DRY4 Hotter, drier summers leading to the discovery of new historic assets in desiccated grassland and crops visible as parch and crop marks.
Example adaptation actions:
Knowledge
2.1 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.
3.1 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
5.3 Prepare case studies to further illustrate climate change risks and adaptation in marginal and upland areas.
6.3 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 paleoenvironmental record.
Resilience
7.1 Work with agricultural advisors to limit adaptations that have potential to damage historic assets e.g. deeper root crops.
7.3 Survey vulnerable areas where drying and shrinkage of peat affects historic assets.
7.4 Establish stakeholder/community groups able to monitor and record assets and respond to significant events such as wild fires.

Table 6: *(Continued)*

Wooded (LMP14 Lowland (Wooded & Wetland)
Risks include:
PD2 Proliferation and expansion in range of pests, pathogens and invasive and non-native (INNS) species.
PD3 Changes in the distribution of tree species and loss of species already at their threshold of tolerance.
DRY2 Soil erosion, land-use change, and slope instability could all damage individual historic features within woodlands.
DRY3 Drying and stress to veteran trees, historic woodland and the setting of historic assets. Changing use of woodland on agricultural land to cope with water shortages, lack of fodder and poor harvests.
WF2 Wild fires leading to alterations in the ecology, vegetation and historic landscape character.
EX2 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.
Example adaptation actions
Knowledge
3.3 Improve understanding of the positive and negative effects of a longer growing season on the maintenance and management of the historic environment.
3.4 Increase our understanding of the threats and opportunities from a changing climate to new woodland planting by using UKCP18 projections.
Capacity
6.3 Promote best-practice guidance on making woodlands more resilient.
Resilience
7.3 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.
7.5 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.
Buildings and Settlements (LMP14 Developed (Communities)
Risks include:
SL1 Sea level rise leading to inundation and flooding causing damage or loss.
SL2 Potential adverse impacts from clean-up operations and flood protection measures.
PD1 Increased incidence and severity of fungal and insect attack.
LGS1 Increased colonisation by vegetation, accelerating the decay of building materials and increasing the cost of maintenance and repair.
LEI1 Changes in lifestyle and leisure patterns increasing the pressure for development and infrastructure in coastal resorts.
DRY1 Subsidence caused by clay shrinkage.
WF1 Damage and increased risk of fire from drier conditions.
FL1 More flood events causing damage, scour and potential adverse impacts from clean-up operations.
EX1 Storm damage and increased rain, ground water and humidity impacting on the health of building fabric, occupants and collections/archives.
EX2 Impacts of extreme and fluctuating temperatures causing overheating of buildings and affecting the physical weathering characteristics of building materials. Potential for maladaptation.
Opportunities include:
LEI2 Increased potential for heritage tourism and conservation-led regeneration, particularly in coastal resorts.
DRY4 Improved humidity levels in buildings during hotter, drier summers.
Example adaptation actions
Knowledge
1.3 Participation in established UK and wider climate heritage groups and networks to maximise knowledge and resources, leading to capacity building and more successful adaptation.
2.2 Establish and implement targeted monitoring regimes on buildings and settlements.
3.1 Improve understanding of the interacting, cascading and cumulative impacts of climate risk factors on building condition and fabric.
Capacity
5.3 Prepare, promote and maintain building and settlement case studies to illustrate examples of adaptation.
6.2 Provide training and support within and across sectors on the risks and opportunities of climate change for buildings and settlements, and their adaptation.
6.3 Prepare guidance/advisory notes that increase the knowledge, understanding and resilience of buildings and settlements to climate change e.g. property flood resilience.
Resilience
7.1 Develop and implement emergency/adaptation plans for buildings.
7.2 Undertake programme of urban characterisation to inform management of change in urban areas.
7.3 Work closely with the all-Wales monuments and listed buildings at risk monitoring work to help prioritise adaptive action.

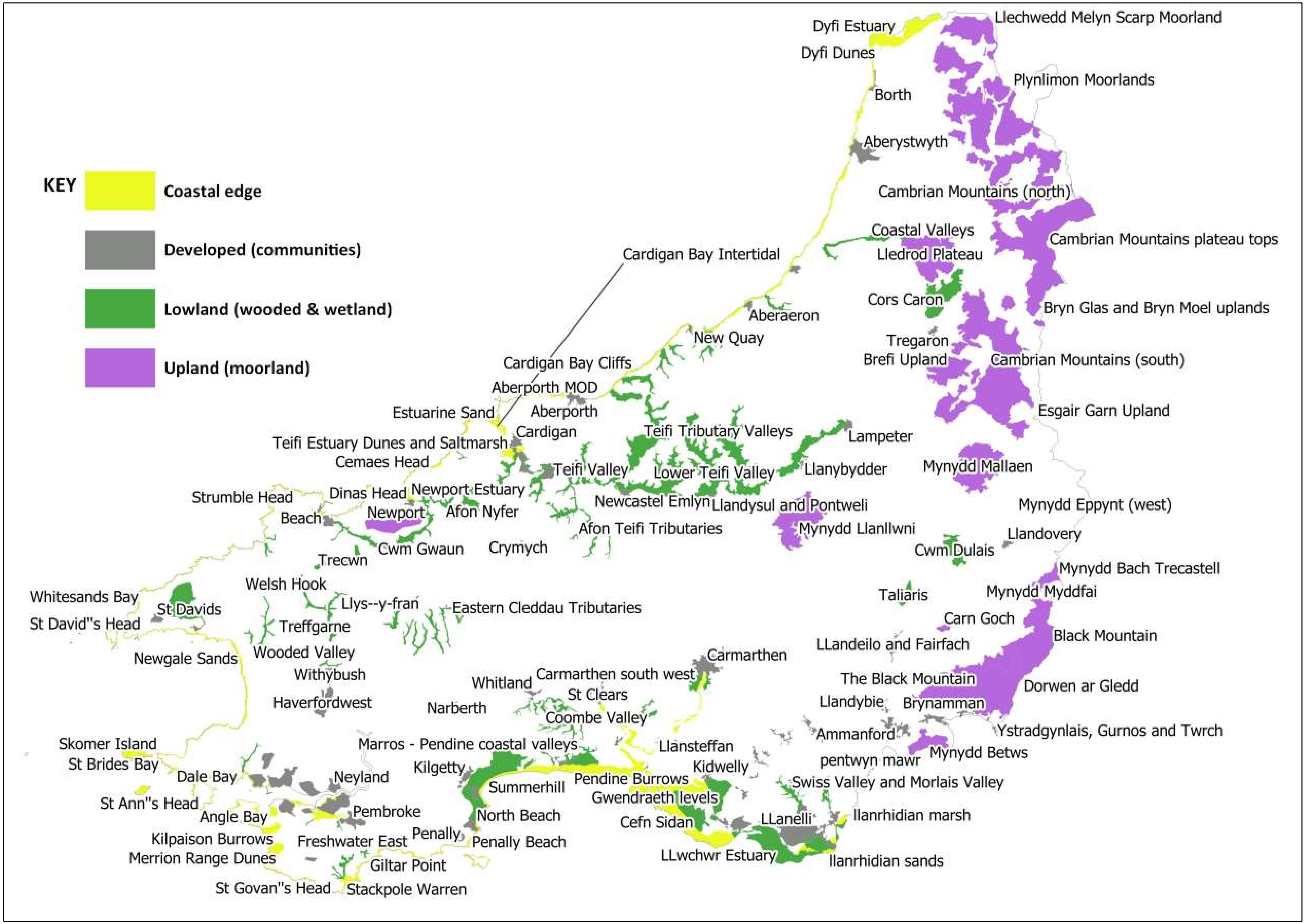


Figure 12: *Map showing the areas identified (and their LMP14 Area names) as being most at risk from the impacts of climatic change.*

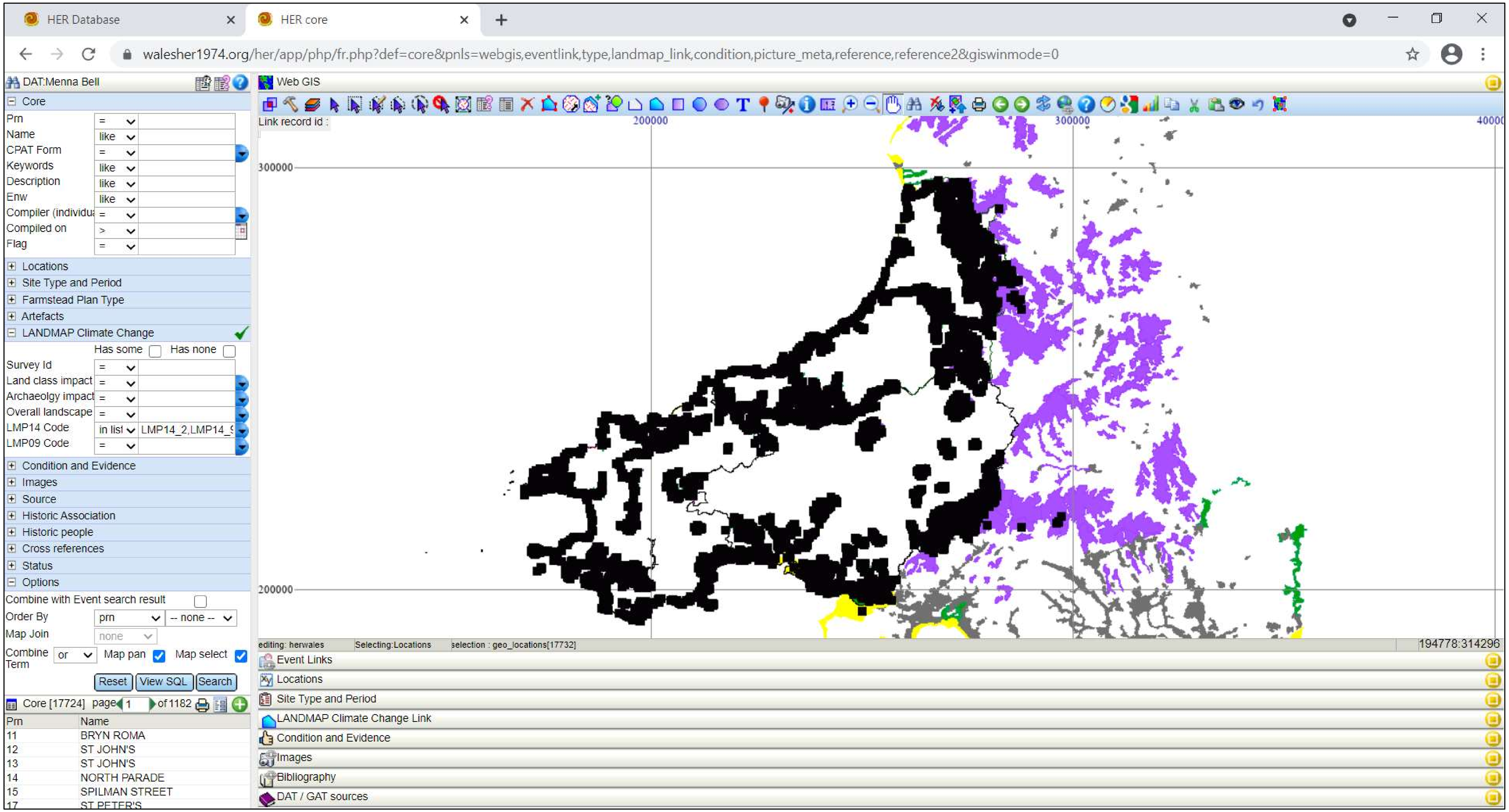


Figure 13: *Screenshot of the HER Core records showing the highlighted PRNs (in black) which fall within the landscape areas identified at being most at risk in Dyfed (Note c. 17,724 records).*

5.2 Recommendations for future work

Risk Assessment of 2020 NRW Flood Risk Assessment data and the historic environment: fluvial and pluvial risks.

Data from NRW's October 2020 Flood Risk Assessment[11] ought to be imported into the HER and/or GIS platforms to undertake full risk analysis for the historic environment. This new data 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. The LANDMAP project and HEG project used the Flood Zone 3 data. This latest flood risk data shows that there is flooding risk where there has not previously been identified.

This data can also be used to inform thematic projects such as water catchments (possibly collaboratively with NRW, Rivers Trusts), riverine and small water course networks and manmade infrastructure (eg. Weirs) and the overlaps and opportunities with the natural environment.

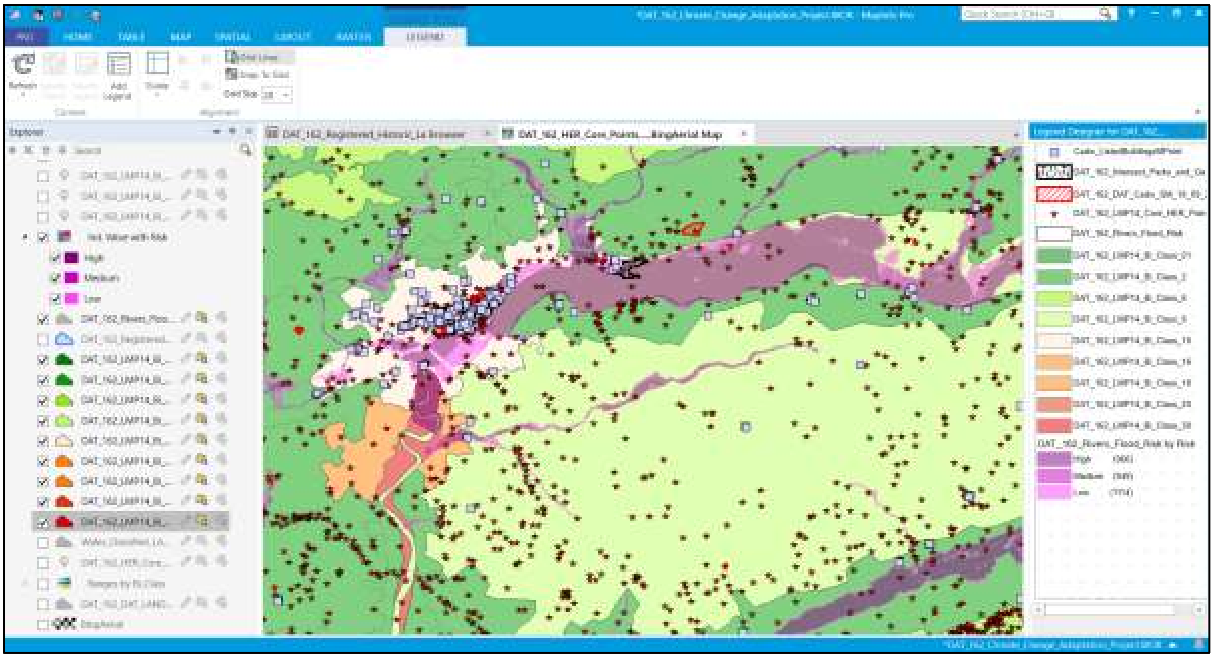


Figure showing the thematic fluvial 2020 NRW flooding risk assessment data (in purple) overlaid with historic environment data and classified LANDMAP LMP14 polygons.

Built structures in Developed Communities

The results of the project identified that built structures in developed communities are within the most vulnerable land classes in Dyfed. These areas host both designated and non-designated assets, the latter of which may often by overlooked or underrepresented in the HER. Initial proposals should include consultation of local Buildings at Risk register and Listed Building lists and community consultation to identify historic assets in risk and

[11] https://gov.wales/sites/default/files/publications/2020-10/the-national-strategy-for-flood-and-coastal-erosion-risk-management-in-wales_0.pdf

in need of monitoring, reactive or proactive, adaptive strategies to ensure sustainable management.

Historic Parks and Gardens; Adaptation and Restoration in the context of Climate Change

A thematic project concentrating on Registered Parks and Gardens. These historic environment assets are highly vulnerable to the impacts of climatic change and provide discrete case studies for reactive and proactive adaptation and conservation strategies. They are rich repositories for past climates and sensitive indicators to changing/future climates. Appropriate management and restoration of these resources requires reliable baseline data for monitoring and informed risk analysis (particularly flooding and storm events) at property, not regional narratives. Initial baseline assessment derived from LANDMAP LMP14 classified polygons.

Baseline data can be collated from current register and historical sources, combined with archaeological surveys (topo, UAV photogrammetry etc) and targeted excavation of vulnerable soils and stratigraphy including paleoenvironmental analysis of micro fauna and flora. Detailed recording of built structures, park/garden features and furniture.

These designated assets provide are well placed outreach and engagement opportunities with landowners (Eg National Trust), WHGT and other stakeholders etc

Managing Loss; auditing loss, curated decay strategies

Adaptation is as much about holding the line as it is about letting go. Managing loss, curating decay of historic environment is an important adaptive strategy. An audit of HER for those records identified during this project as being most vulnerable combined with a search of external data repositories (eg NMR, Cadw) to find feasibility of a sort of "loss triage" of exiting data to identify such opportunities and gap analysis. Cadw's latest round of monitoring data should be integrated with the classified LMP14 data sets, trends identified and targeted investigation of those assets with a declining condition or in severe, adverse condition can be sampled for evaluation.

Coastal monitoring; collaborative approaches and adaptive technologies:

As predicted, coastal erosion continues to be the most severe impact of climatic change on the historic environment in the near future. Therefore, it is necessary to undertake continuing monitoring of erosion of coastal heritage, using baselines from early 1990s surveys, Arfordir, CHERISH, LMP14 LANDMAP polygons. Identifying opportunities for collaborative working with local authorities, national parks, landowners, RCAHMW and national agencies such as NRW and the British Geological Survey. Identify opportunities to integrate remotely sensed data and technologies for monitoring coastal erosion.

Collaboration with NRW's National Peatland Action Programme, 2020-2025

The project highlighted the vulnerability of Dyfed's Upland moorlands and in particular that of peat bogs and peaty soils, threatening a large proportion of Wales's significant archaeological remains and paleoenvironmental resource. The loss of the organic content of peaty soils transforming the types of vegetation and changing the historic character of peatland. Changing land use to cope with water shortages, lack of fodder and poor harvests. The loss of peat bogs also represents the loss of a significant storage of carbon.

Wales' first national peatland action progamme[12] outlines a plan of action to be taken over the next five years with six priority themes:

- Peatland erosion
- Peatland drainage
- Sustainable management of blanket peats
- Sustainable management of lowland peats
- The restoration of afforested peatlands
- The gradual restoration of our highest carbon emitting peatlands

The programme will target those peatland bodies most in need of restoration with the aim of delivering 600-800 hectares of restoration per year. It will also safeguard those in good and recovering condition. Activity will be delivered by NRW and partners across a range of land uses on both private and public land.

Defining metrics of change and risk

A collaborative project to build on the foundations of 2020 Historic Environment and Climate Change in Wales Sector Adaptation Plan, to define metrics for identifying change, risk (climate hazards) and assessing the impacts of climatic change on the historic (and natural) environments. Potentially UK collaborative approach with organisations such as Historic Environment Scotland, Historic England and the National Trust. Joining Climate and Heritage Network.

6. ACKNOWLEDGMENTS

The author would like to extend sincere thanks and gratitude to Mr Michael Norman, former Chairman of the Welsh Historic Gardens Trust and now MSc student at University of Wales, Trinity St David for his invaluable and generous knowledge, direction, support and patience in his capacity as a key consultant on this project. It is he who first recognised the importance of Berry et al's *LANDMAP, Landscape and a Changing Climate* report. Thanks are also extended to colleagues at GGAT, GAT, DAT, for their help and feedback, with special mention to Andrew Davidson. Integration into the HER would not have been possible without the support of its developer Steve Smith, for which the author is very grateful.

The author would like to thank Jon Dollery at the RCAHMW for looking over the initial spatial mapping methodology and Jill Fairweather at Cadw for providing access to the HEC Climate Change Group and online repository. Finally, the author would like to thank David Harkin, Climate Change Scientist at Historic Environment Scotland for his time in sharing information and best practice.

[12] *National Peatlands Action Programme, 2020-2025 (cyfoethnaturiol.cymru)*

7. SOURCES

ASC, 2016. *UK Climate Change Risk Assessment 2017 Evidence Report – Summary for Wales*. Adaptation Sub-Committee of the Committee on Climate Change, London.

Berry, R., Dwyer, J., Gaskell, P., Lake, J., Powell, J. and Young I. 2019. *LANDMAP, Landscape and a Changing Climate.* NRW Report No: 314, 278 pp, Natural Resources Wales, Bangor.

HEG, 2020. *Historic Environment and Climate Change in Wales Sector Adaptation Plan.* Historic Environment Group Climate Change Subgroup

Research Framework for the Archaeology of Wales, 2016. *Refresh Review Documents 2016.* http://www.archaeoleg.org.uk/documents2016.html

Roberts, R. 2020. *GGAT 153 Climate Change Adaptation Pilot Scoping.* Glamorgan-Gwent Archaeological Trust

Welsh Government. 2020. *The National Strategy for Flood and Coastal Erosion Risk Management in Wales*

UK Climate Projections (UKCP18) Met Office: www.ukclimateprojections.metoffice.gov.uk

APPENDIX 1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Coastal Edge	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform	6						4	4		
Field boundaries										
Tree Cover										
Vegetation	6						5		20	72
Surface water	6							5		
Settlement & Structures	6						5	5		
Archaeological Asset	6				4		5	5		

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Water (Inland)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform							4			
Field boundaries										
Tree Cover										
Vegetation			4	5			4		4	52
Surface water			4		6		5	4		
Settlement & Structures			4				4	4		
Archaeological Asset					4					

Impact Ranking	
High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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 precipiation (FL)	Frequent high winds, storms and heat/cold events (EX)		
Water (Sea)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform	6						6	6		
Field boundaries										
Tree Cover										
Vegetation		5	3				4	5	4	55
Surface water	4	4					4	4		
Settlement & Structures										
Archaeological Assest								4		

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Developed (Communities)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform										
Field boundaries										
Tree Cover		5	3	5				4		
Vegetation		4	3	5			4		4	68
Surface water					4		5			
Settlement & Structures	5	4			4		5	4		
Archaeological Assest					4					

Impact Ranking	
High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Developed (Industry and Infrastructure)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform								4		
Field boundaries										
Tree Cover										
Vegetation		4	3	4					4	44
Surface water			4	4			4	5		
Settlement & Structures							4	4		
Archaeological Assest								4		

Impact Ranking	
High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Developed (Industry and Infrastructure)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform								4		
Field boundaries										
Tree Cover										
Vegetation		4	3	4					4	44
Surface water			4	4			4	5		
Settlement & Structures							4	4		
Archaeological Asset								4		

Impact Ranking	
High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Developed (Amenity)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform	4						4			
Field boundaries										
Tree Cover		5		5				4		
Vegetation		4	3	5				4	9	60
Surface water					5					
Settlement & Structures					4			4		
Archaeological Assest	5						4			

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Lowland (Wood and Wetland)	SL1 Total	PD1 Total	LGS1 Total	TP 1 Total	DRY1	WF Total	FL Total	EX Total	Total Archaeology Impact Score	Total Impact Score
Landform							4			
Field boundaries		4		4	4					
Tree Cover		5	3	5	5		4	4		
Vegetation		4	3	4	4		4		8	73
Surface water					4					
Settlement & Structures										
Archaeological Assest					4		4			

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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 precipiation (FL)	Frequent high winds, storms and heat/cold events (EX)		
Lowland Valleys (Hedgerow)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform										
Field boundaries		4	3	4			4			
Tree Cover										
Vegetation			2	4					4	24
Surface water										
Settlement & Structures							-1			
Archaeological Assest					4					

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Lowland Valleys (Open)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform										
Field boundaries		5								
Tree Cover		5	3	5		5				
Vegetation		4	3	4		4			4	56
Surface water					4		5			
Settlement & Structures							5			
Archaeological Assest					4					

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Upland (Grassland)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform										
Field boundaries		5	4	5						
Tree Cover										
Vegetation			4	4	4	4			**8**	**42**
Surface water				4						
Settlement & Structures										
Archaeological Assest			4		4					

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Upland (Rock and Scree)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform			3		4			4		
Field boundaries										
Tree Cover										
Vegetation			5	5					0	25
Surface water					4					
Settlement & Structures										
Archaeological Assest										

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Upland (Wooded Hills)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform										
Field boundaries										
Tree Cover		6	3	5		6	1	5		
Vegetation			3						1	30
Surface water										
Settlement & Structures										
Archaeological Assest					1					

Impact Ranking	
High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Upland (Wooded)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform										
Field boundaries										
Tree Cover		5	2	2		5	4	5		
Vegetation		4	3	3		4			4	45
Surface water					4					
Settlement & Structures										
Archaeological Assest					4					

Impact Ranking

High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)		
Upland (Moorland)	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Impact Score**
Landform					4					
Field boundaries										
Tree Cover		4	4	5						
Vegetation		5	5	6	6	6			**10**	**61**
Surface water					6					
Settlement & Structures										
Archaeological Assest					5	5				

Impact Ranking

Impact Ranking	
High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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)	Var1_Class	Var2_Class
LANDMAP LMP14 Classes	**SL1 Total**	**PD1 Total**	**LGS1 Total**	**TP 1 Total**	**DRY1**	**WF Total**	**FL Total**	**EX Total**	**Total Archaeology Impact Score**	**Total Land Impact Score**
Coastal Edge	6				4		5	5	20	72
Developed (Amenity)	5						4		9	60
Developed (Communities)					4				4	68
Developed (Industry)								4	4	44
Lowland (Wooded & Wetland)					4		4		8	73
Lowland Valleys (Hedgerow)					4				4	24
Lowland Valleys (Open)					4				4	56
Upland (Grassland)			4		4				8	42
Upland (Moorland)					5	5			10	61
Upland (Rock and Scree)									0	25
Upland (Wooded Hills)					4				4	30
Upland (Wooded)					4				4	45
Water (Inland)					5				5	52
Water (Sea)								4	4	55

Impact Ranking	
High Negative	6
Moderate Negative	5
Low Negative	4
No Change	0
Low Positive	3
Moderate Positive	2
High Positive	1

APPENDIX 2

Cadw Climate Change Adaptation Pilot Project: DAT Spatial Modelling Methodology

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.

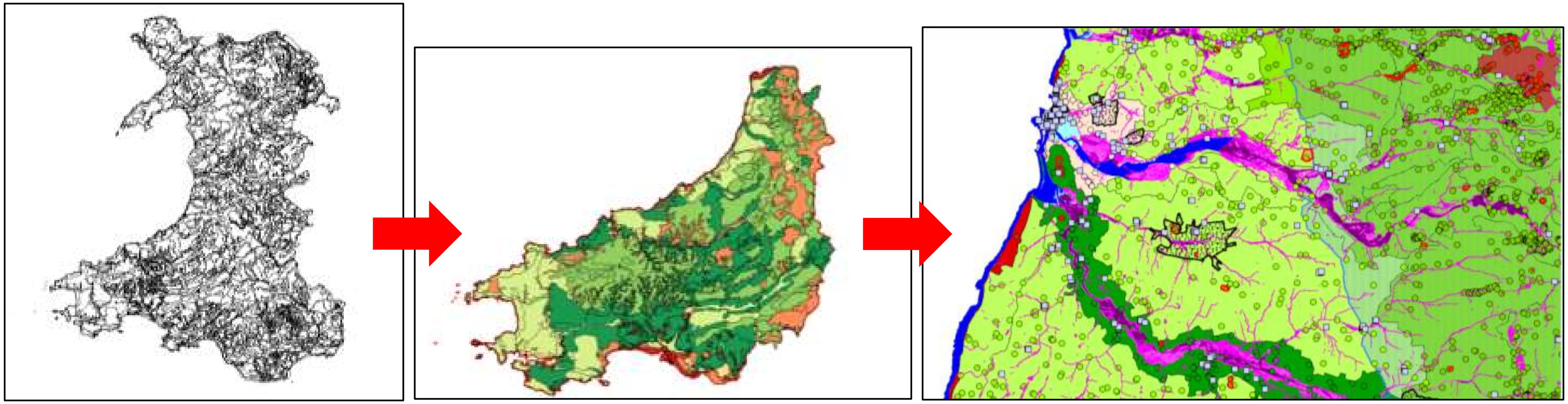
- This is possible by using the landscape climate change impact metrics as provided by NRW's 2019 Report 314 Landscape and a Changing Climate: https://cdn.naturalresources.wales/media/689497/eng-evidence-report-314-landscape-and-changing-climate.pdf of which the geospatial data is freely available to 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 is 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:



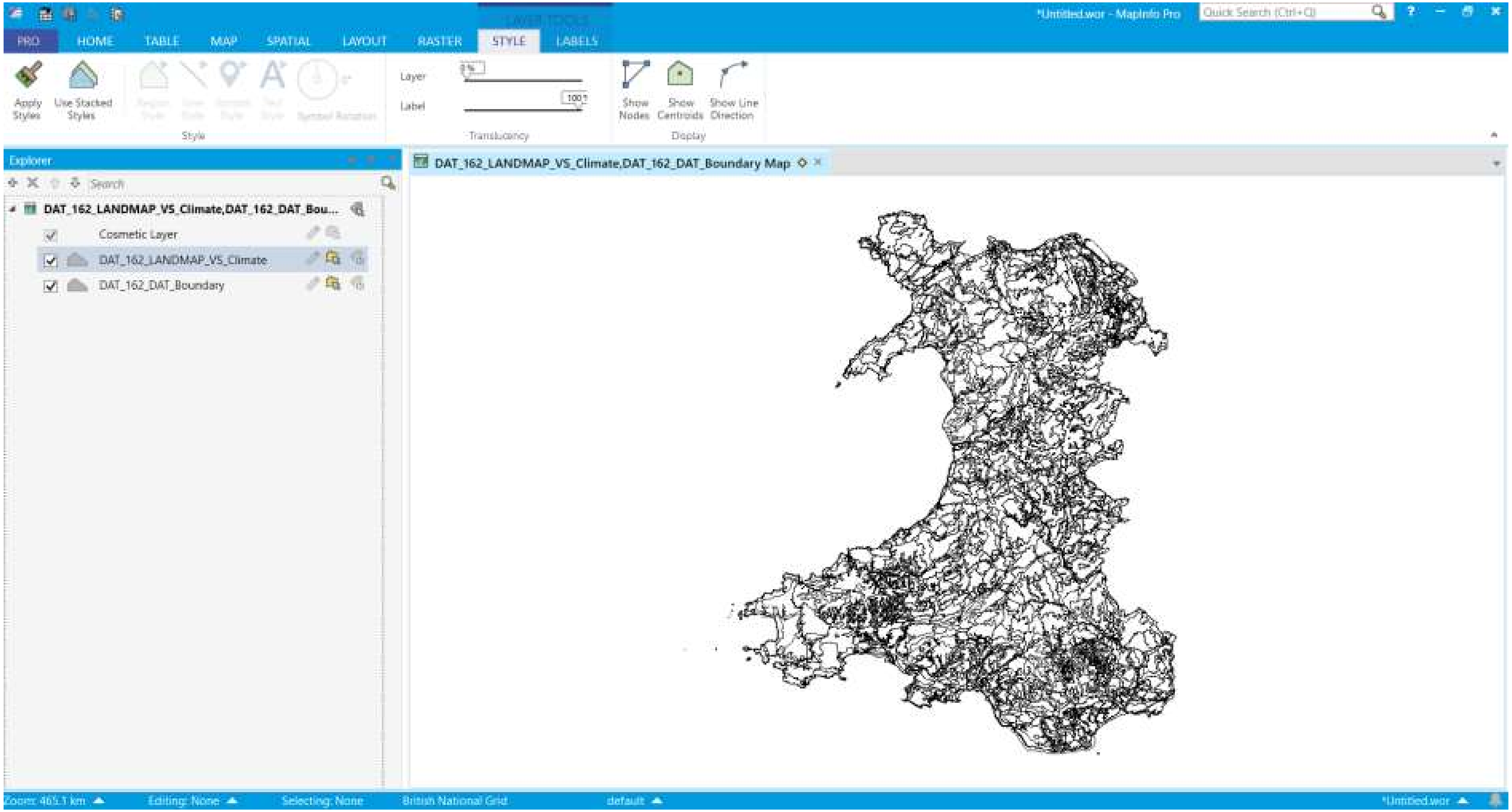
Data requirements

- 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

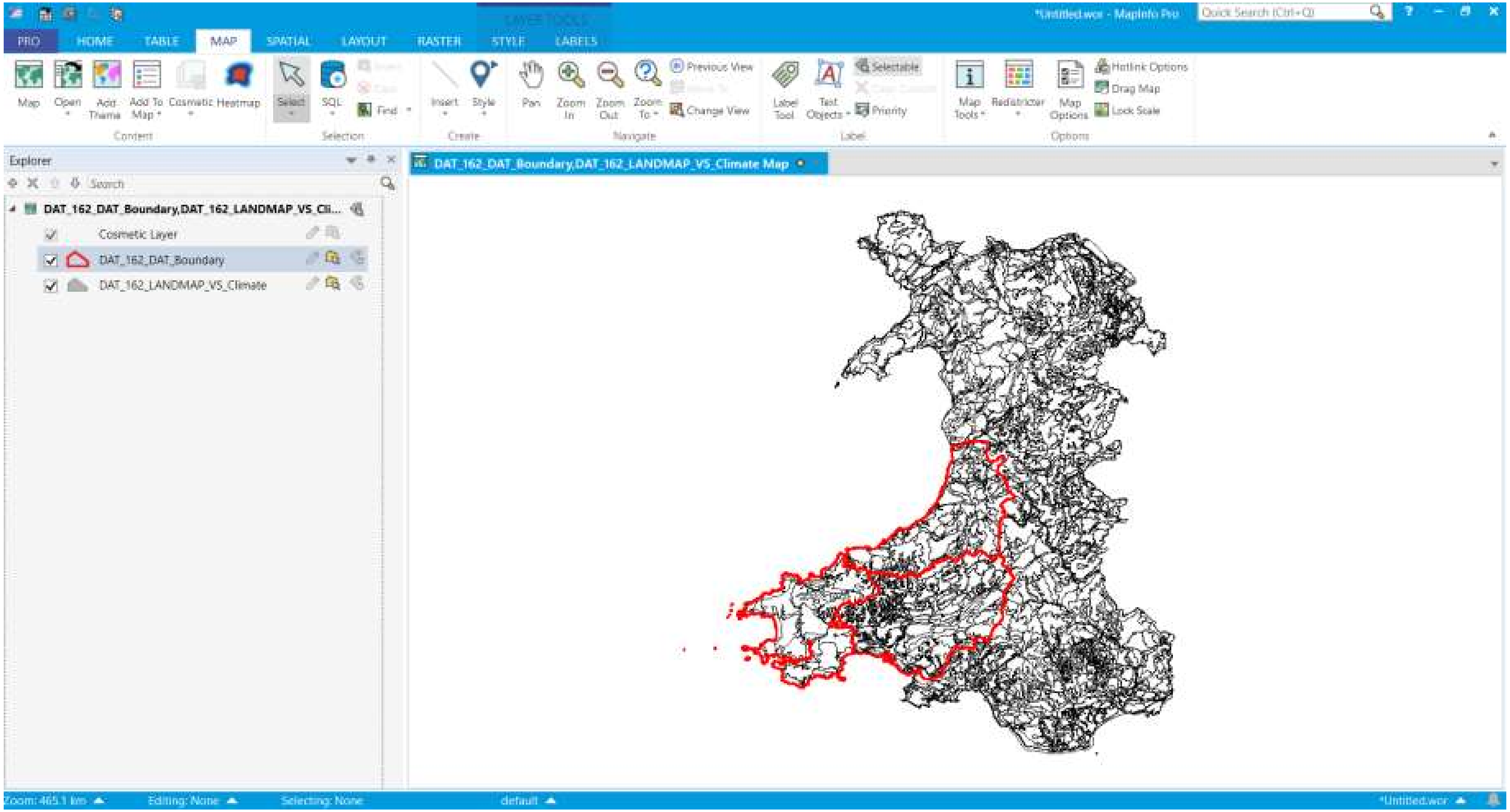
Open a new workspace in MapInfo. All the images in this methodology show DAT data, but in reality, it will be your WAT data.

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.


*Untitled.wor - MapInfo Pro
Quick Search (Ctrl+Q)
PRO
HOME
TABLE
MAP
SPATIAL
LAYOUT
RASTER
STYLE
LABELS
Apply Styles
Use Stacked Styles
Style
Layer
Label
Translucency
Show Nodes
Show Centroids
Show Line Direction
Display
Explorer
Search
DAT_162_LANDMAP_VS_Climate,DAT_162_DAT_Bou...
Cosmetic Layer
DAT_162_LANDMAP_VS_Climate
DAT_162_DAT_Boundary
DAT_162_LANDMAP_VS_Climate,DAT_162_DAT_Boundary Map
Zoom: 465.1 km
Editing: None
Selecting: None
British National Grid
default
*Untitled.wor

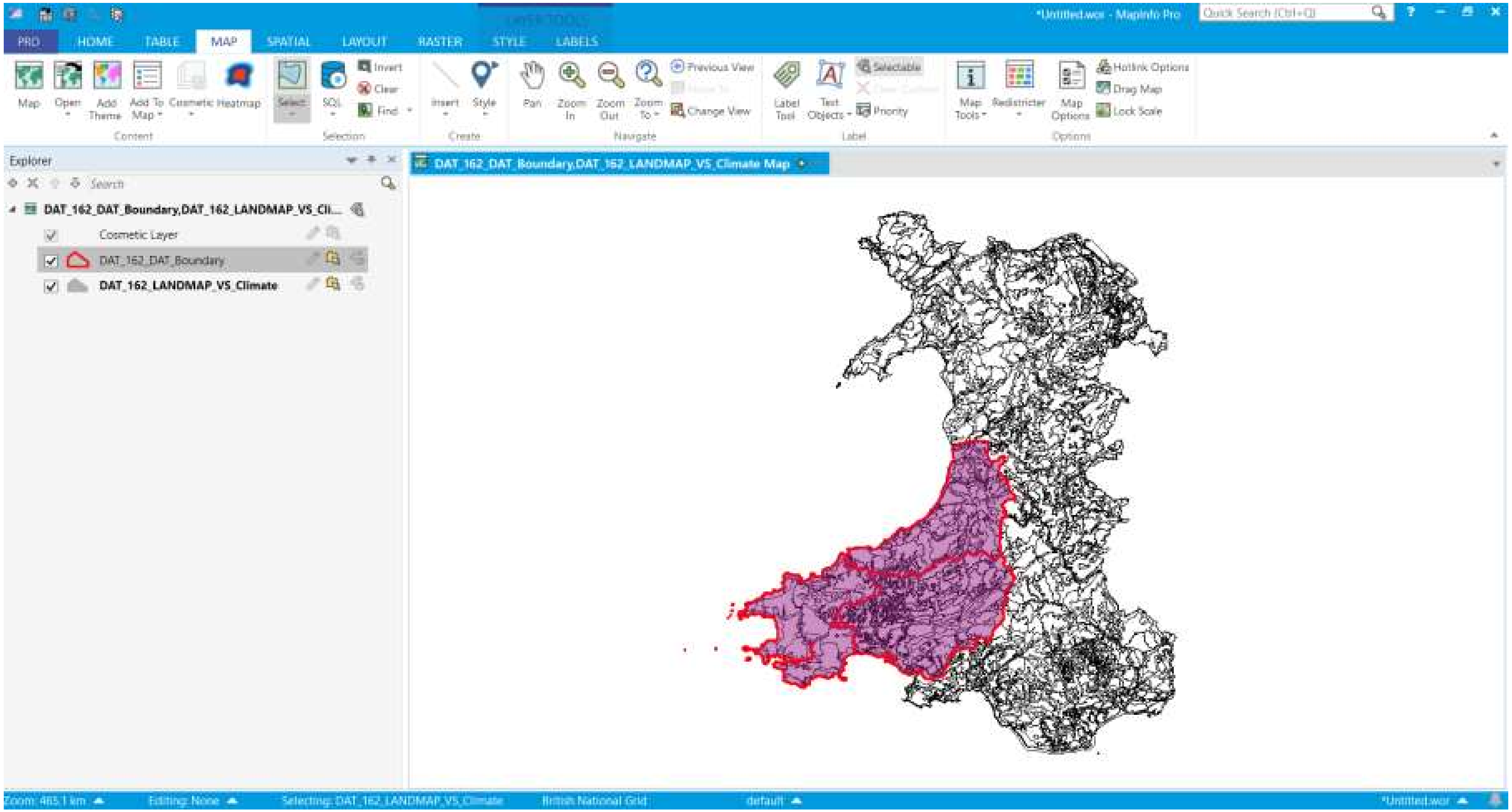
STEP 2

Open and overlay your WAT boundary polygon.



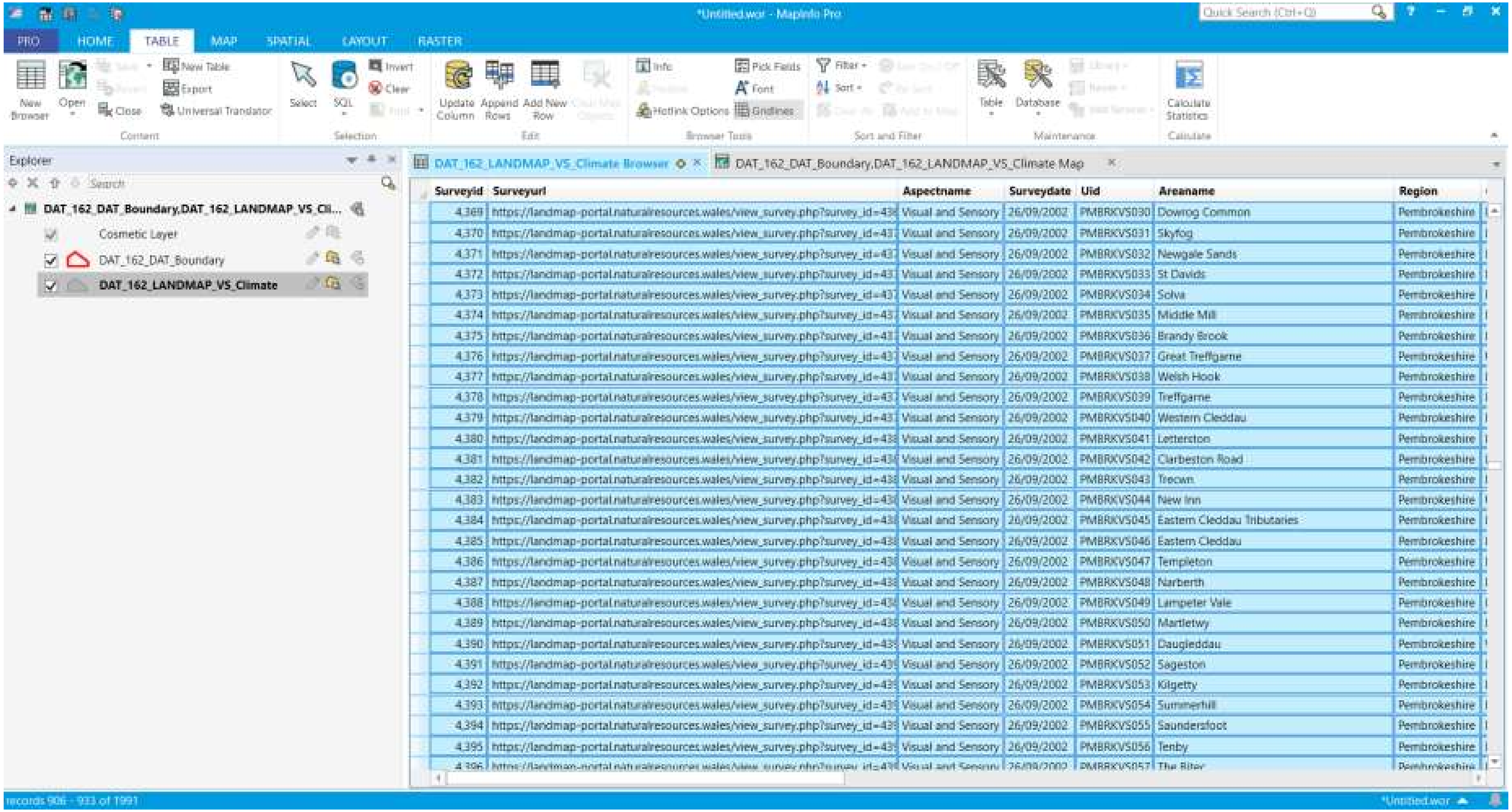
STEP 3

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).



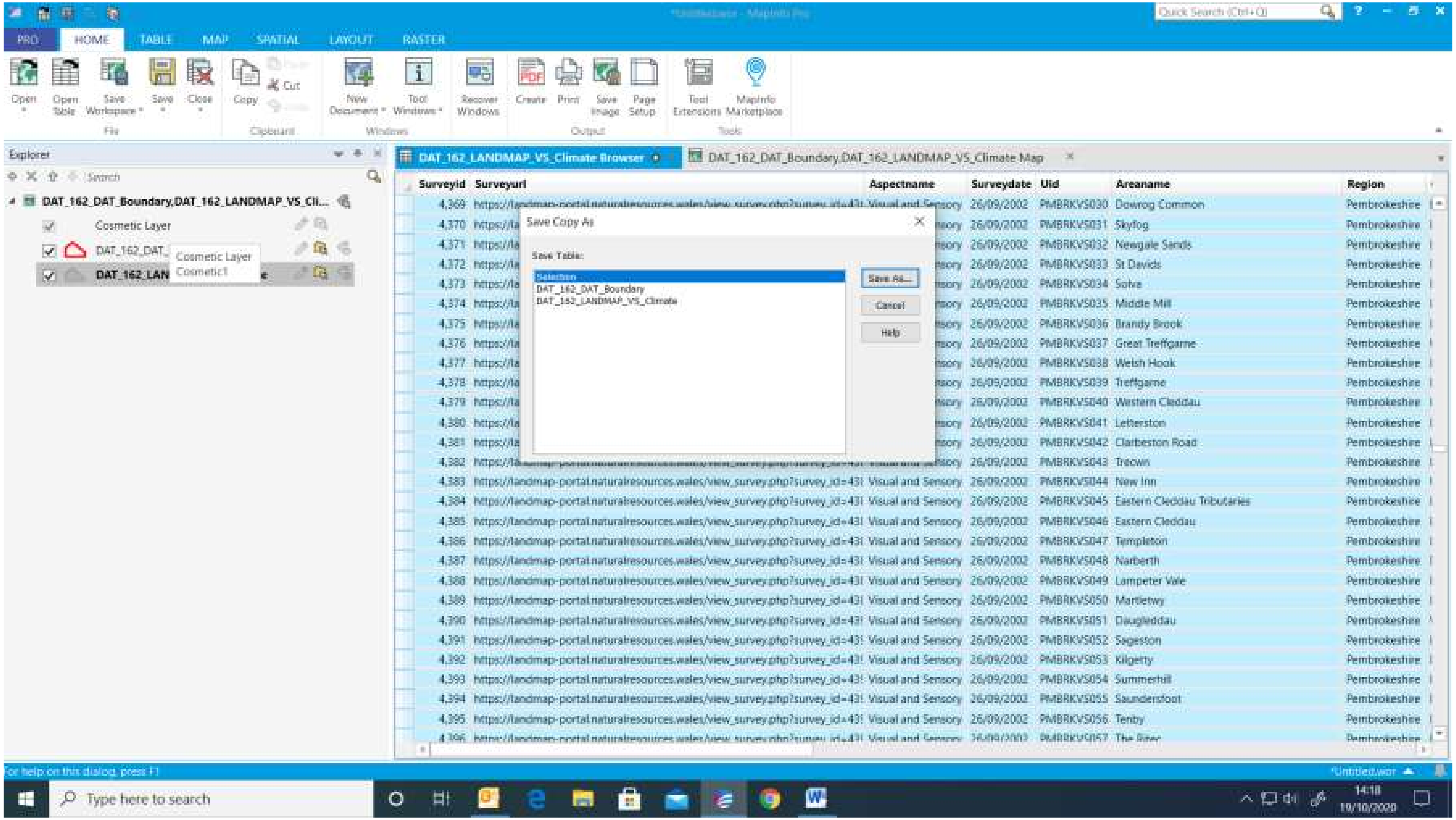
STEP 4

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.



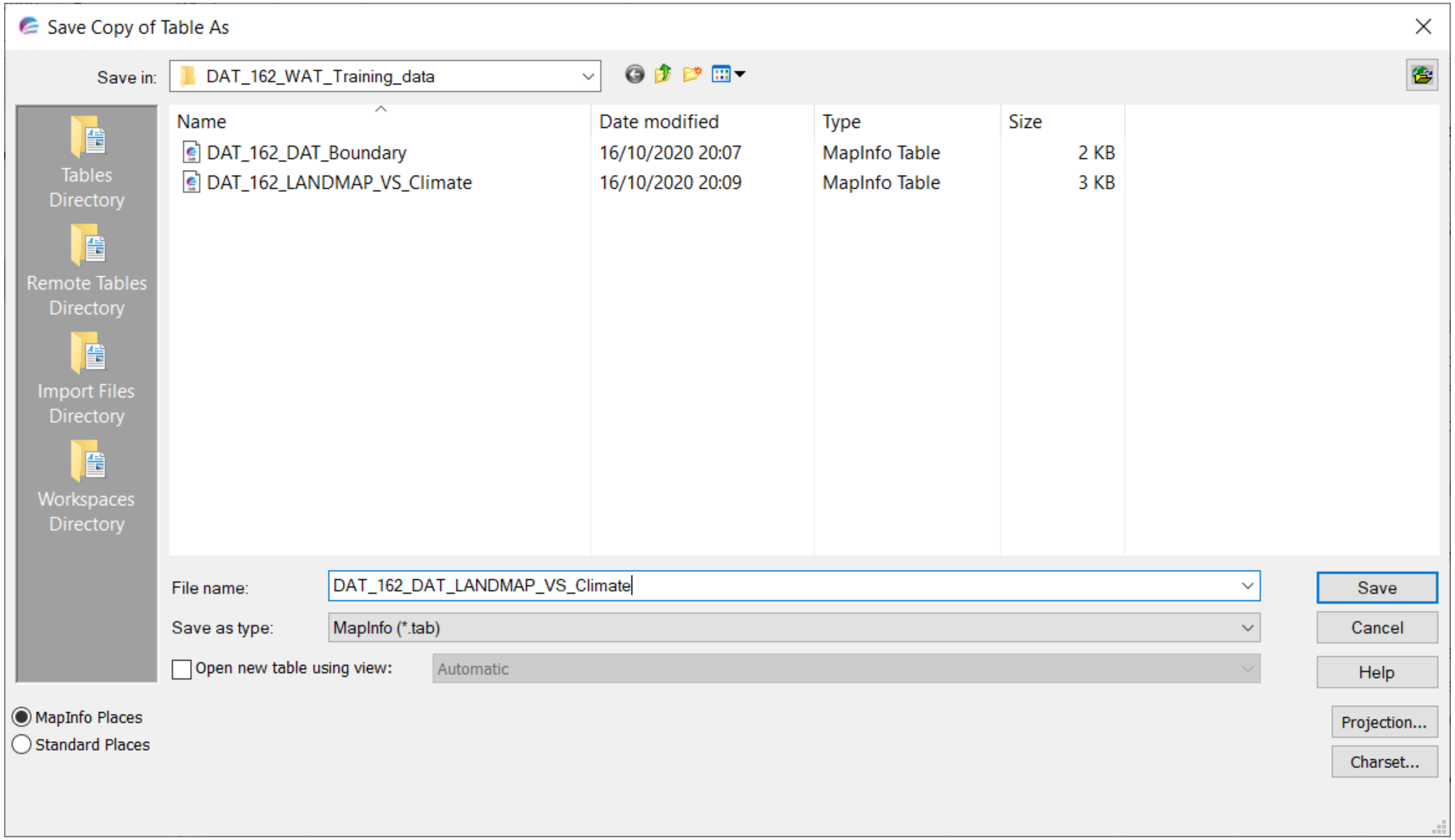
STEP 5

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



STEP 6

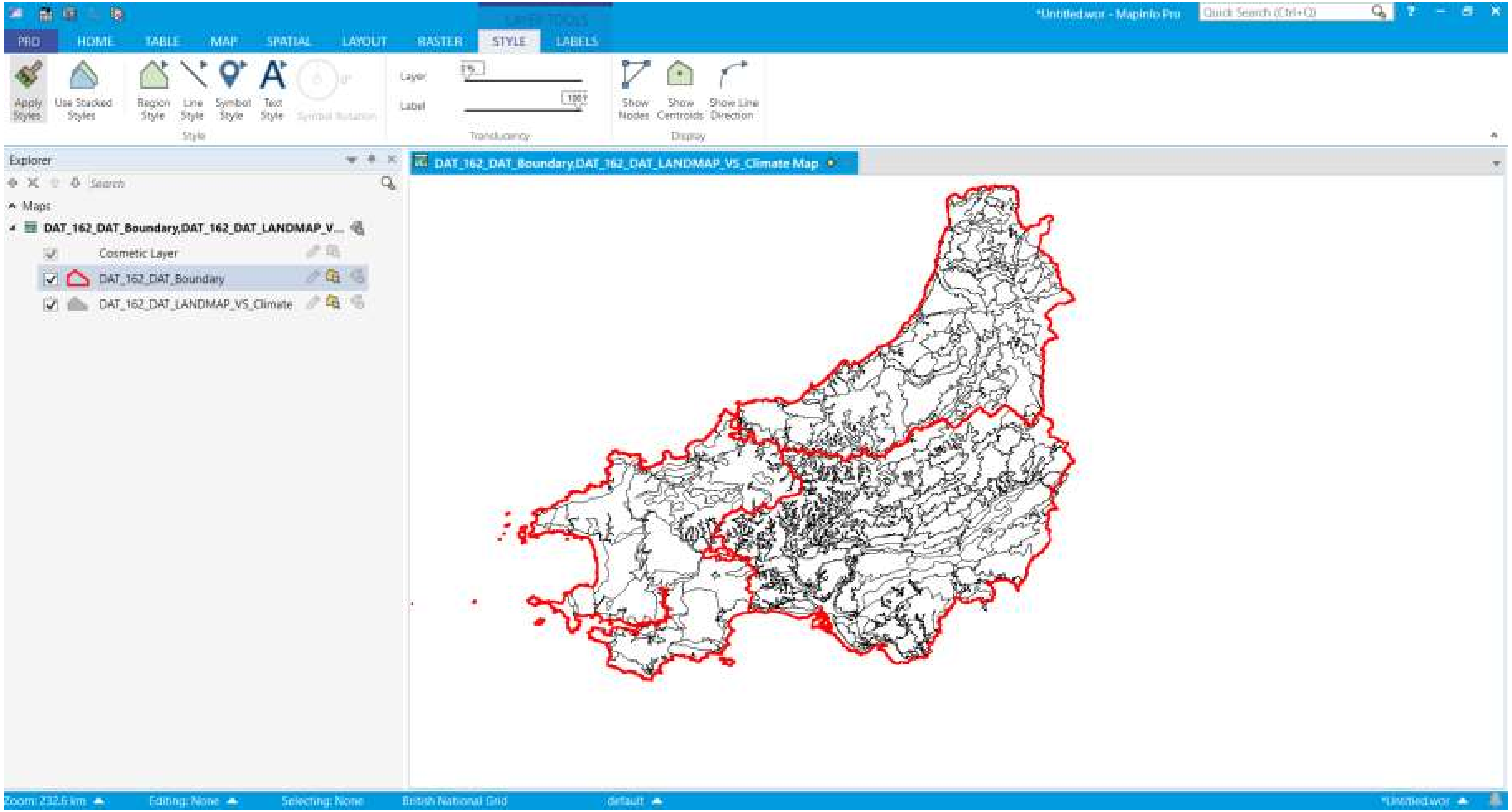
Save the table, prefixed with the WAT project code in your dedicated directory.



STEP 7

Open this new table into your workspace.

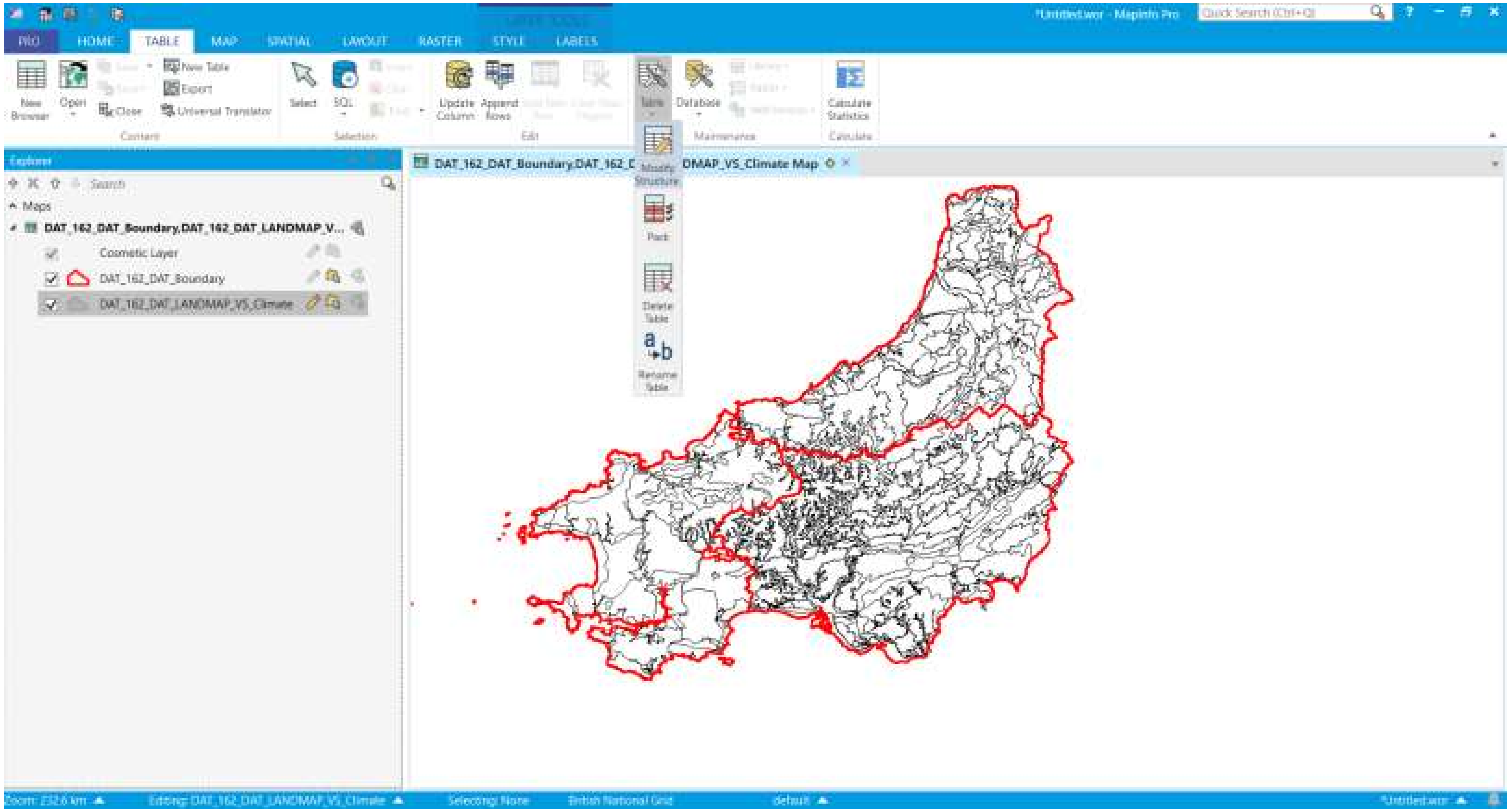
Save the workspace.



STEP 8

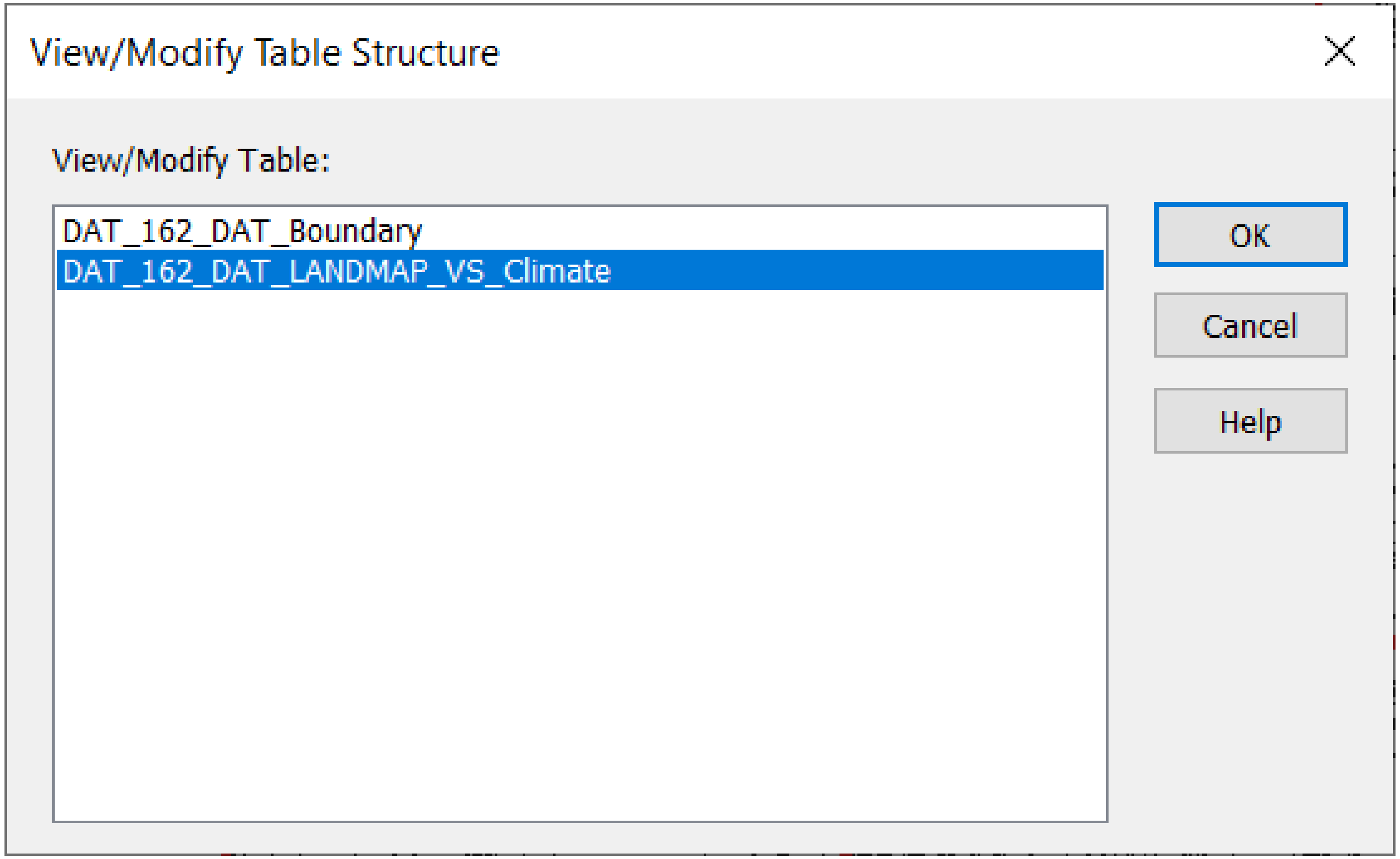
Now that the clipped LANDMAP table we must alter the table structure to accommodate the impact scoring.

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

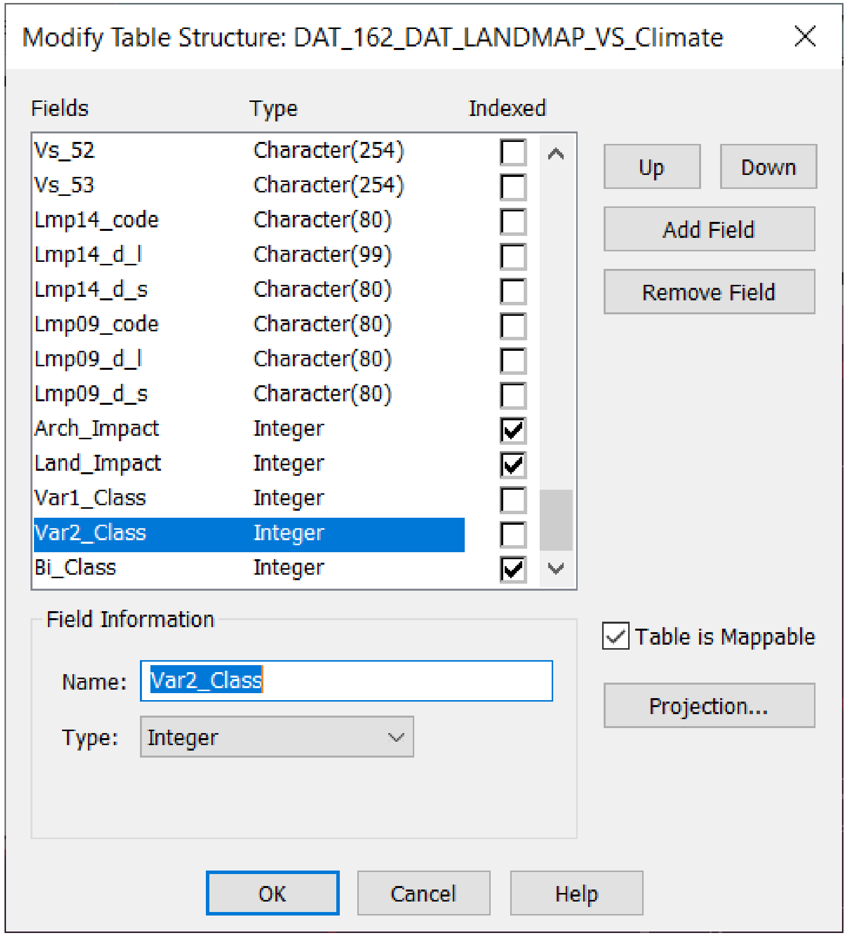
In the following popup select the LANDMAP table.



STEP 10

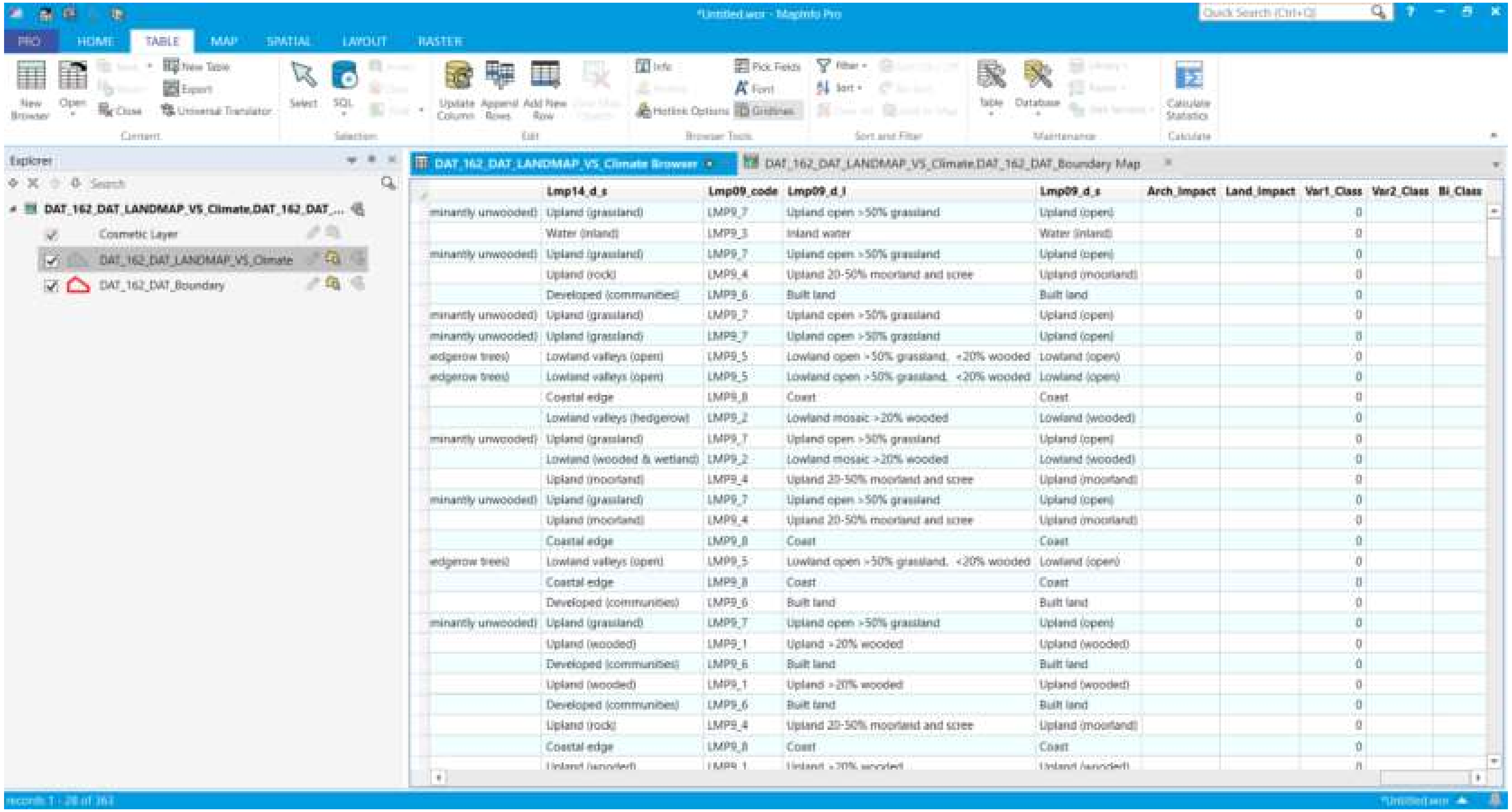
You will now see the table structure of the layer showing the attribute fields. Scroll to the end the list which should end in “lmp09_d_s”. Click “Add Field” and in turn, add the following 5 fields making sure that their types are Integers:

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.

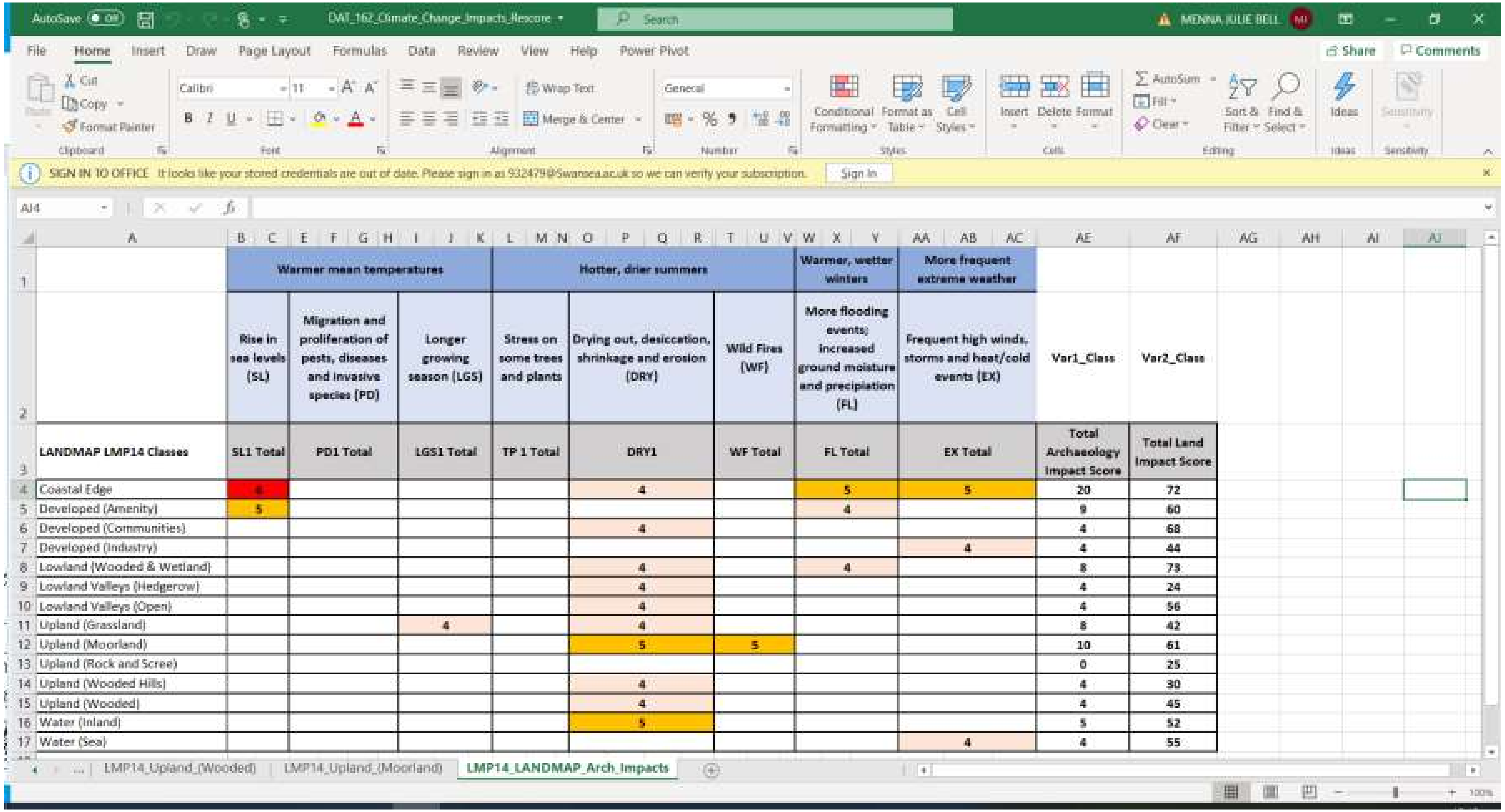


STEP 12

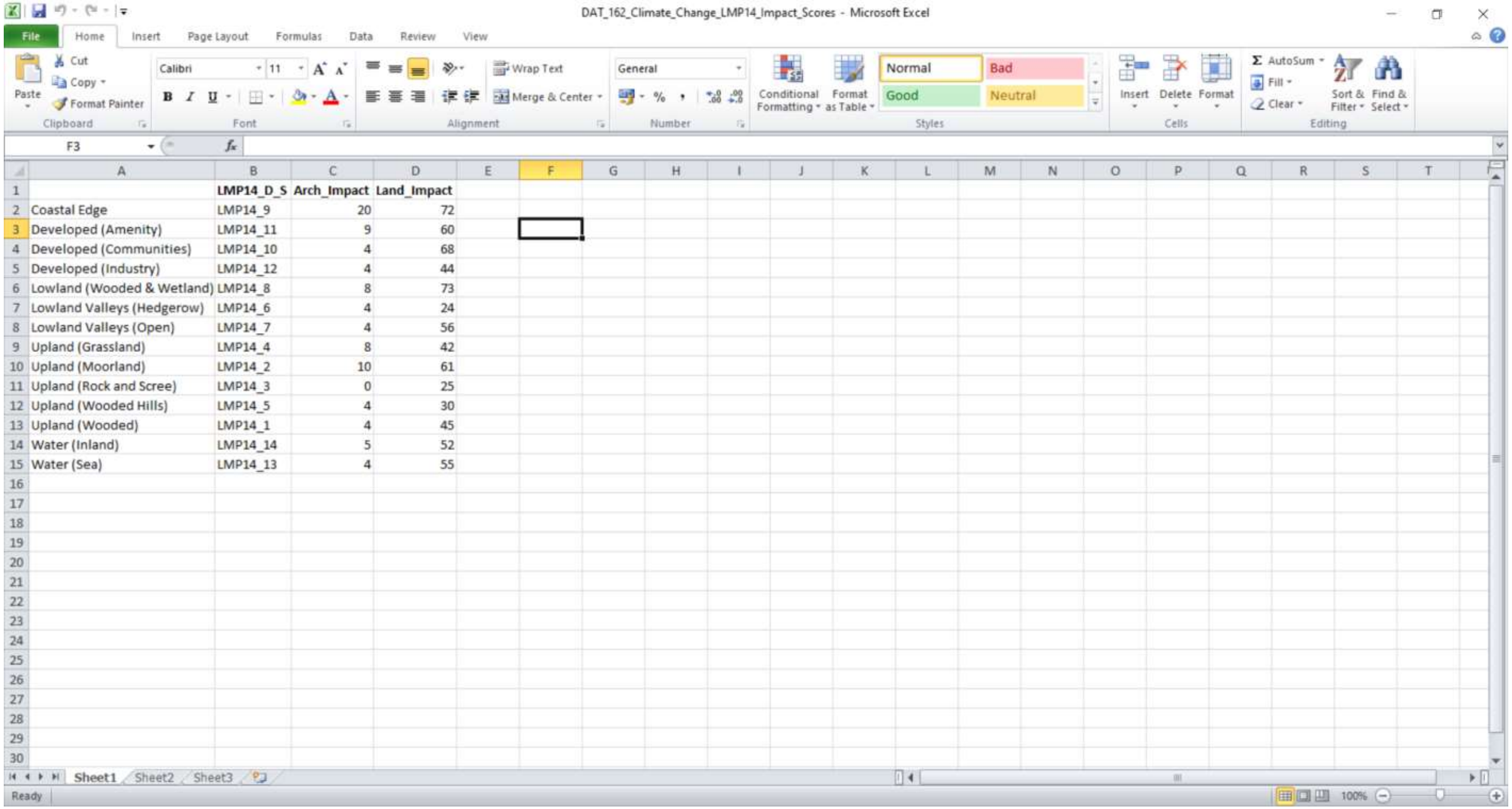
You are now going to need to refer to the "DAT_162_Climate_Change_Impacts_Rescore" and "DAT_162_Climate_Change_LMP14_Impact_Score" spreadsheets. Open these on a 2nd screen if you have one, it'll be easier to refer back to.

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 process 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.



	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather		
	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 precipiation (FL)	Frequent high winds, storms and heat/cold events (EX)	Var1_Class	Var2_Class
LANDMAP LMP14 Classes	SL1 Total	PD1 Total	LGS1 Total	TP 1 Total	DRY1	WF Total	FL Total	EX Total	Total Archaeology Impact Score	Total Land Impact Score
Coastal Edge	6				4		5	5	20	72
Developed (Amenity)	5						4		9	60
Developed (Communities)					4				4	68
Developed (Industry)								4	4	44
Lowland (Wooded & Wetland)					4		4		8	73
Lowland Valleys (Hedgerow)					4				4	24
Lowland Valleys (Open)					4				4	56
Upland (Grassland)			4		4				8	42
Upland (Moorland)					5	5			10	61
Upland (Rock and Scree)									0	25
Upland (Wooded Hills)					4				4	30
Upland (Wooded)					4				4	45
Water (Inland)					5				5	52
Water (Sea)								4	4	55



DAT_162_Climate_Change_LMP14_Impact_Scores - Microsoft Excel

	LMP14_D_S	Arch_Impact	Land_Impact
Coastal Edge	LMP14_9	20	72
Developed (Amenity)	LMP14_11	9	60
Developed (Communities)	LMP14_10	4	68
Developed (Industry)	LMP14_12	4	44
Lowland (Wooded & Wetland)	LMP14_8	8	73
Lowland Valleys (Hedgerow)	LMP14_6	4	24
Lowland Valleys (Open)	LMP14_7	4	56
Upland (Grassland)	LMP14_4	8	42
Upland (Moorland)	LMP14_2	10	61
Upland (Rock and Scree)	LMP14_3	0	25
Upland (Wooded Hills)	LMP14_5	4	30
Upland (Wooded)	LMP14_1	4	45
Water (Inland)	LMP14_14	5	52
Water (Sea)	LMP14_13	4	55

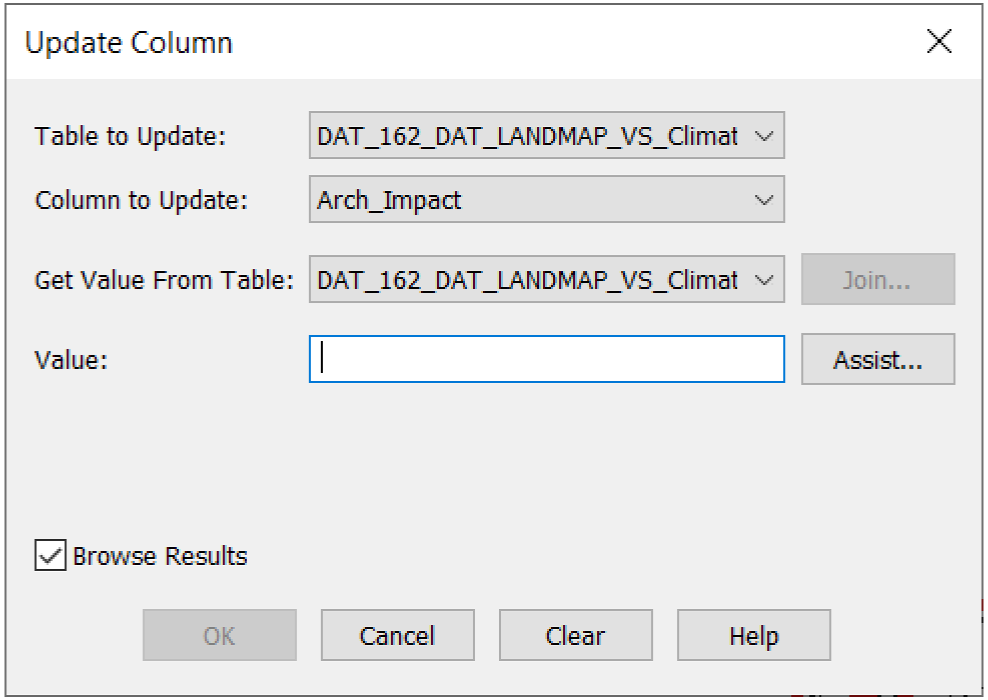
STEP 13

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.

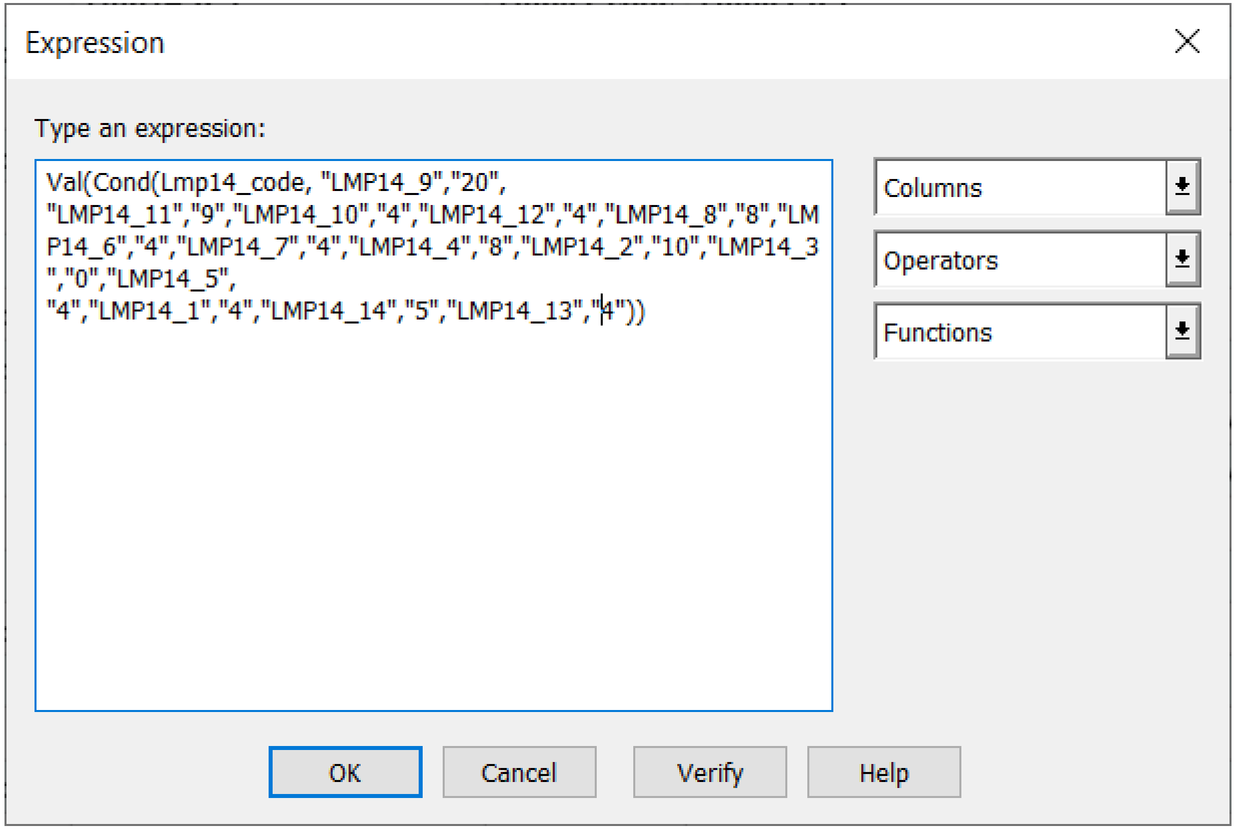
In the "Value" box click on "Assist".

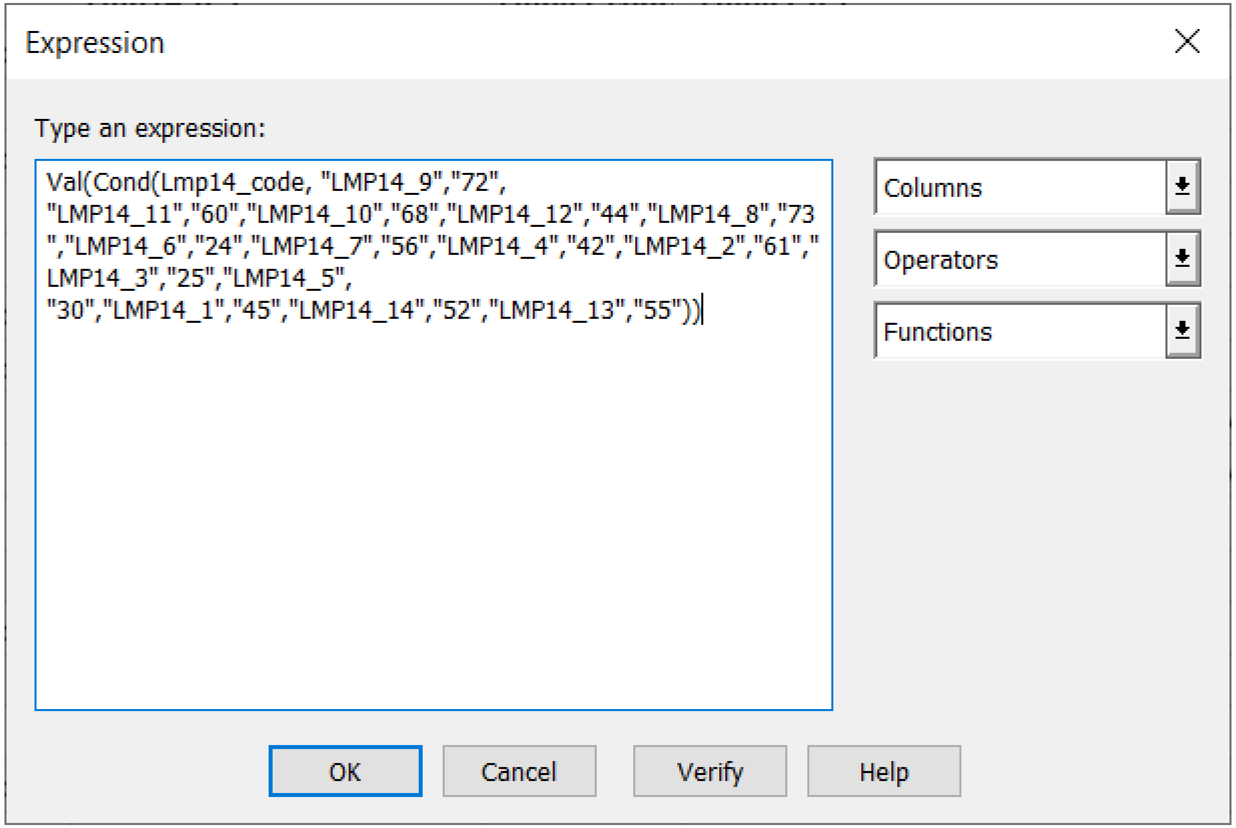


STEP 14

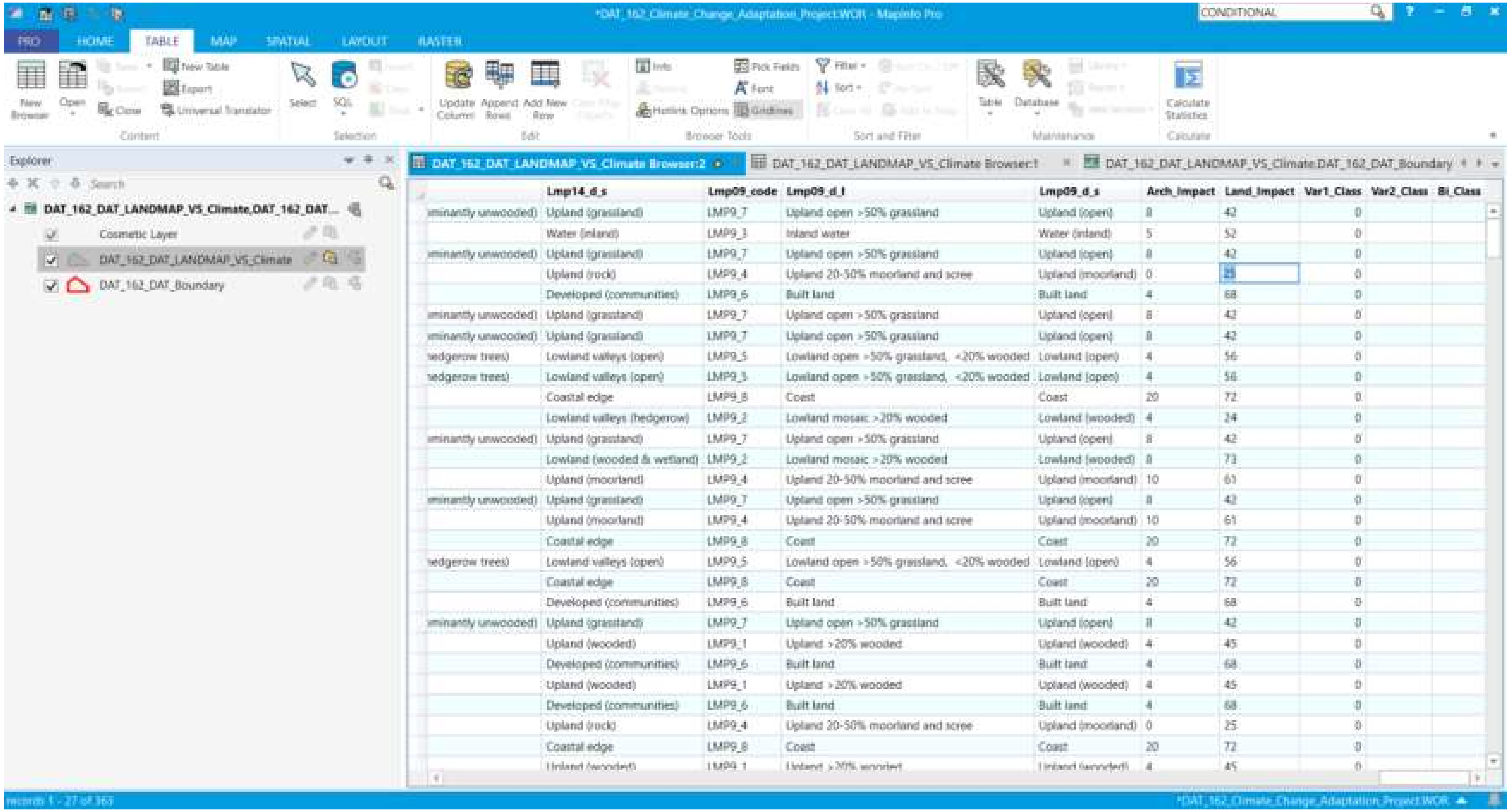
Open the “WATs_Climate_Change_Adaptation_Mapinto_function_syntax_ text file (it should open in Notepad).

We are going to use the MapInfo Con() function to populate the cells. Copy and past 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 its 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.




Expression
Type an expression:
Val(Cond(Lmp14_code, "LMP14_9","72",
"LMP14_11","60","LMP14_10","68","LMP14_12","44","LMP14_8","73
","LMP14_6","24","LMP14_7","56","LMP14_4","42","LMP14_2","61","
LMP14_3","25","LMP14_5",
"30","LMP14_1","45","LMP14_14","52","LMP14_13","55"))
Columns
Operators
Functions
OK
Cancel
Verify
Help

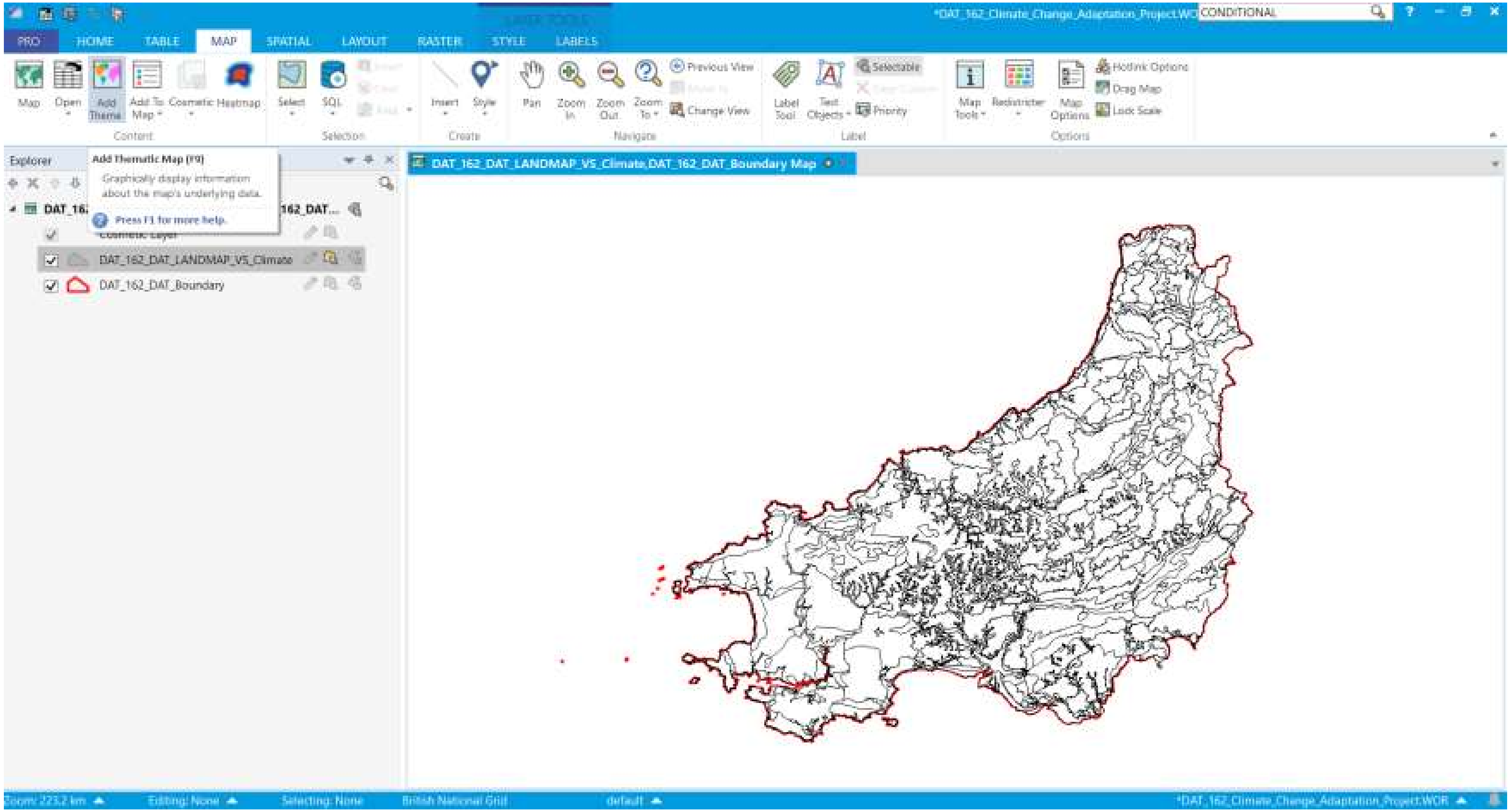
Once completed you can check by browsing the LANDMAP table to see if the columns have been updated.



STEP 15

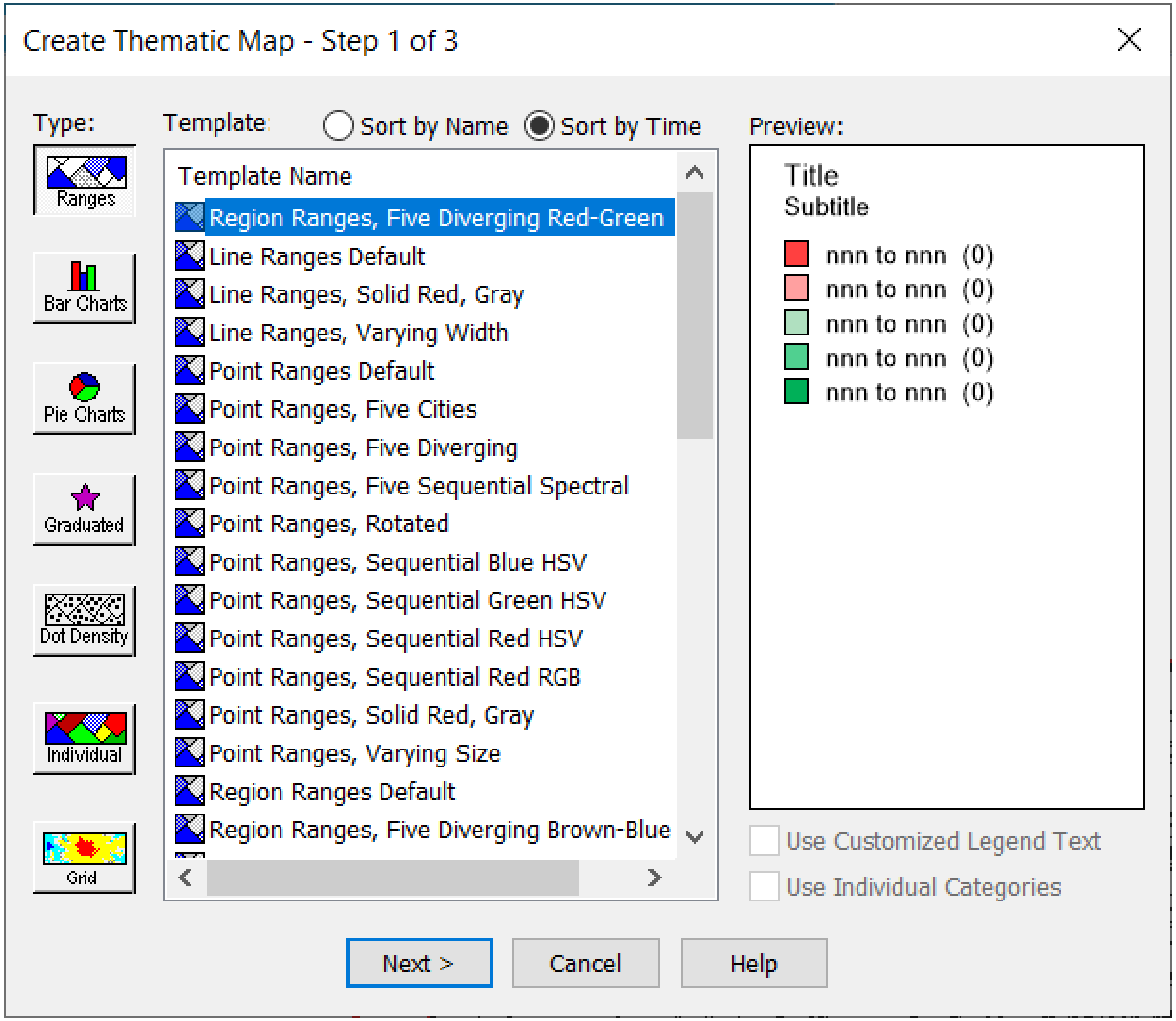
Now that these fields have been populated it is possible to classify this data to create the thematic mapping show the risk impacts in a traffic light colour scheme.

In the "Map" ribbon, click on the "Add Theme" icon in the "Content" tab.



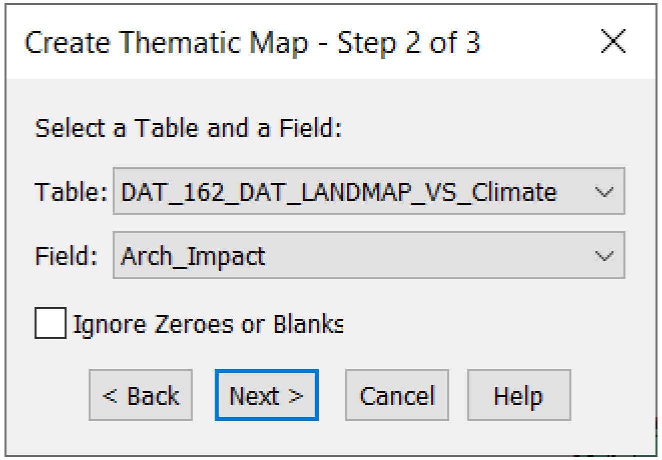
STEP 16

Select “Ranges” in the popup and the highlighted template.



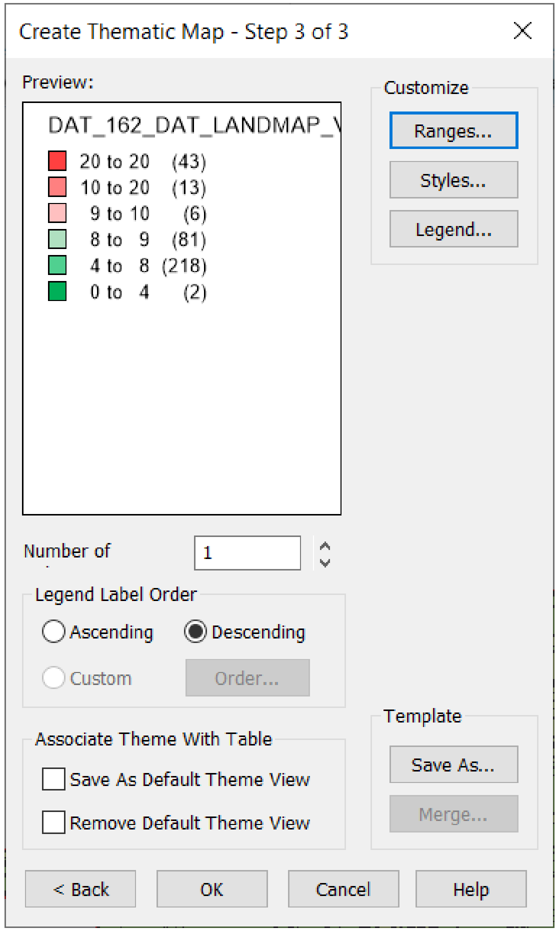
STEP 17

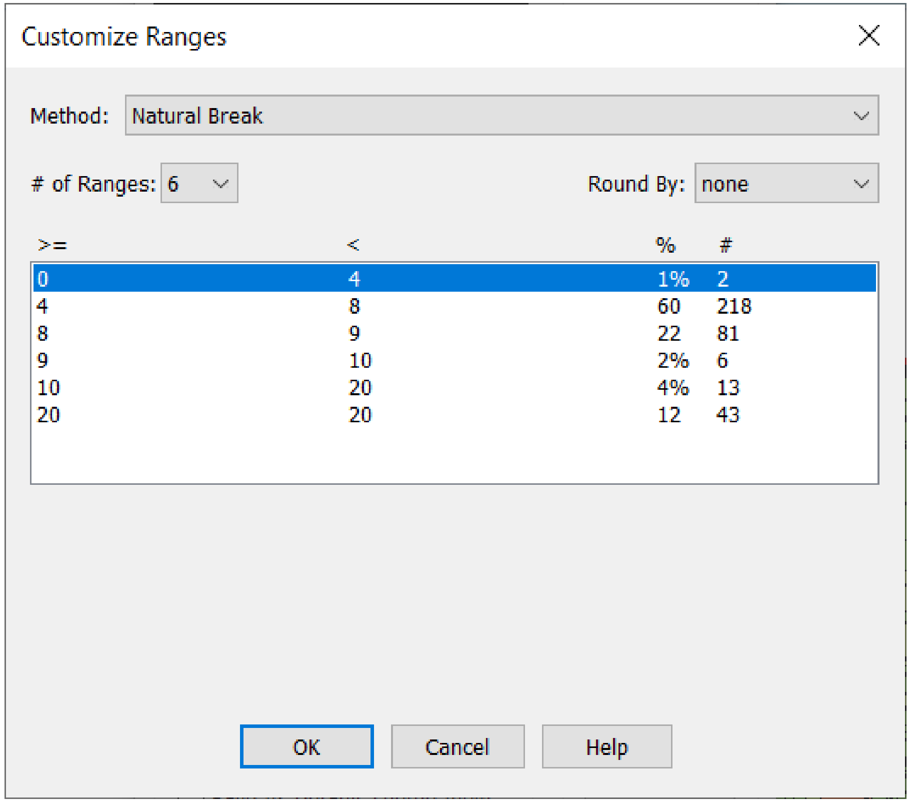
Select the LANDMAP table and the "Arch_Impact" field



STEP 18

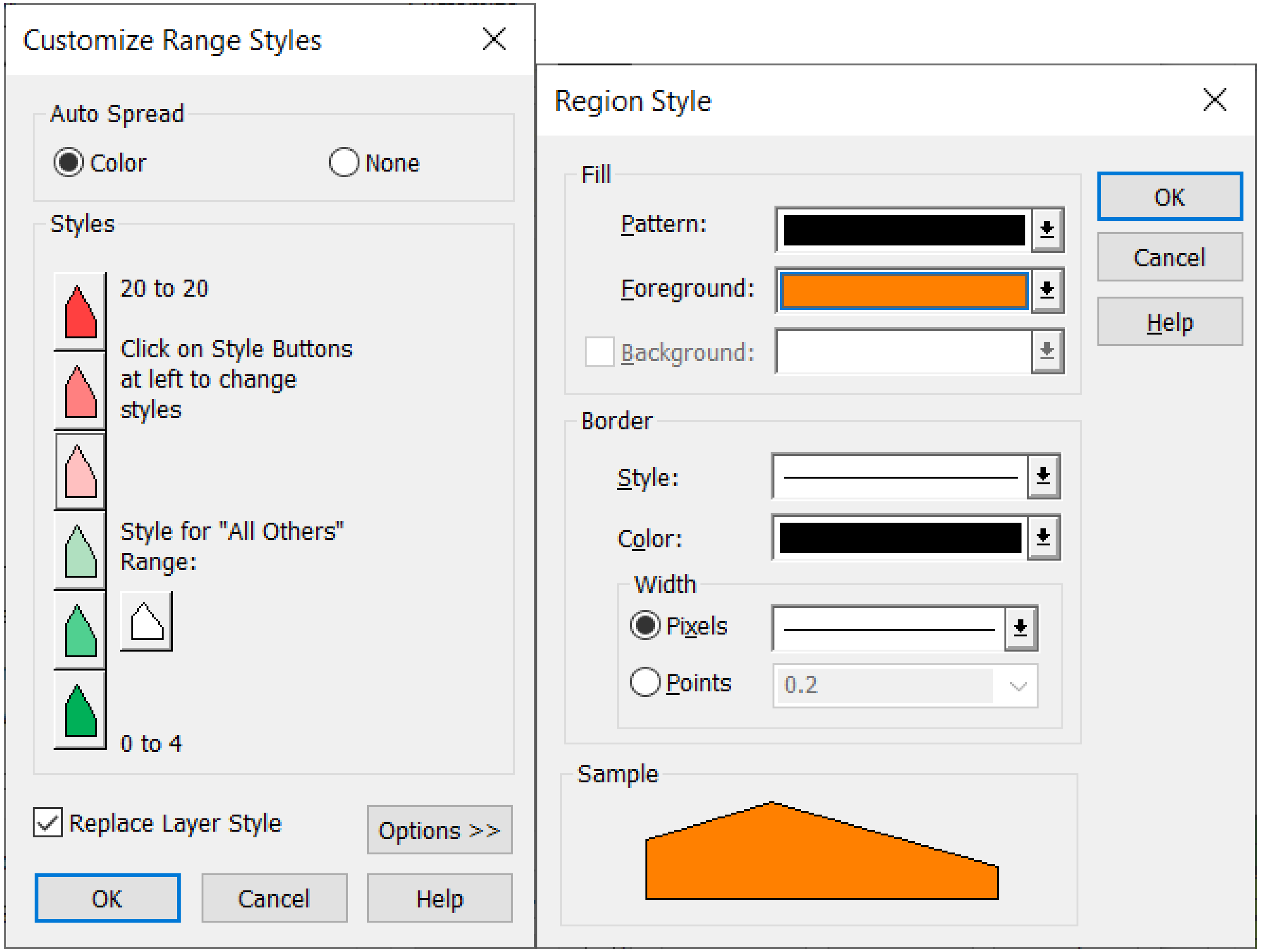
The default setting for this tool is to classify values into 5 ranges, we want 6 ranges. Click on the “Ranges”. In the following popup change the number of ranges to 6 and the classifying method to “Natural Break”. Click on “Recalc” to reclassify the values. Click ok





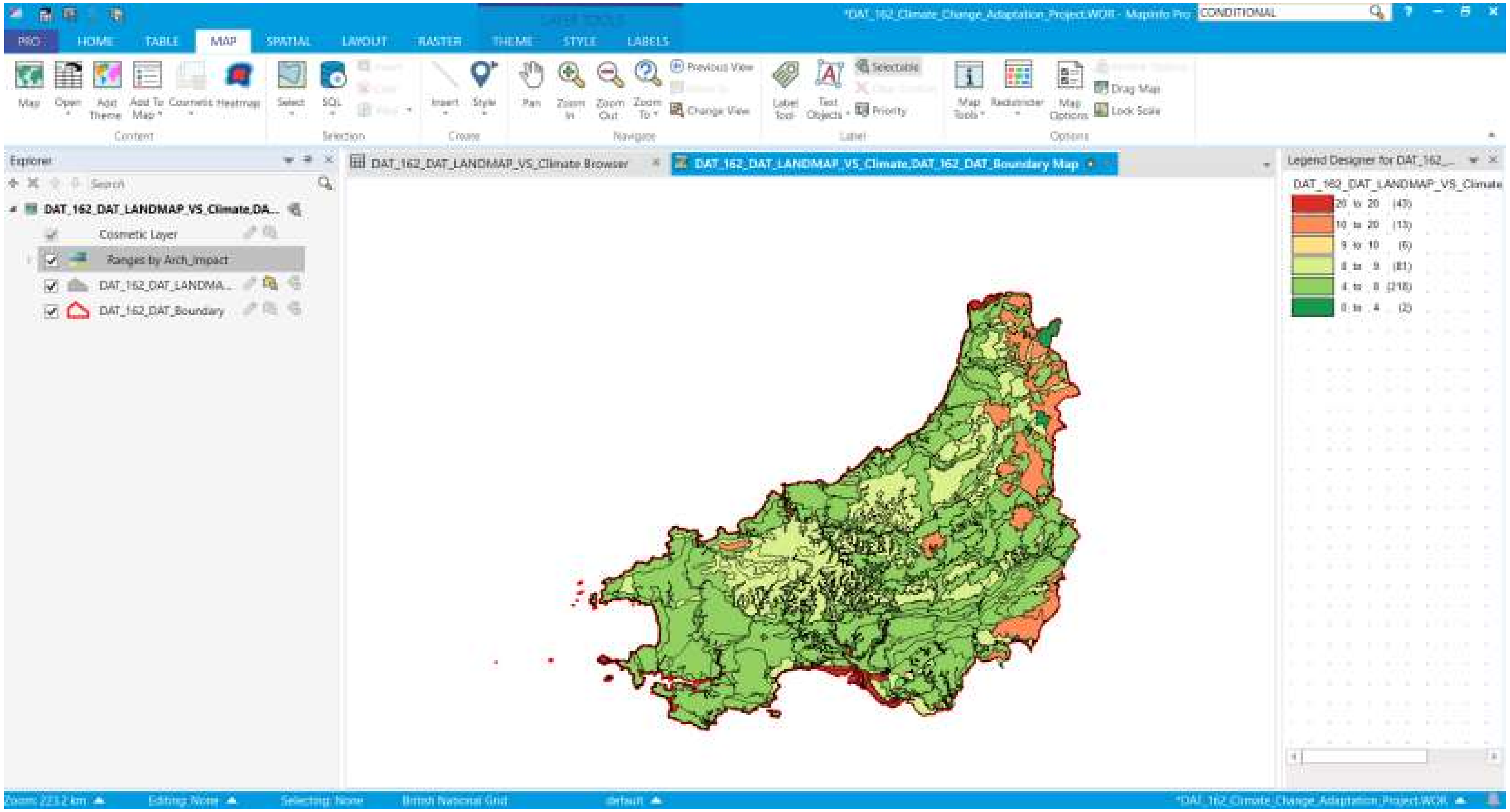
STEP 19

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.



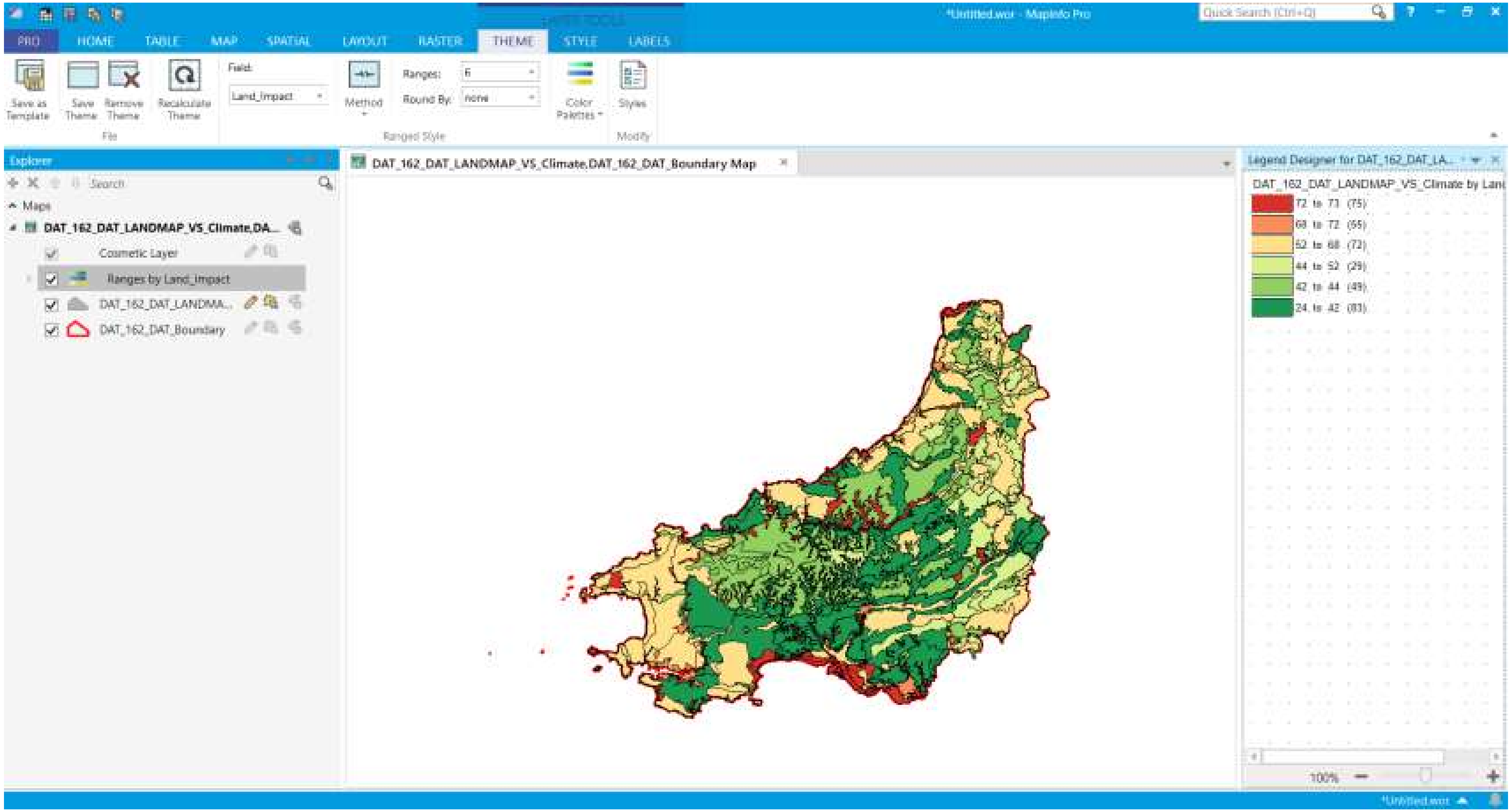
STEP 20

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



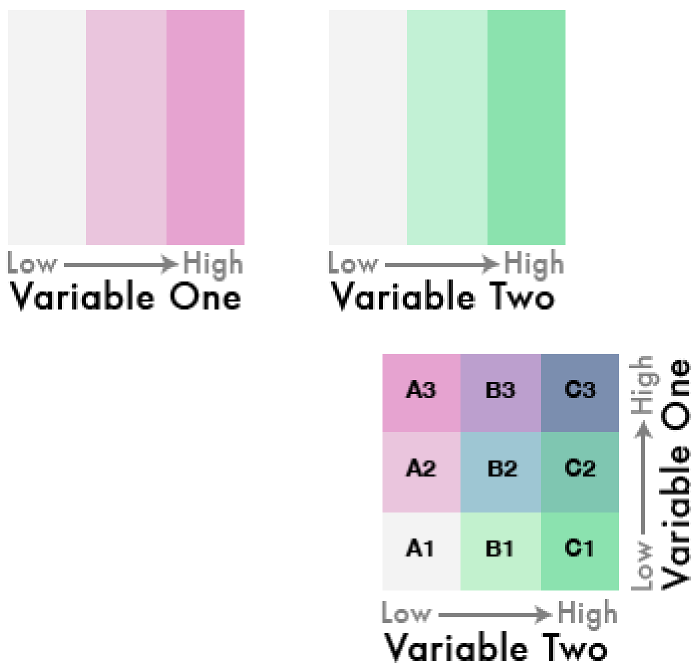
STEP 21

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 its 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: bivariate mapping

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

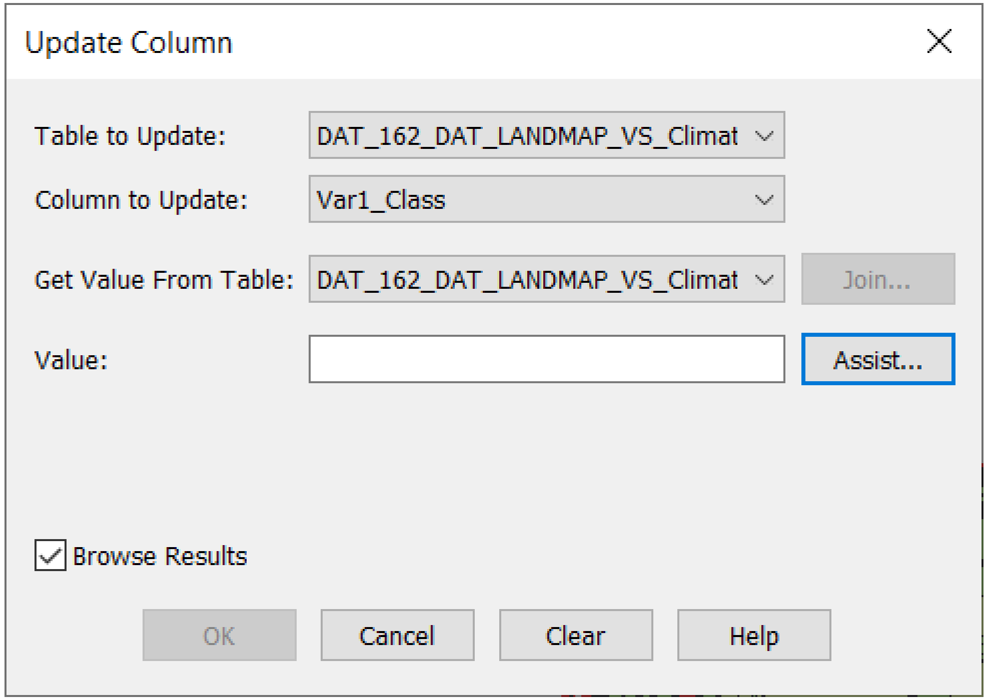
Before we can begin this process, we must normalise our data. This is what "Var1_Class" and "Var2_Class" fields are for. We need to reclassify the values in the "Arch_Impact" and "Land_Impact" columns in to 6 classes. I have chosen to use 1 to 6 as the ranges where in both variables 6 is equivalent to the highest scores and 1 is lowest. In other examples of bivariate maps that I have seen, it often that the two variable 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

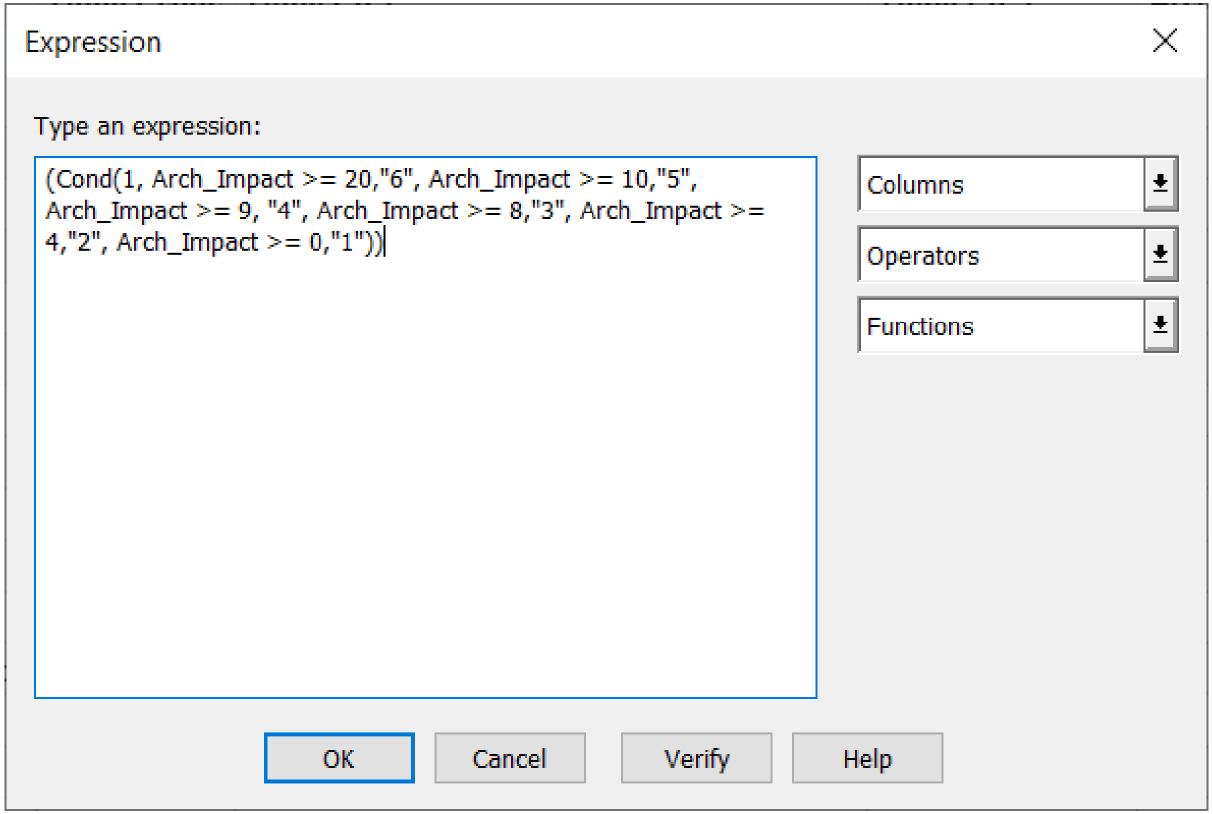
Refer to the "DAT_162_Climate_Change_LMP14_Impact_Scores" to see how this tallies with the land classes and the two variable total scores.

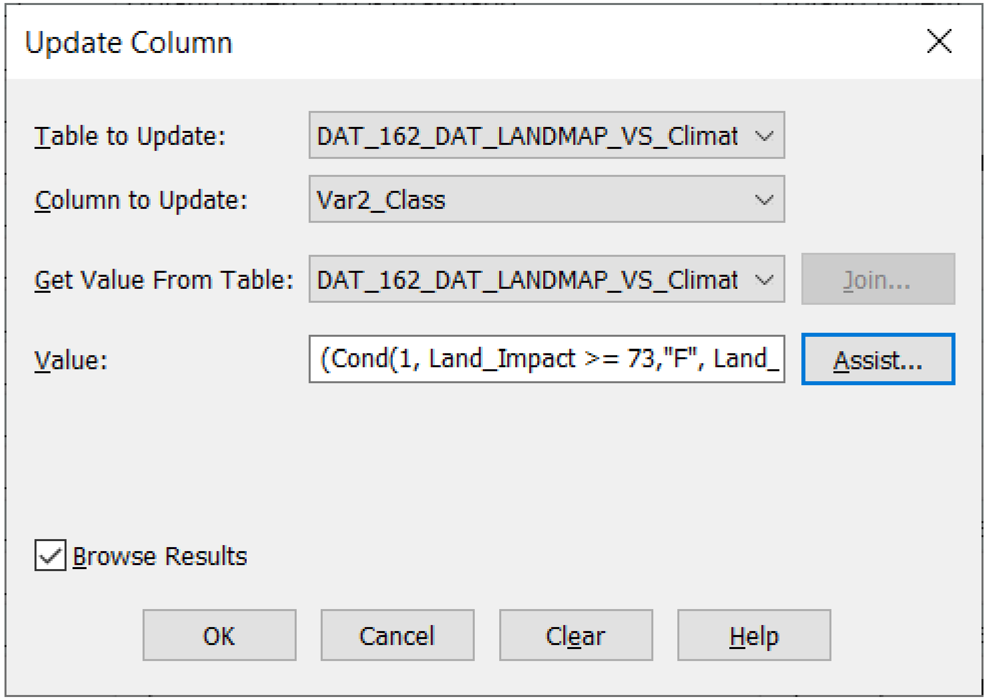
The reclassifying process is based on the ranges produced in steps 20 and 21 (and shown in the above table). Populating the "Var1_Class" and "Var2_Class" columns used the same condition processing as before (make sure that the table is editable!):

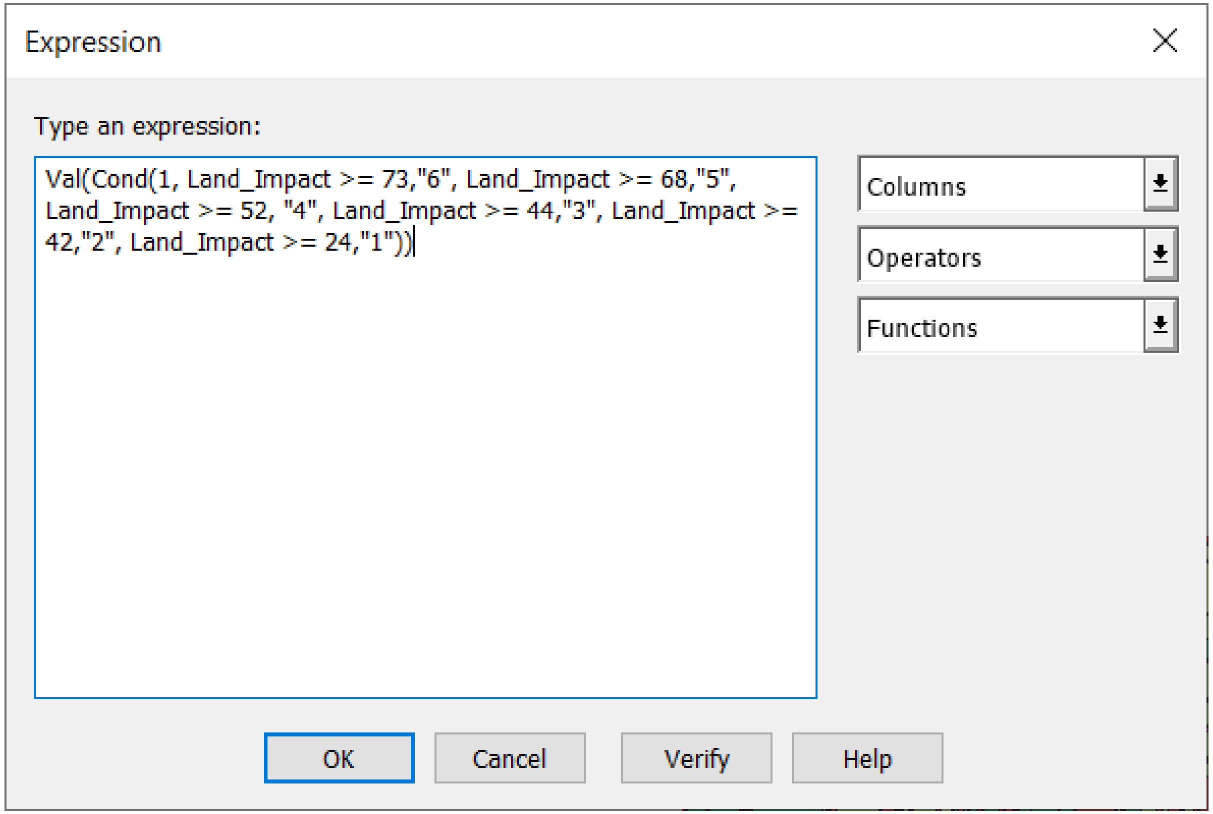


STEP 24

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

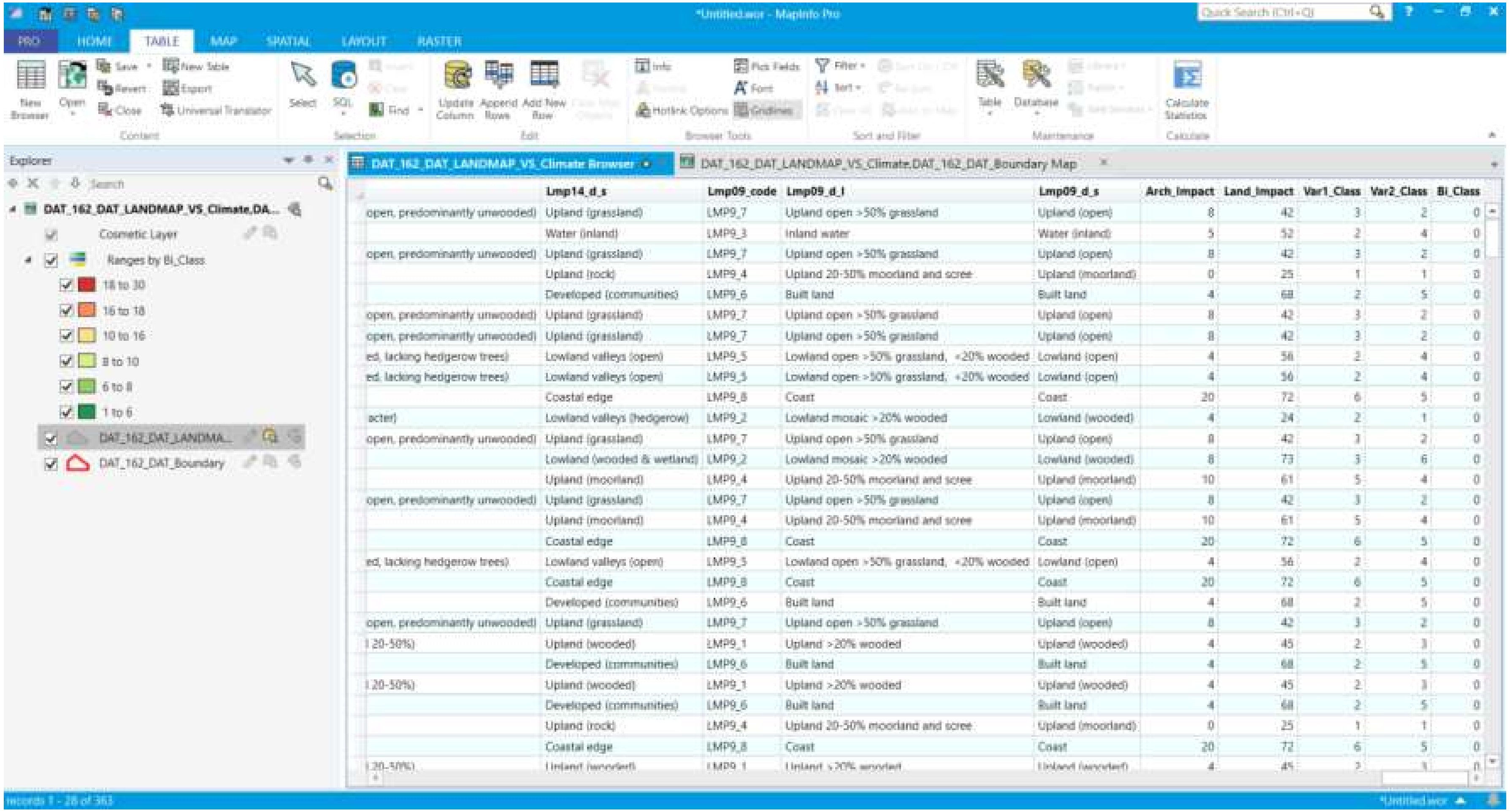



Update Column
Table to Update:
DAT_162_DAT_LANDMAP_VS_Climat
Column to Update:
Var2_Class
Get Value From Table:
DAT_162_DAT_LANDMAP_VS_Climat
Join...
Value:
(Cond(1, Land_Impact >= 73,"F", Land_
Assist...
Browse Results
OK
Cancel
Clear
Help


Expression
Type an expression:
Val(Cond(1, Land_Impact >= 73,"6", Land_Impact >= 68,"5", Land_Impact >= 52, "4", Land_Impact >= 44,"3", Land_Impact >= 42,"2", Land_Impact >= 24,"1"))
Columns
Operators
Functions
OK
Cancel
Verify
Help

STEP 25

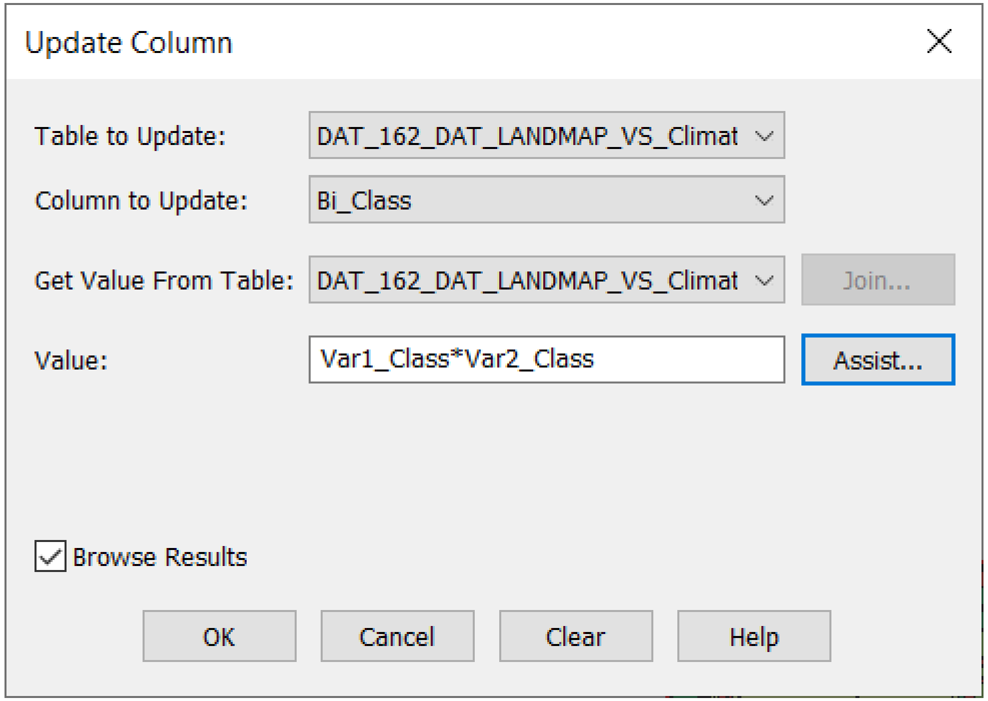
You can browse the table to check the values in these fields.



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.

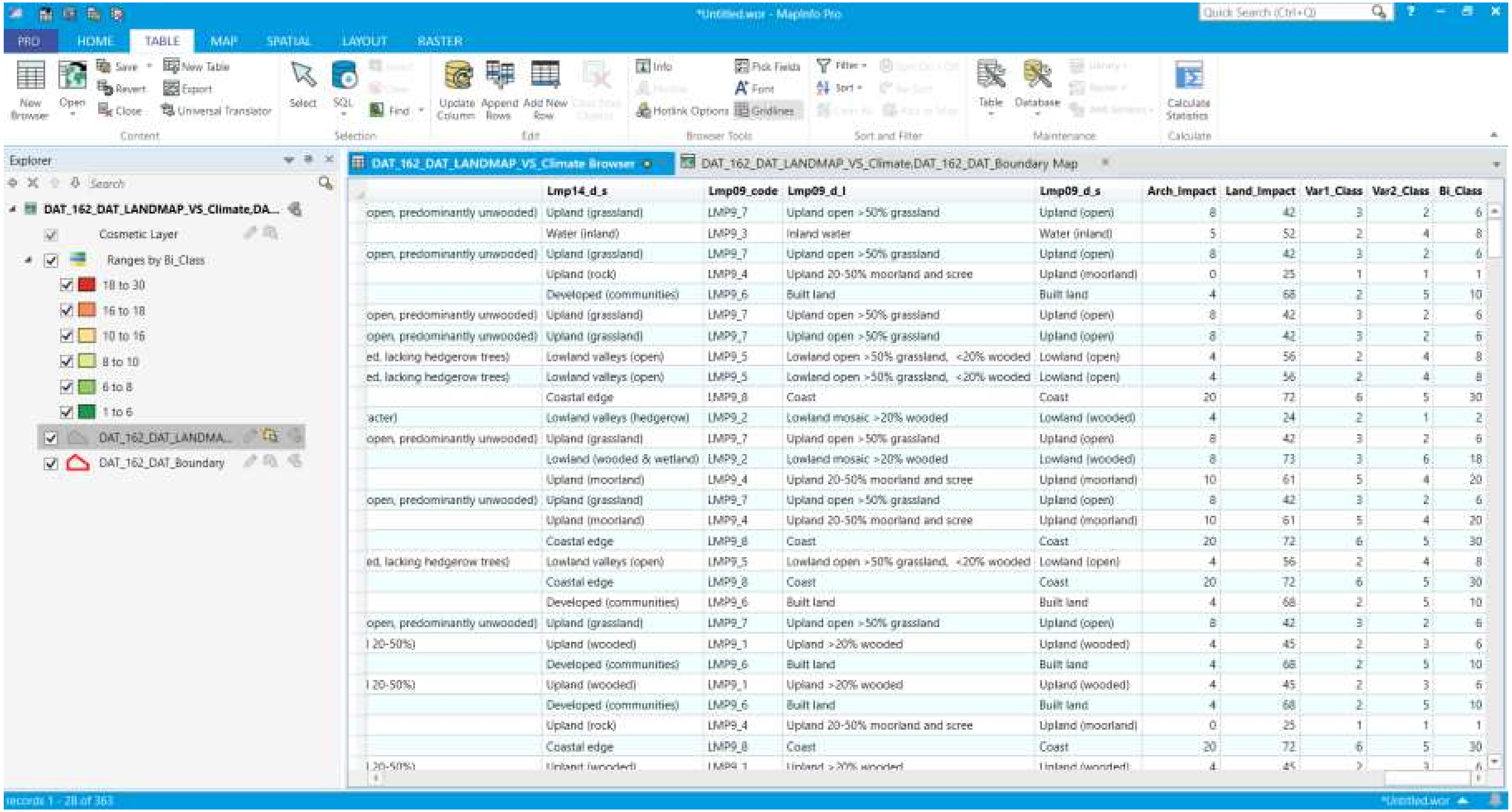
Copy the following text into the "Value" box in the "Update Column" box:



STEP 27

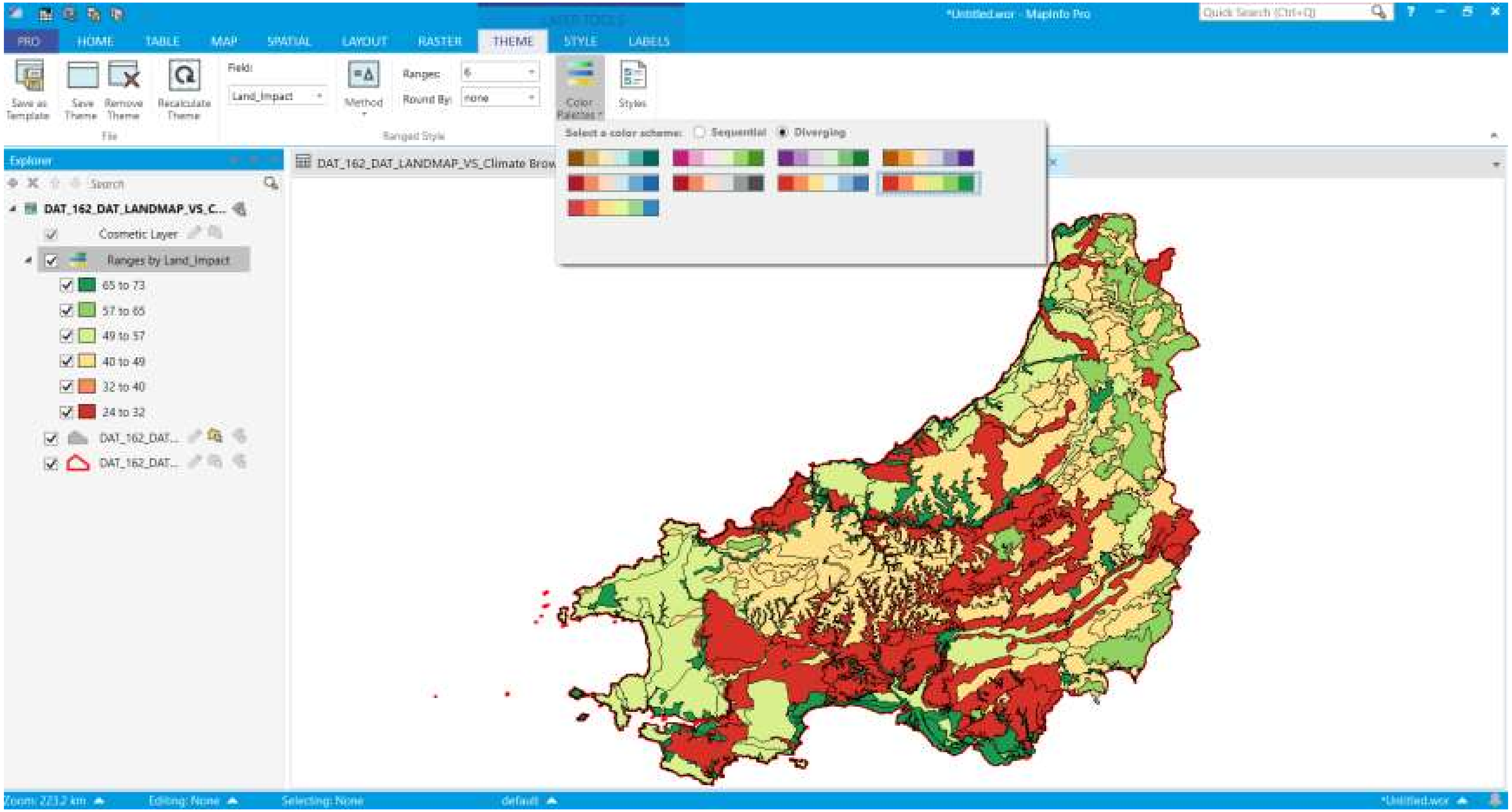
Check the table in the browser to see the values. Sort columns as you wish and refer back to the spreadsheets and range tables to make sense of it.

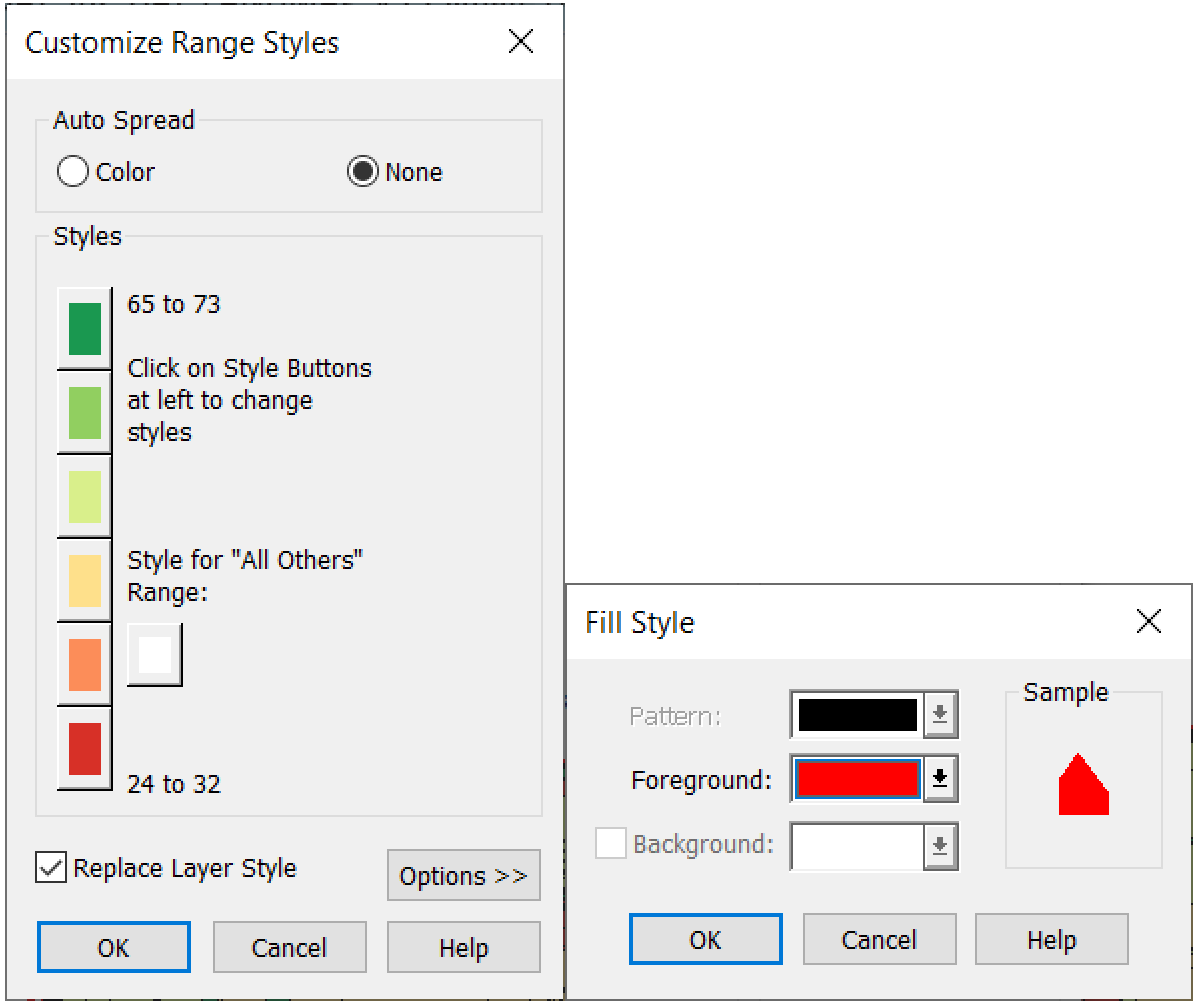
SAVE THE LANDMAP TABLE.



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.

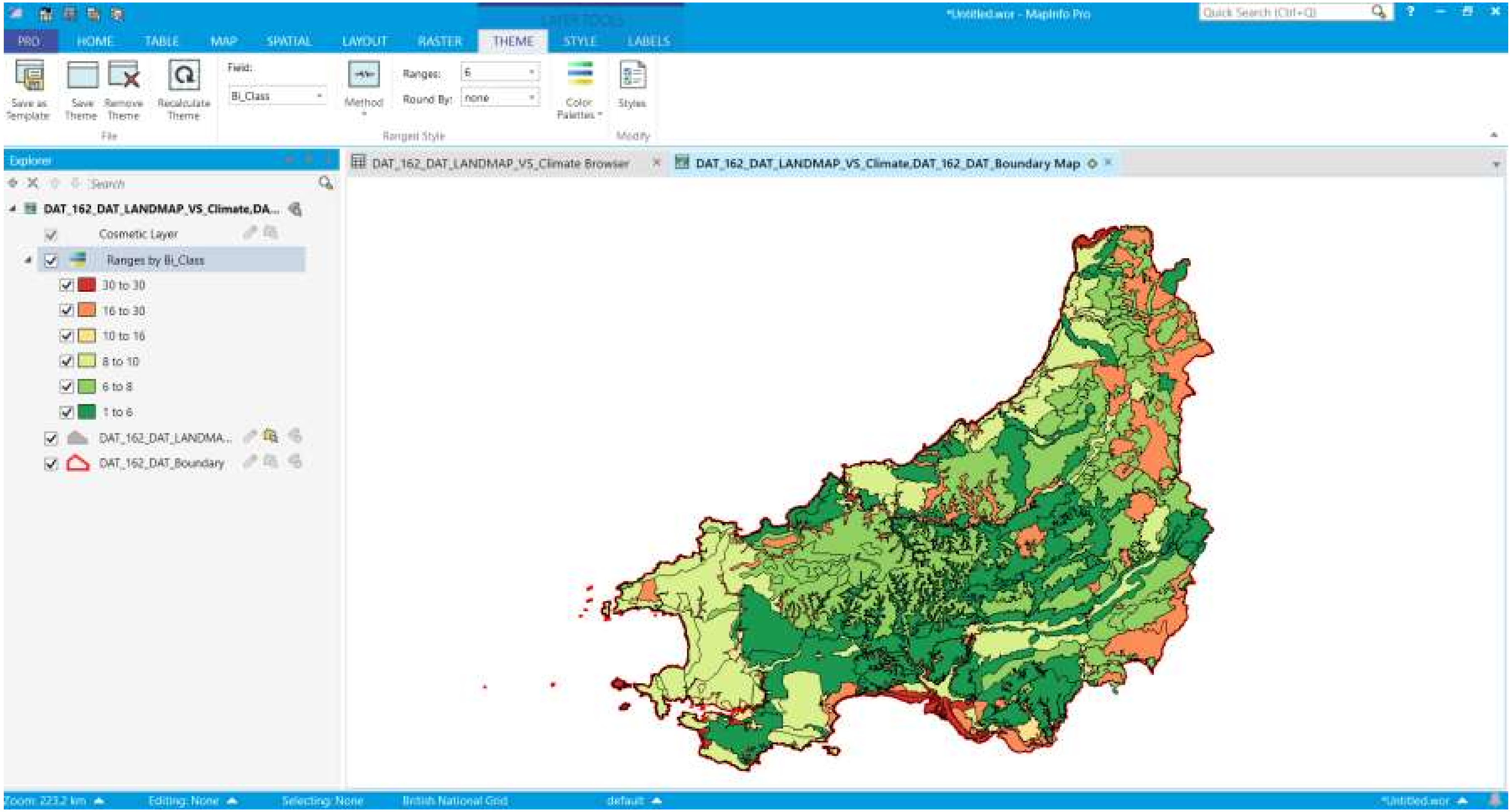



Customize Range Styles
Auto Spread
Color
None
Styles
65 to 73
Click on Style Buttons at left to change styles
Style for "All Others" Range:
24 to 32
Replace Layer Style
Options >>
OK
Cancel
Help
Fill Style
Pattern:
Foreground:
Background:
Sample
OK
Cancel
Help

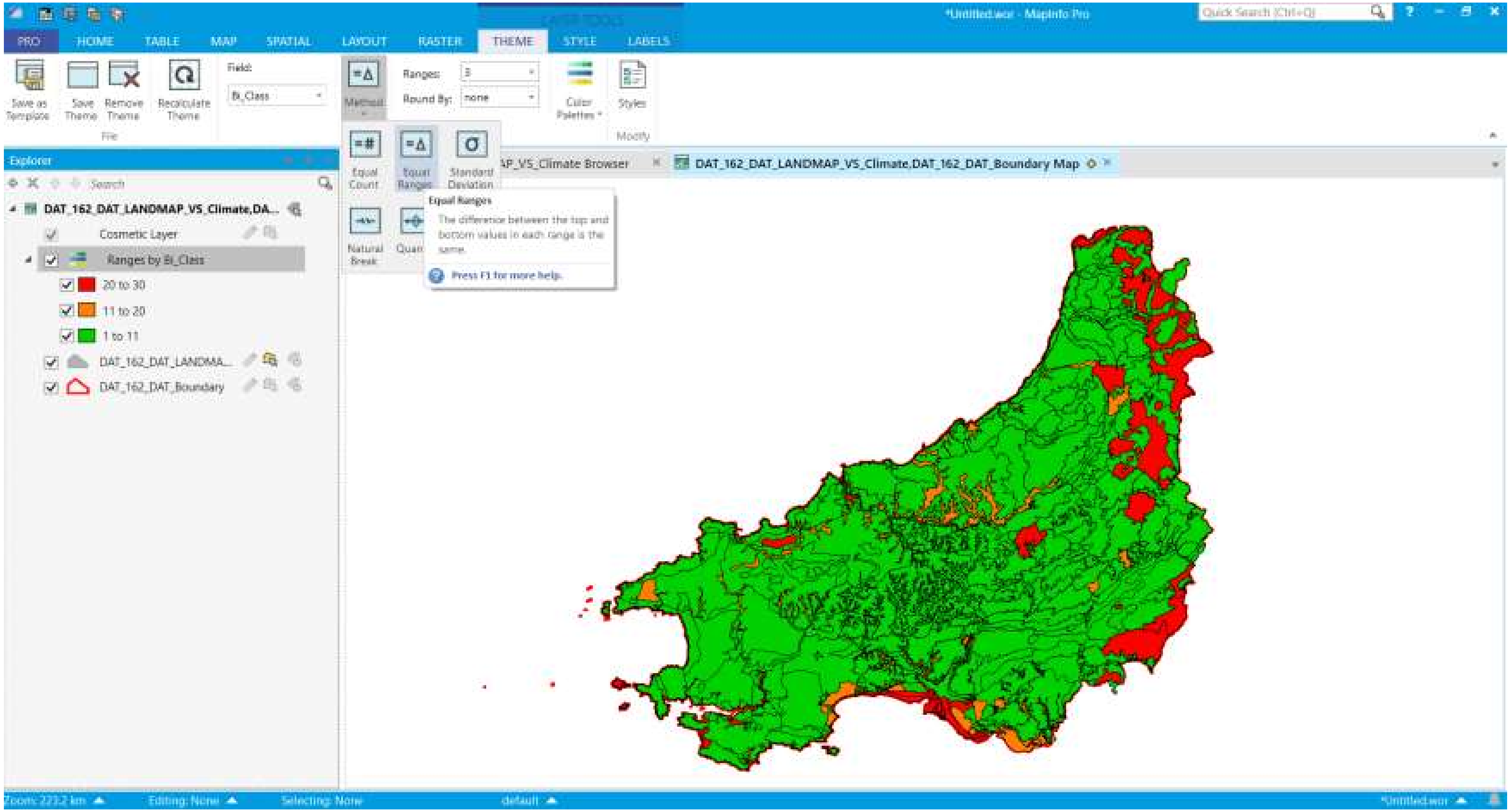
STEP 29: the final bivariate map

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



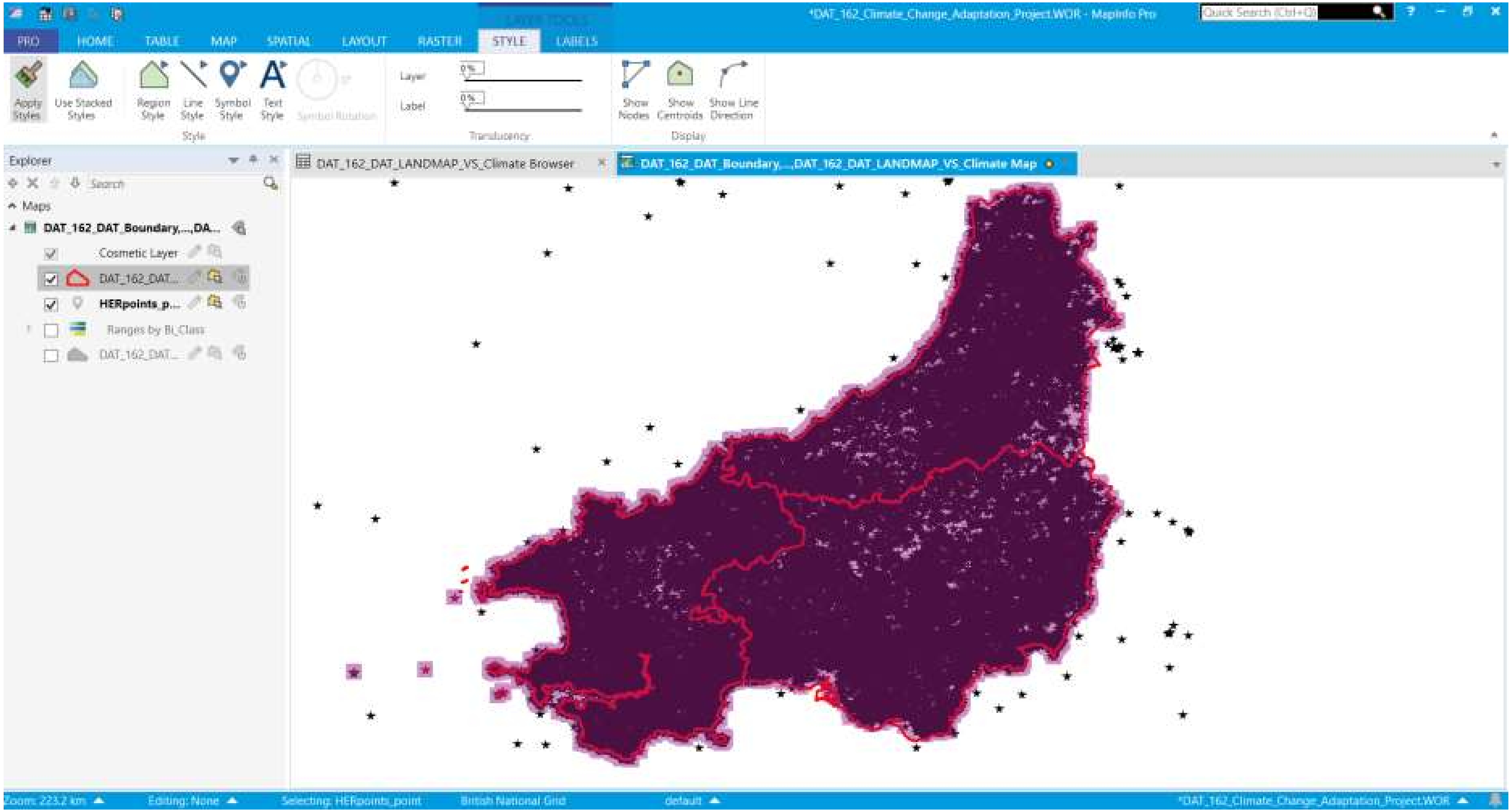
It is possible to change this to 3 ranges to create a broad “High”, “Medium” and “Low” risk map such as this:



STEP 30: adding data to the map

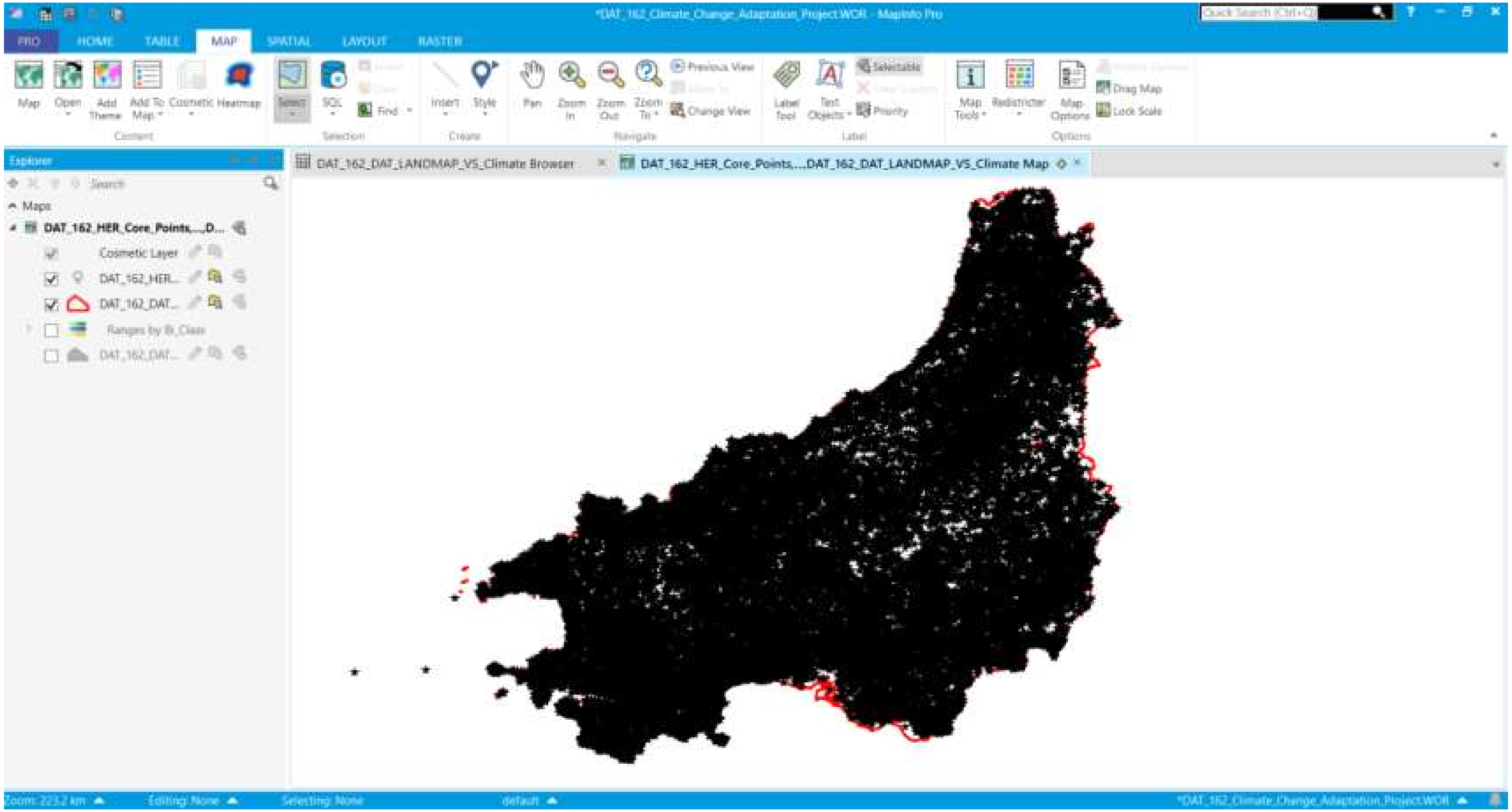
Now that we have our classified base map it is possible to overlay our historic environment data, beginning with the HER Core point data.

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 is:

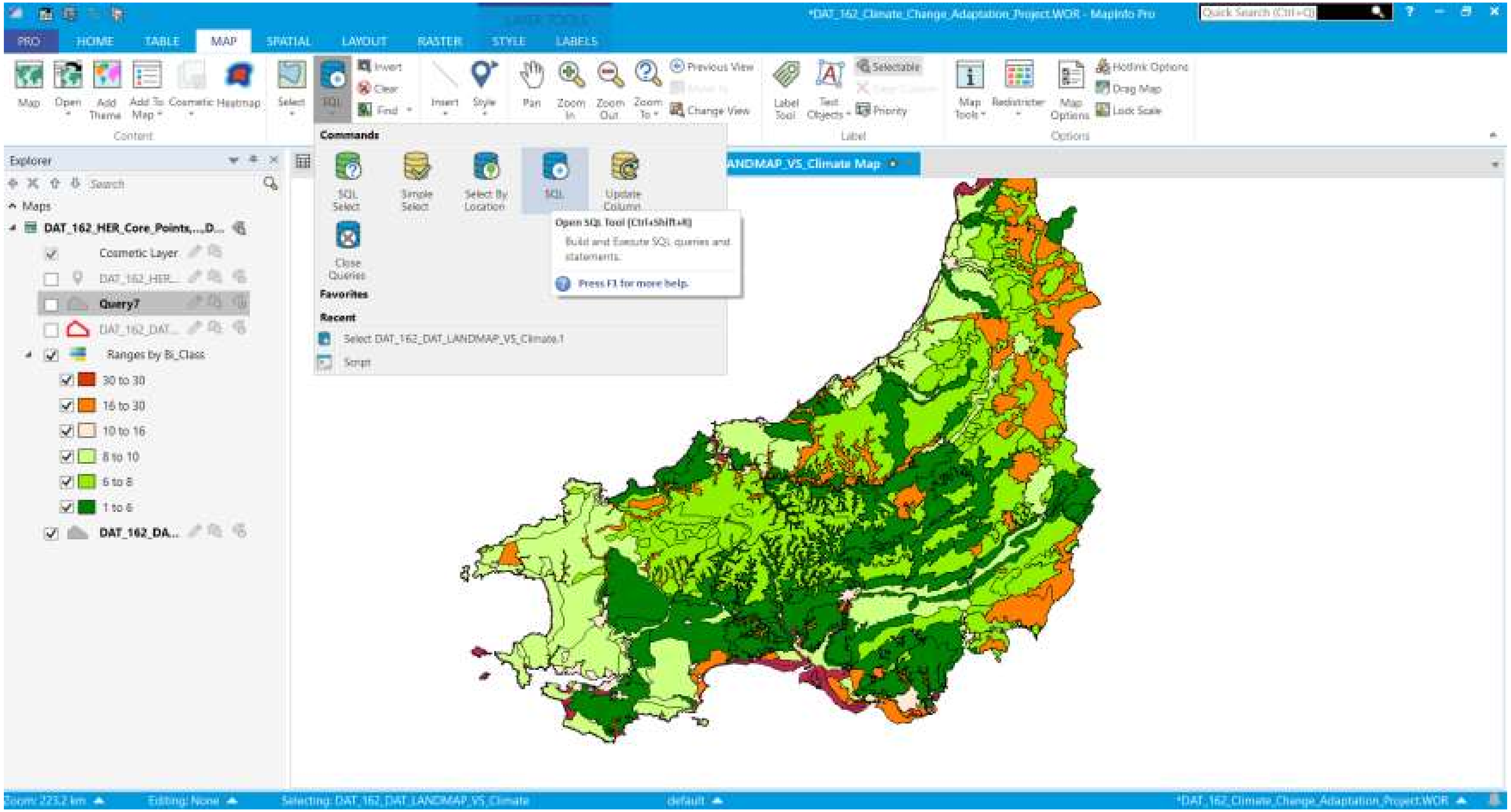
Bi_Class Score	Risk level
30	Highest
20	
18	
16	
10	
8	
6	
2	
1	Level

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: SQL

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.

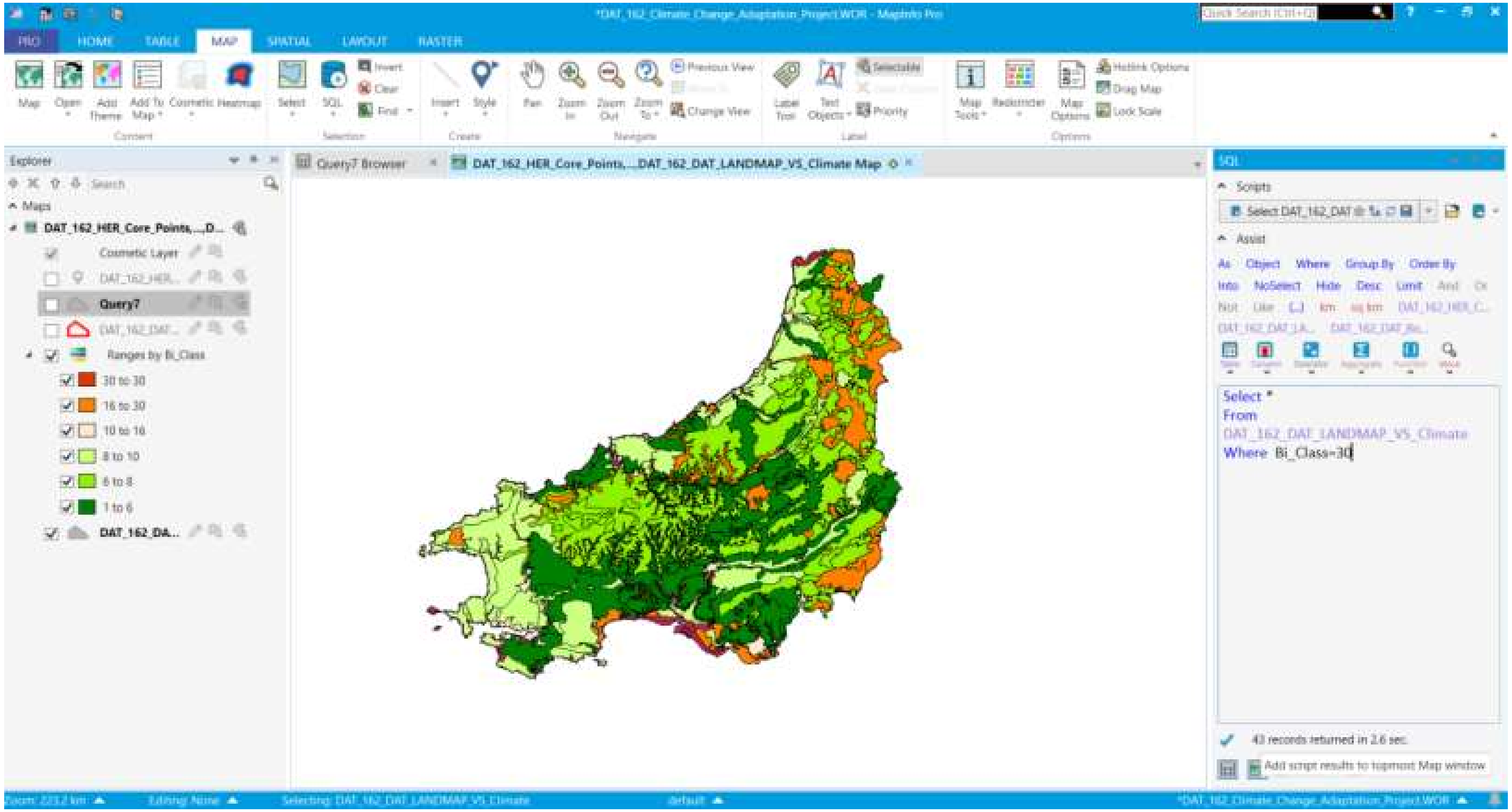


STEP 34

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

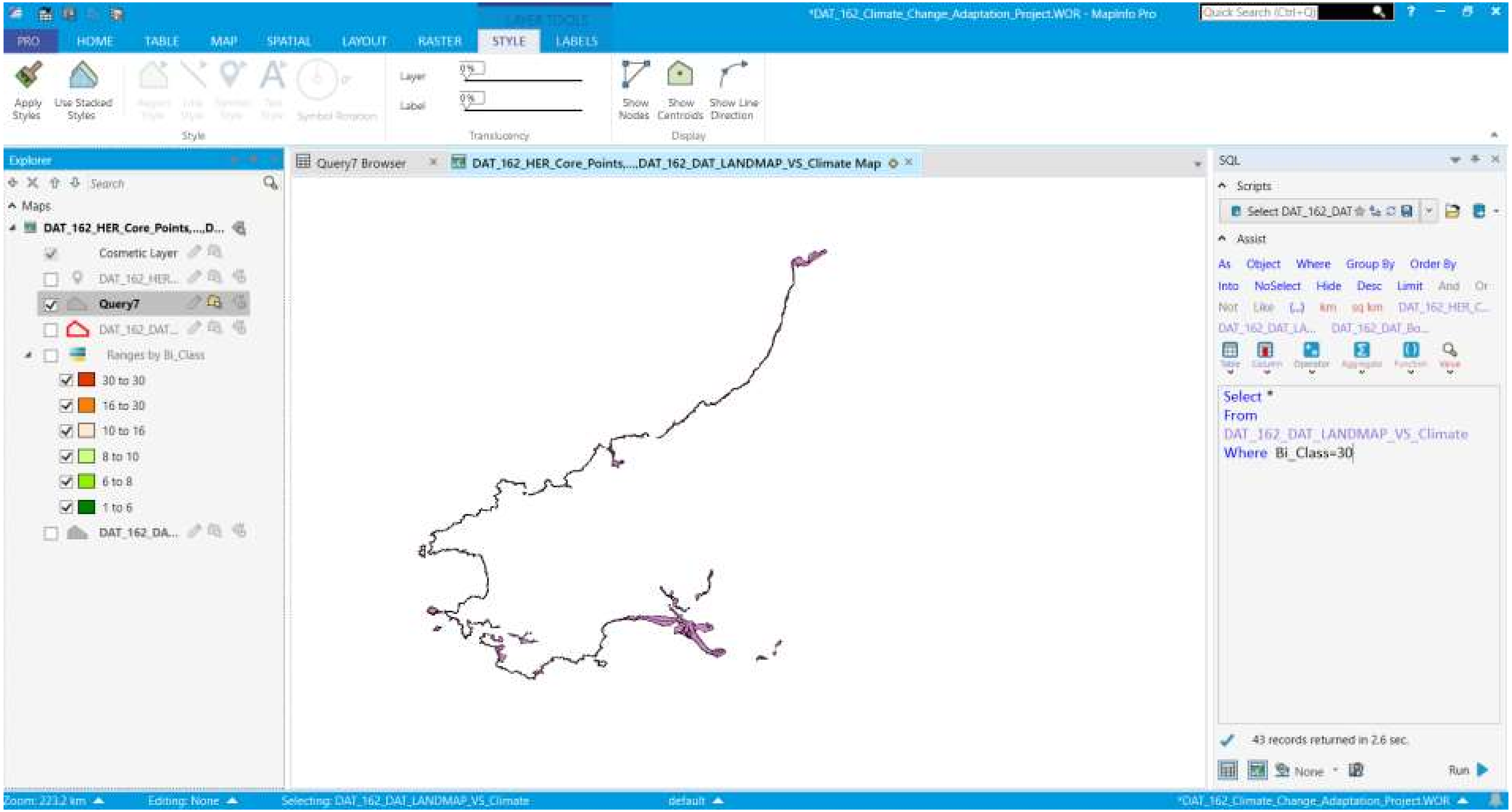
Turn off the visibility of the LANDMAP table in the layers panel.

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.



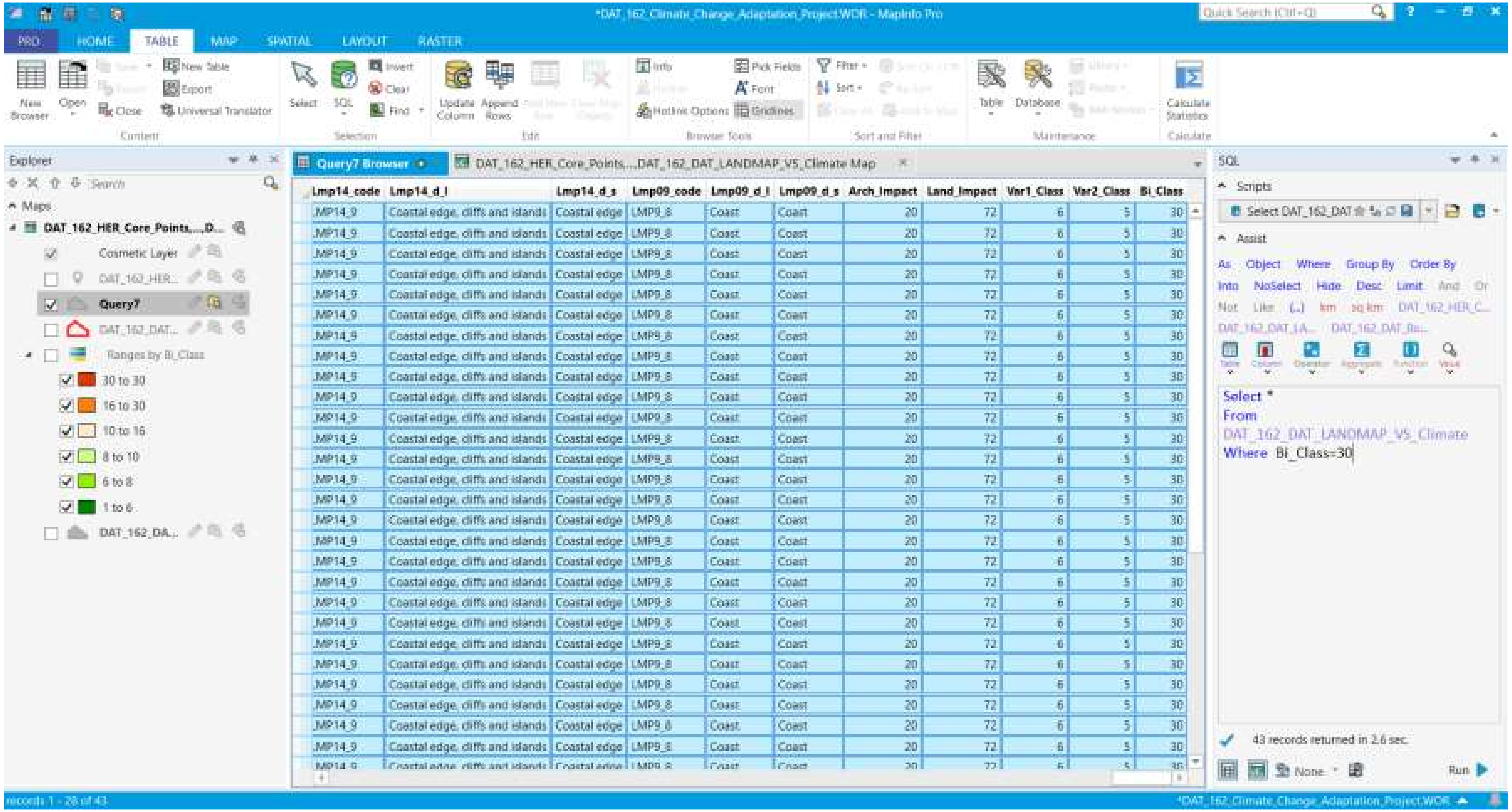
STEP 35

What should now appear as those polygons which satisfy this SQL query:



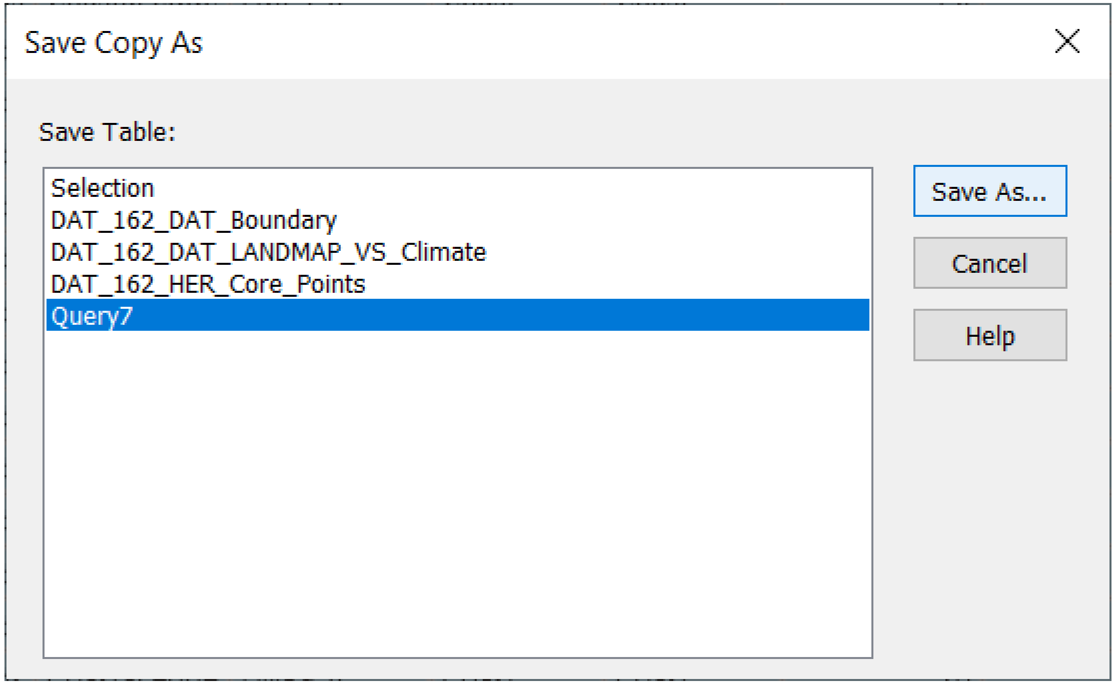
STEP 36

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



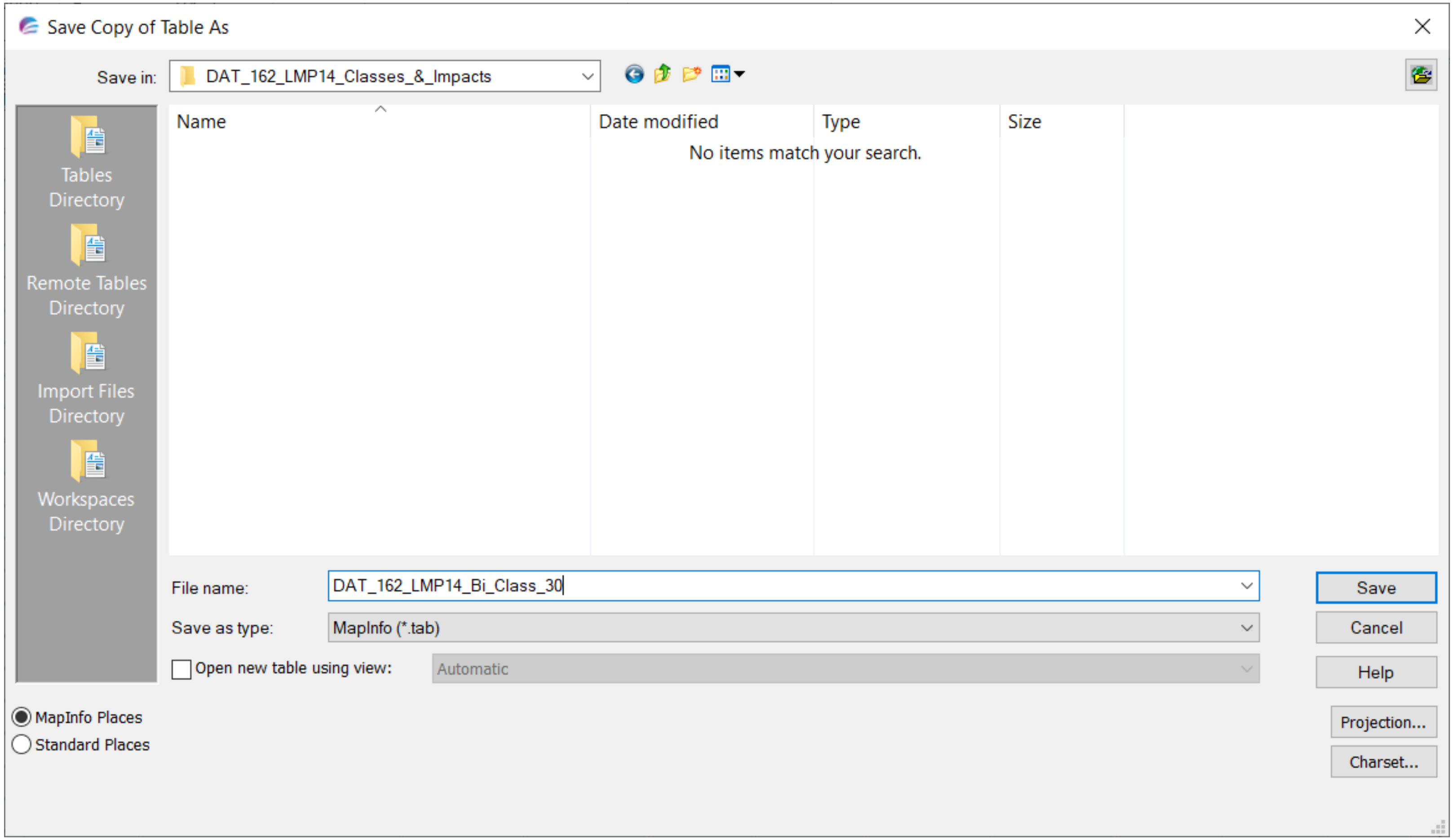
STEP 37

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.



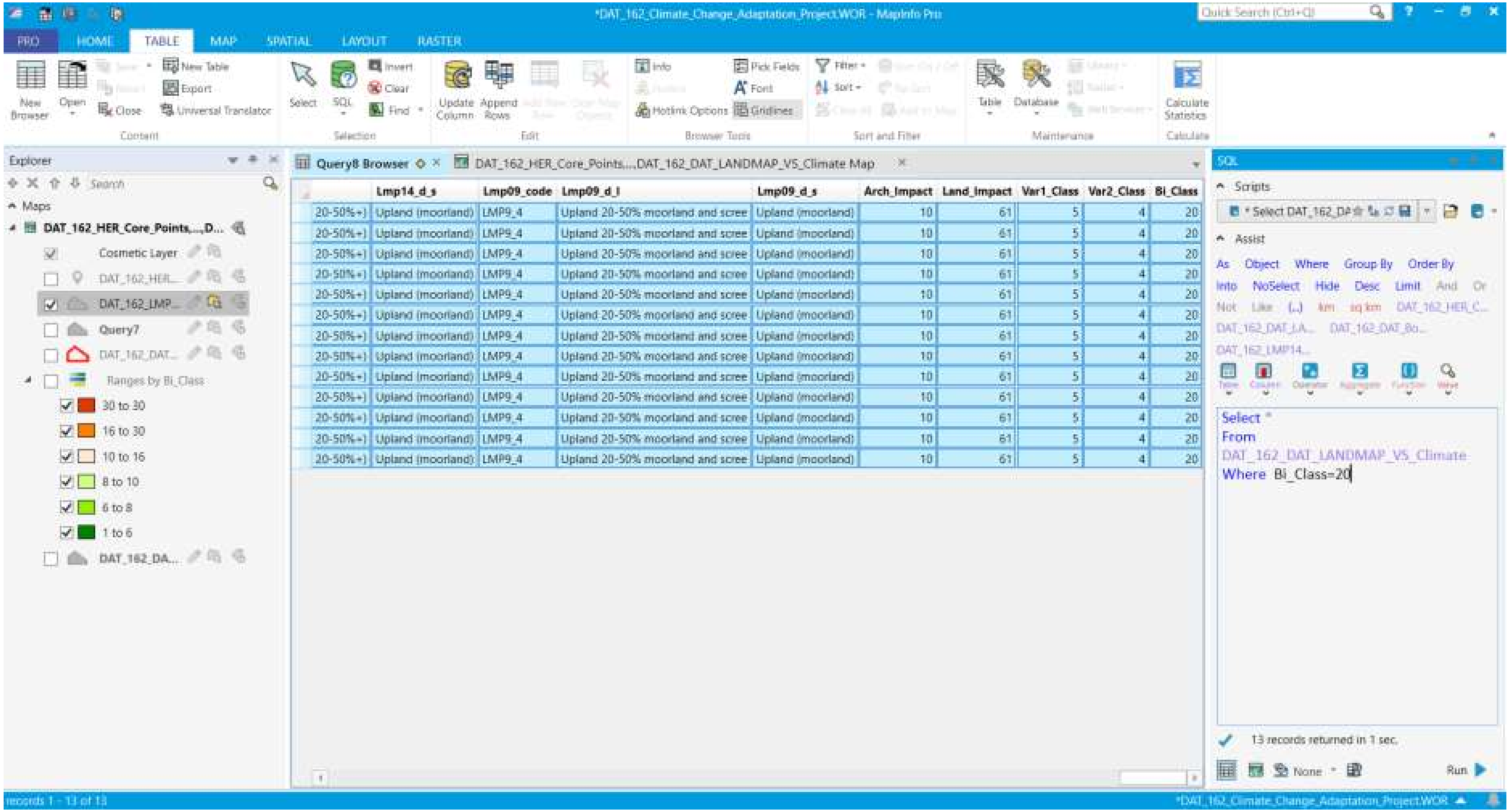
STEP 38

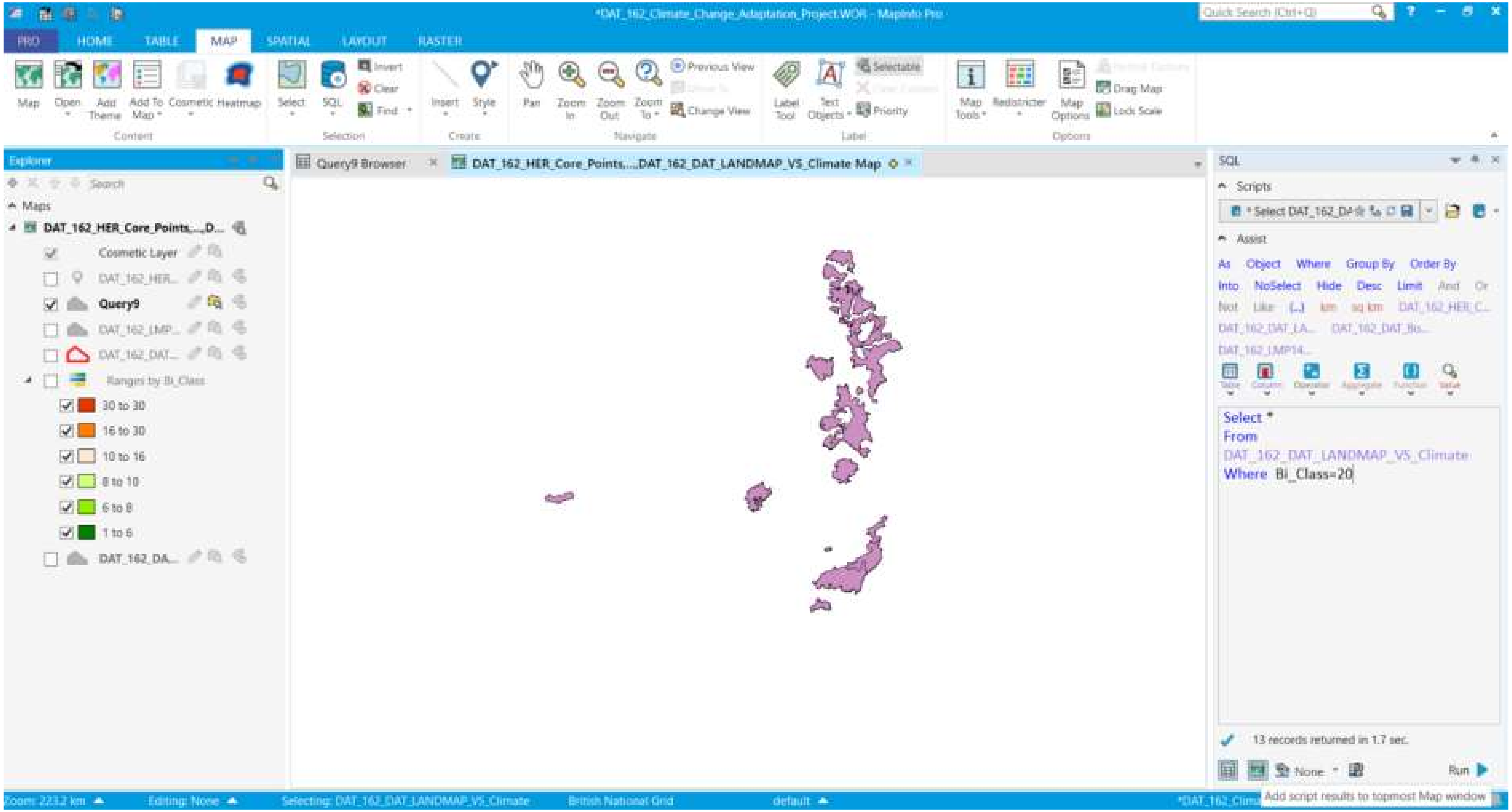
Save the new table with the WAT project code prefix and include the Bi_Class value.



STEP 39

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

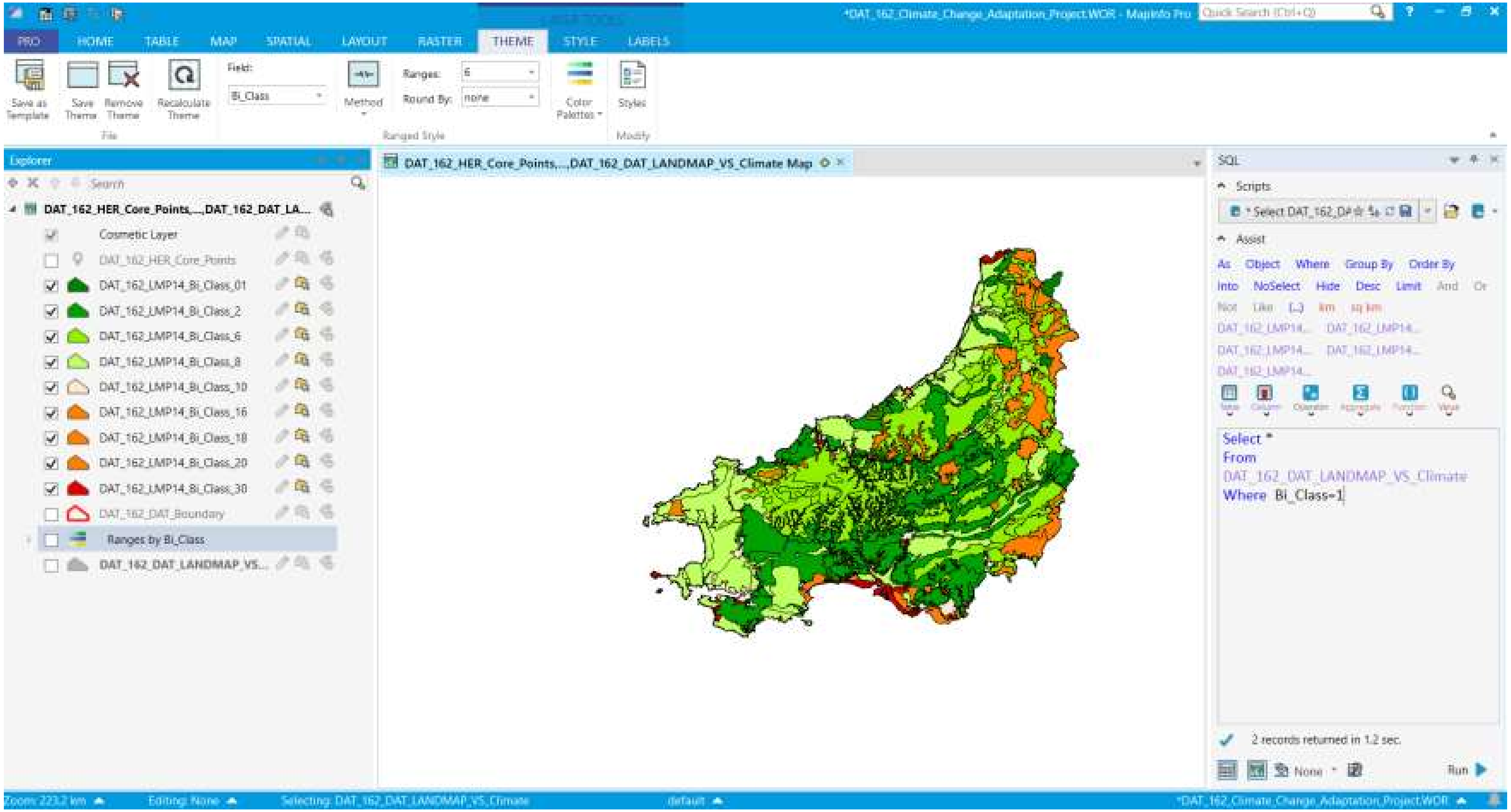



*DAT_162_Climate_Change_Adaptation_Project.WOR - MapInfo Pro
PRO HOME TABLE MAP SPATIAL LAYOUT RASTER
Explorer
Maps
DAT_162_HER_Core_Points,...D...
Cosmetic Layer
Query9
Ranges by Bi_Class
30 to 30
16 to 30
10 to 16
8 to 10
6 to 8
1 to 6
Query9 Browser
DAT_162_HER_Core_Points,...DAT_162_DAT_LANDMAP_VS_Climate Map
SQL
Scripts
Assist
Select *
From
DAT_162_DAT_LANDMAP_VS_Climate
Where Bi_Class=20
13 records returned in 1.7 sec.
Run
Selecting: DAT_162_DAT_LANDMAP_VS_Climate
British National Grid
Add script results to topmost Map window

STEP 40

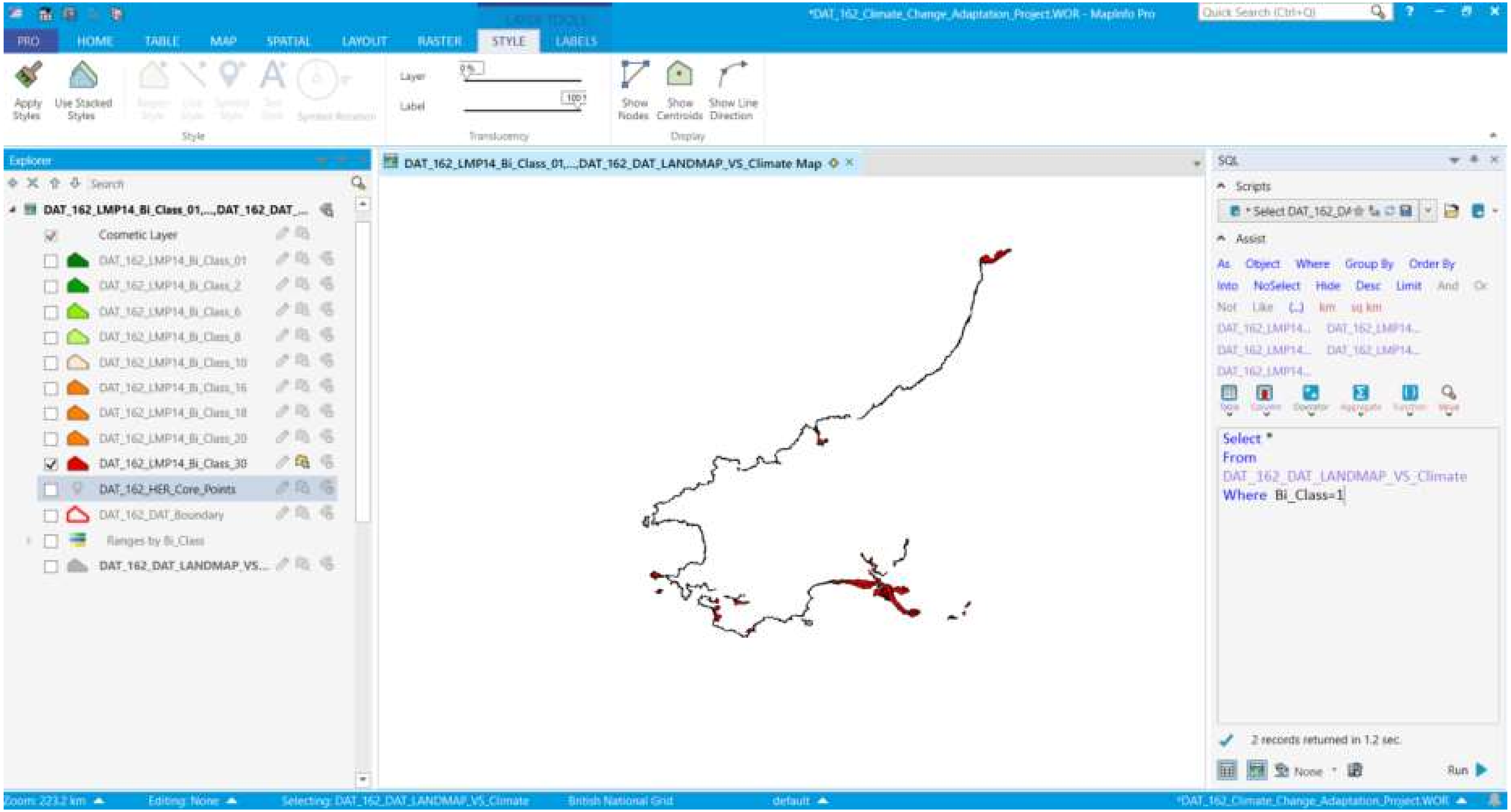
At the end of this process you should now have 9 separate polygonal tables which you can turn off and on freely and alter the style to correspond to the traffic light colouring used in previous sections.

SAVE YOUR WORKSPACE



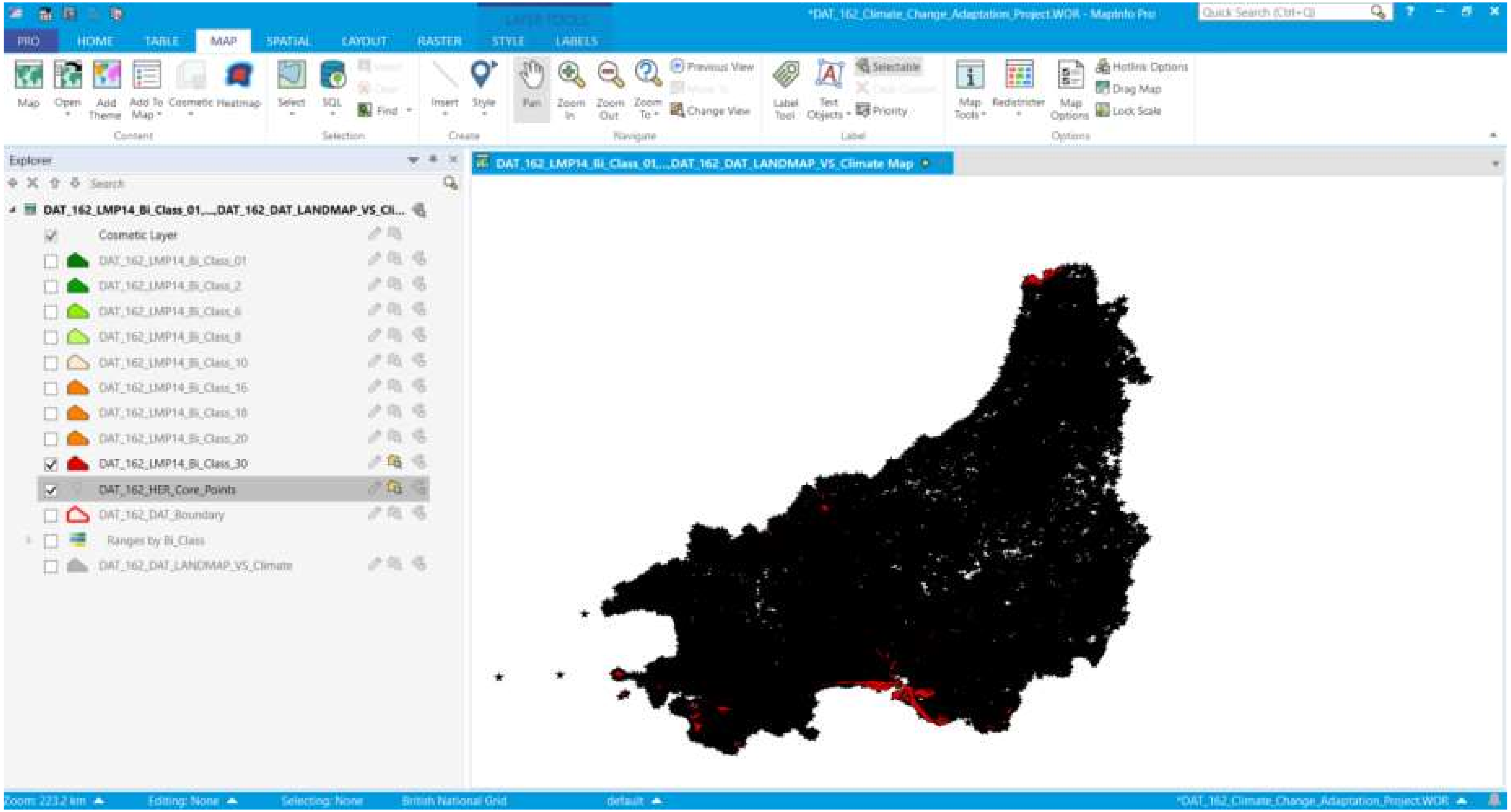
STEP 41: clipping the HER data

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

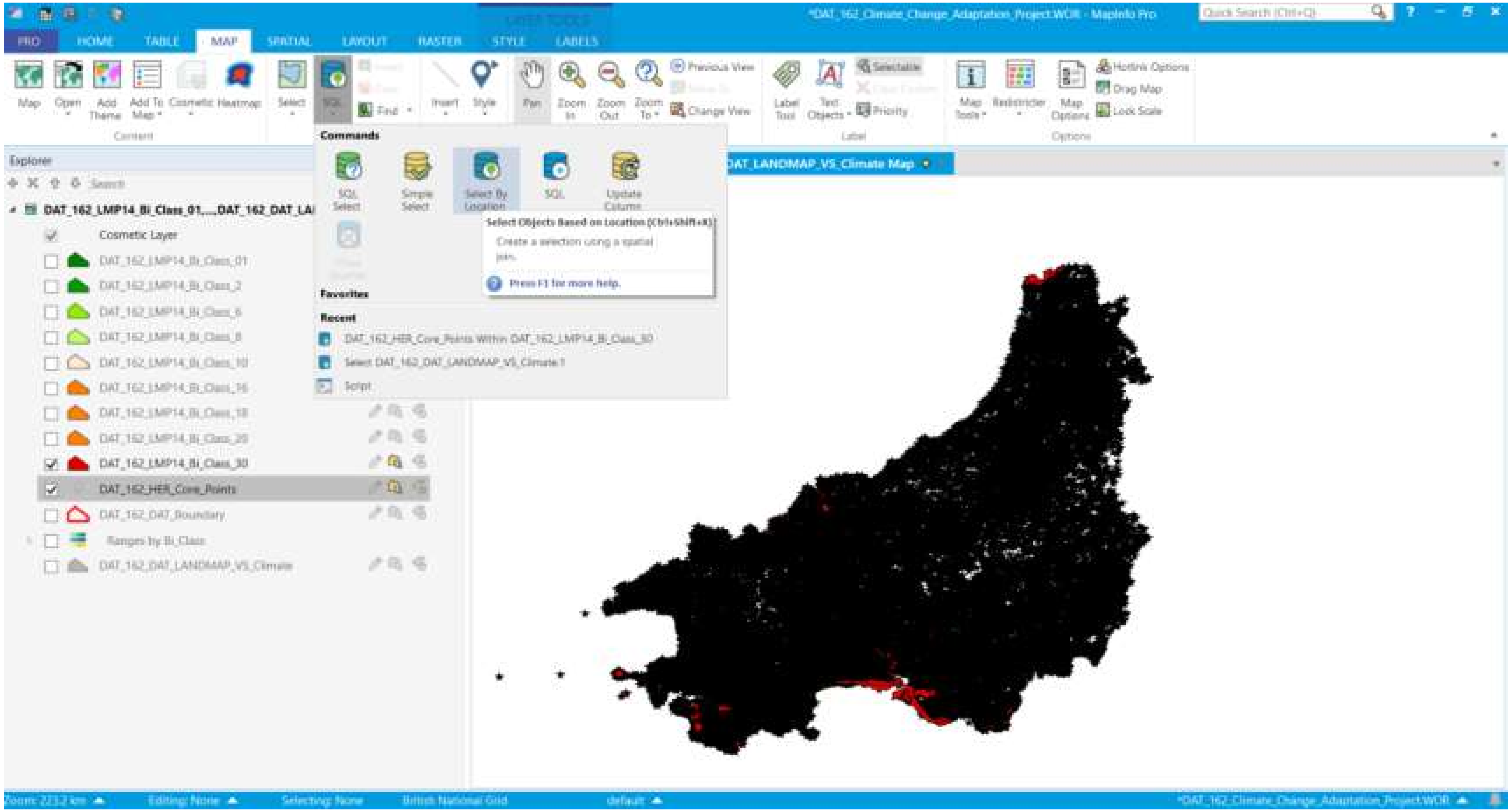
Load the HER Core point data from the table we created in step 30.



STEP 43

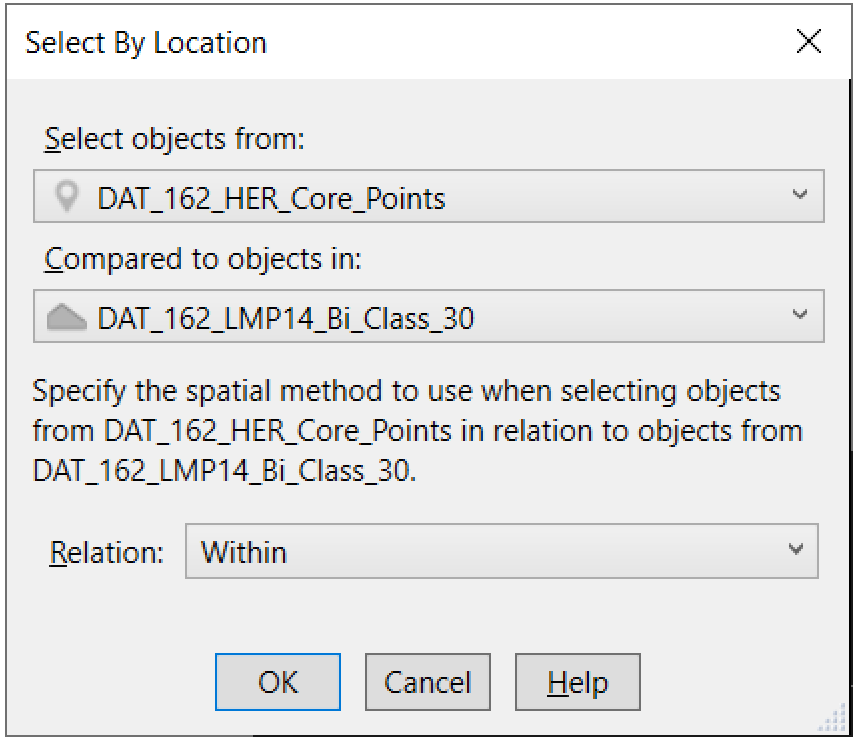
We need to create a layer which contains *both* the HER Core point table attributes and the LMP14_Bi_Class table attributes. The benefit of this being that we can click on a HER point and see all the LANDMAP attribute data too. We have also merged the natural and historic environment data.

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:



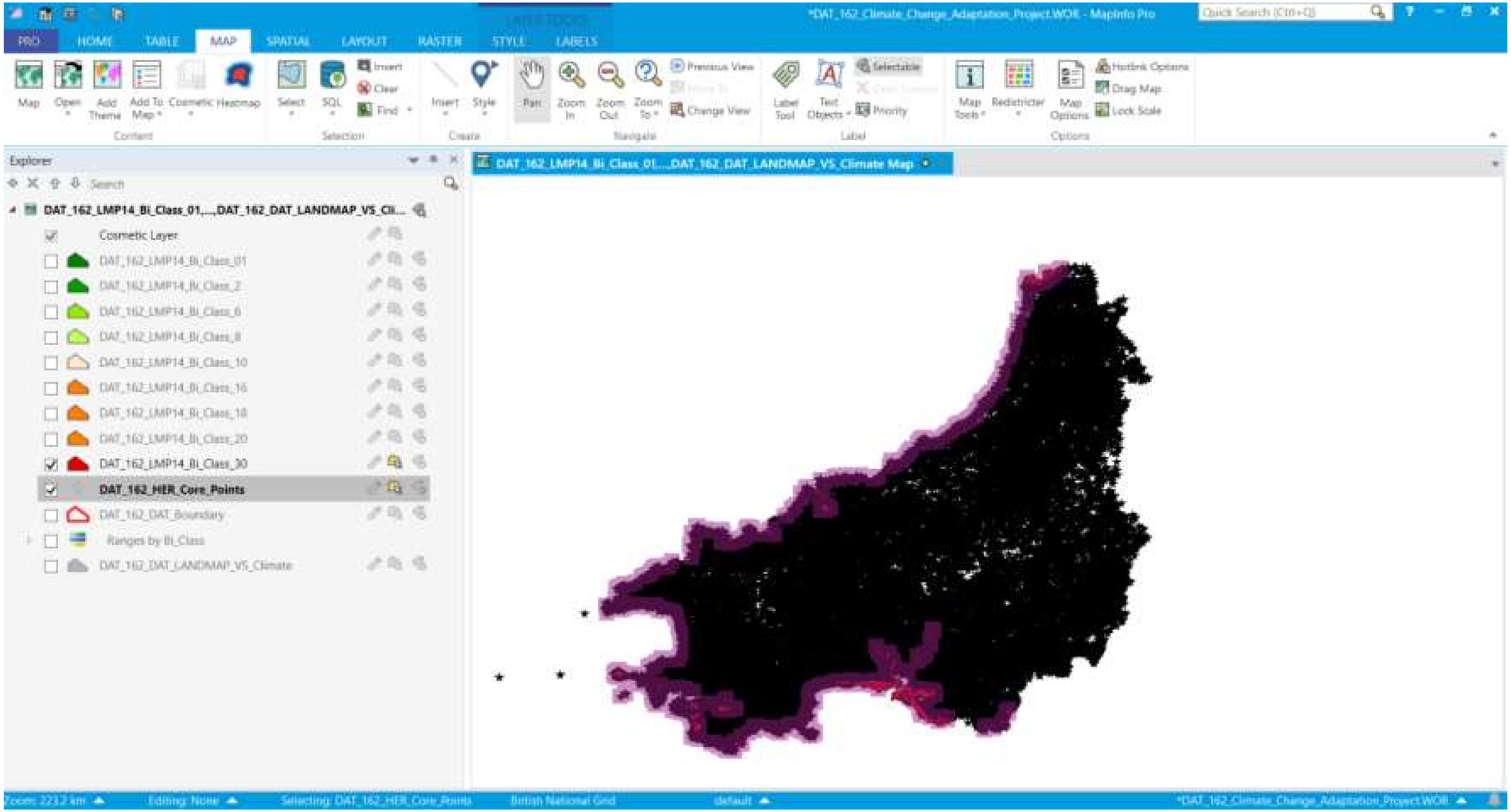
STEP 44

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”.



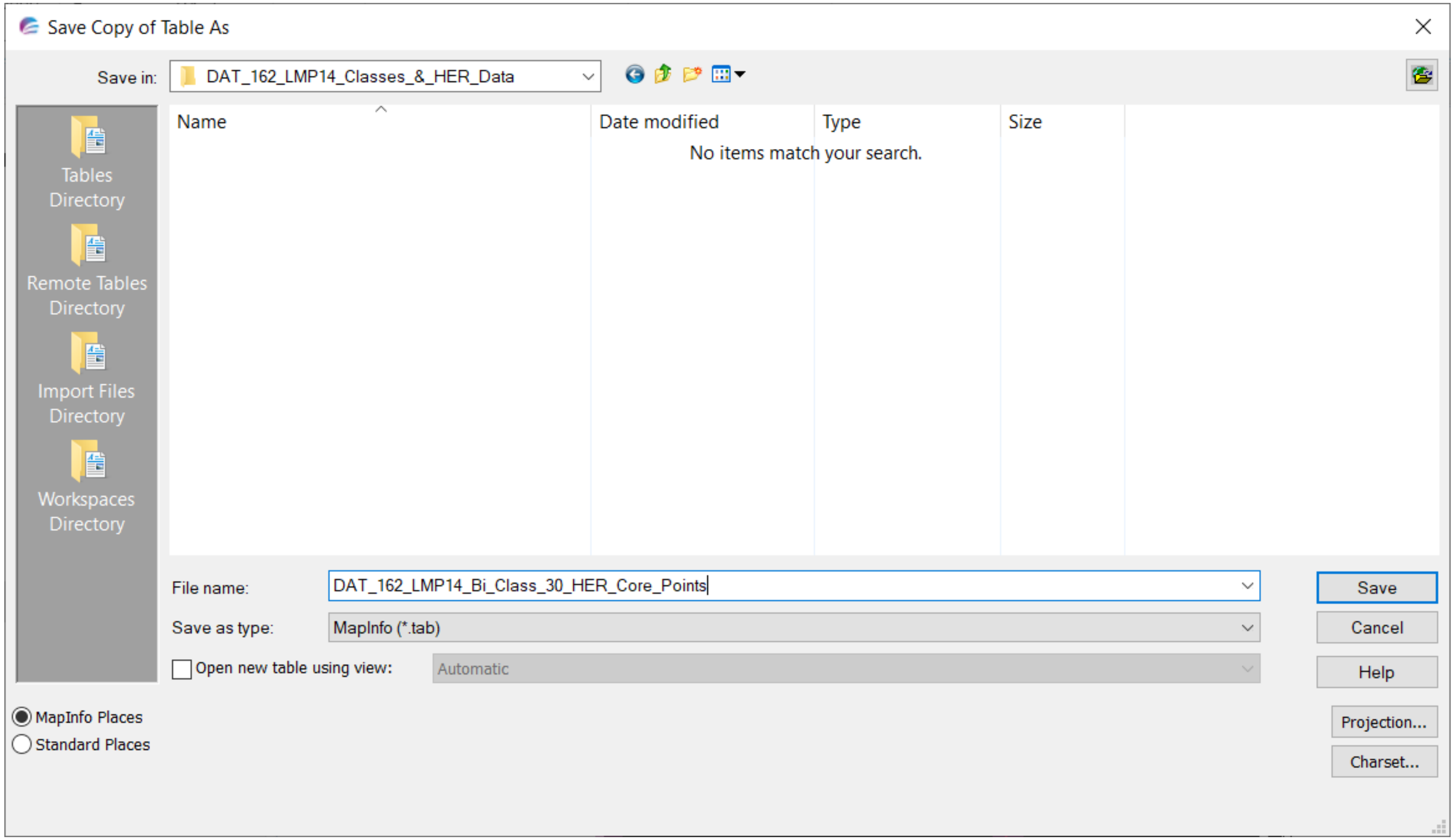
STEP 45

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



STEP 46

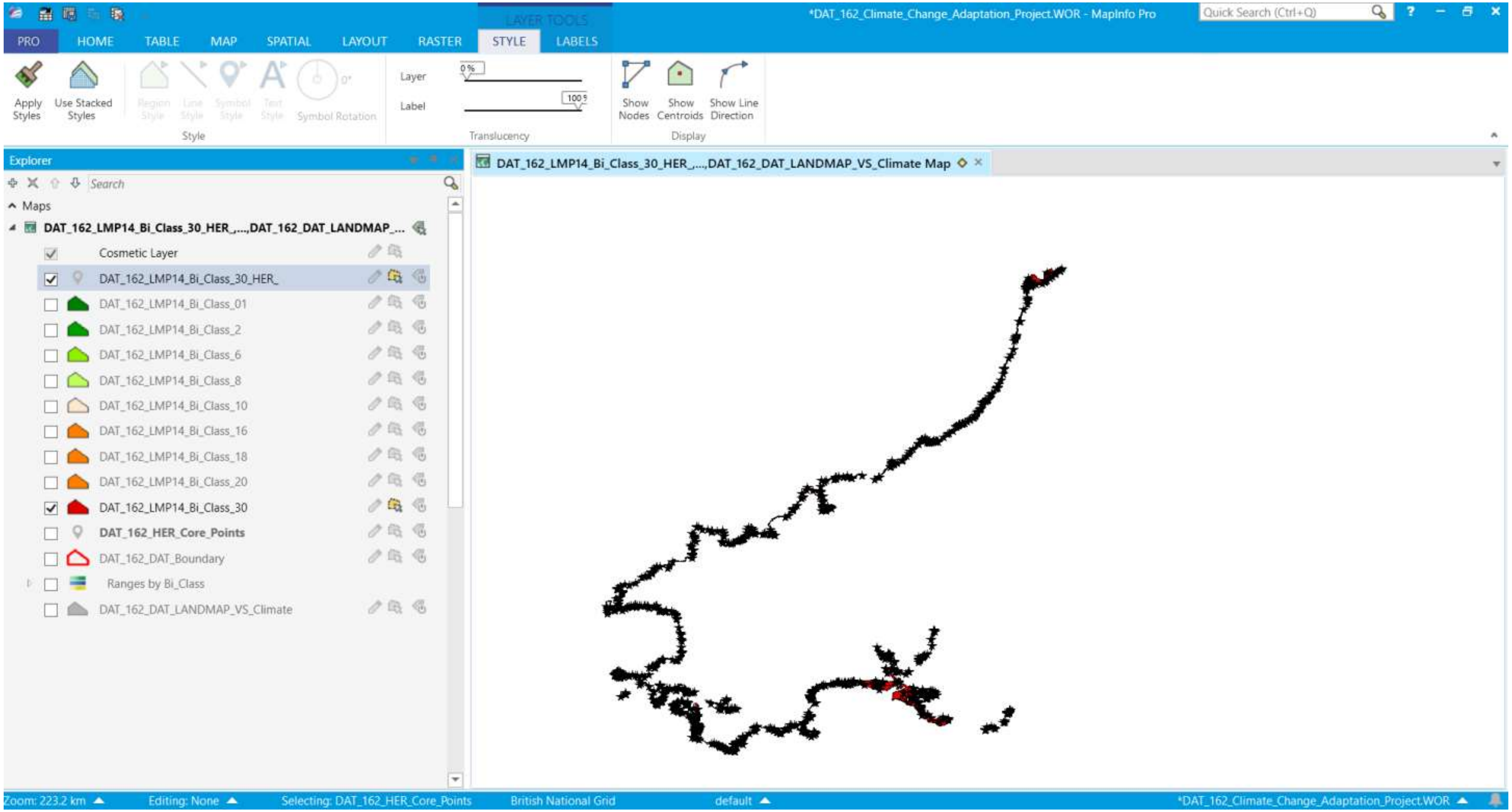
You must go to the "Save Copy As" icon and save the "Selection" from the list of tables. I suggest that you make a new folder in the directory to accommodate these new tables. 8 more will follow.



STEP 47

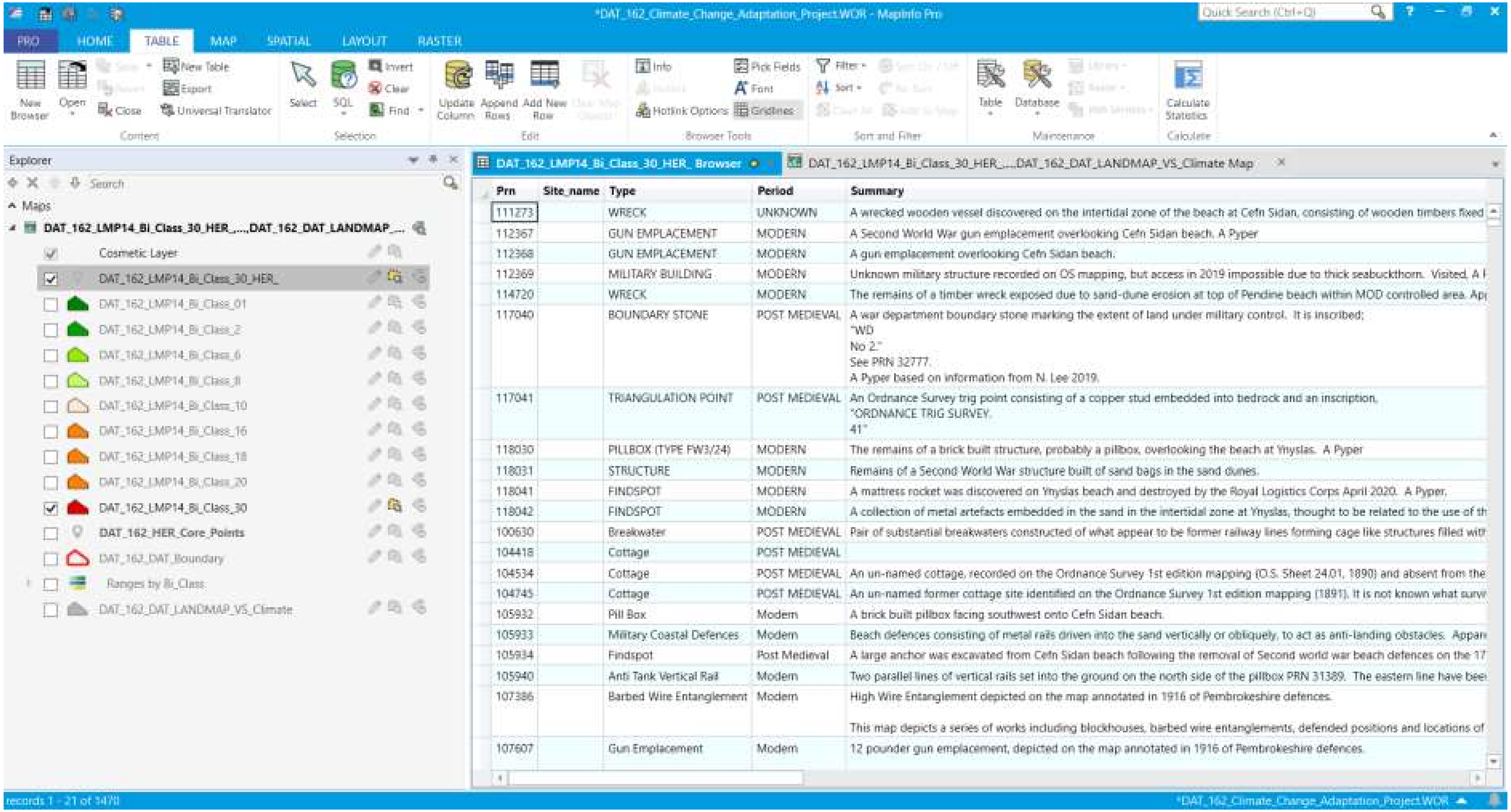
Open this new table in your workspace.

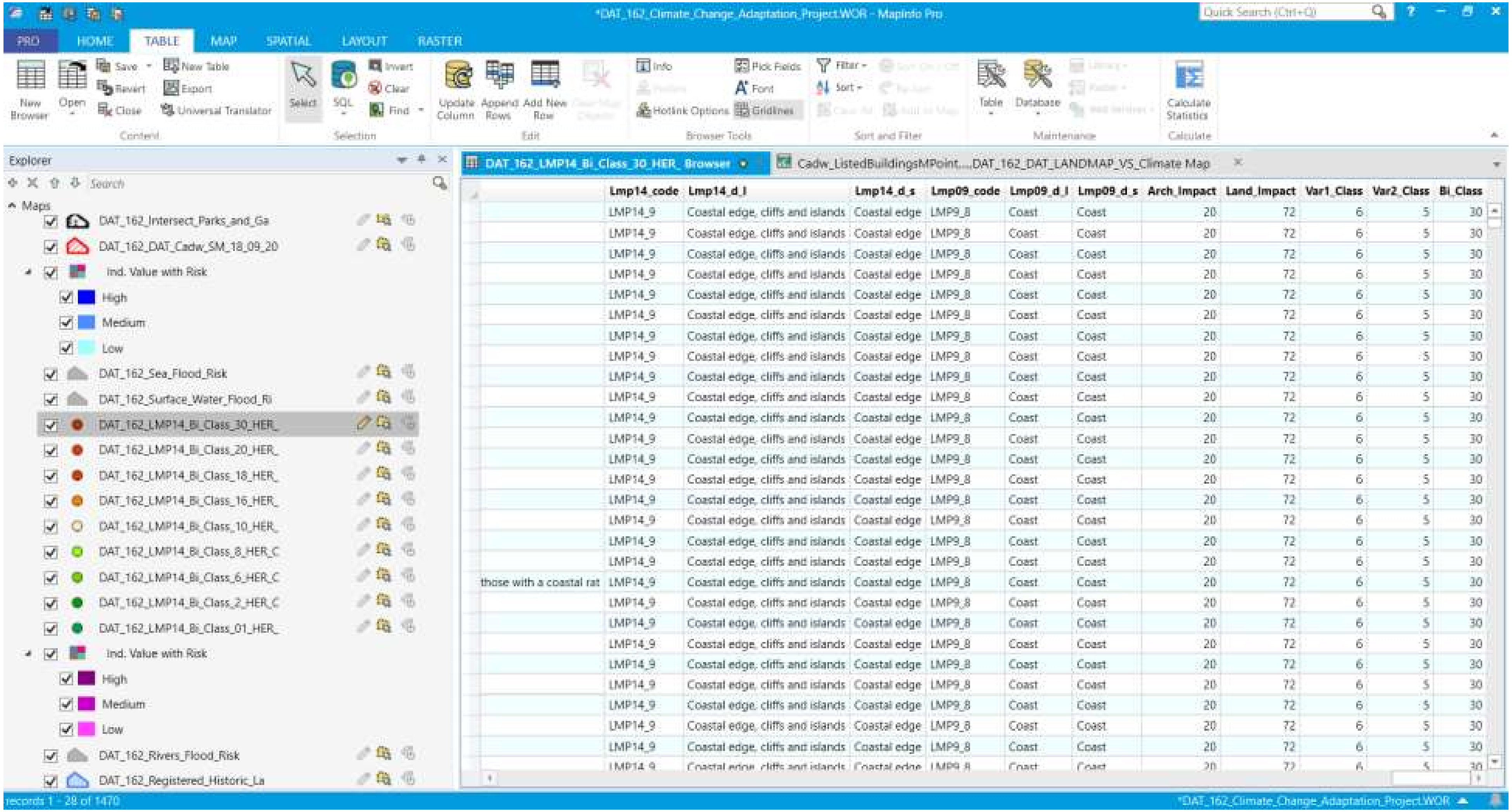
SAVE THE WORKSPACE



STEP 48

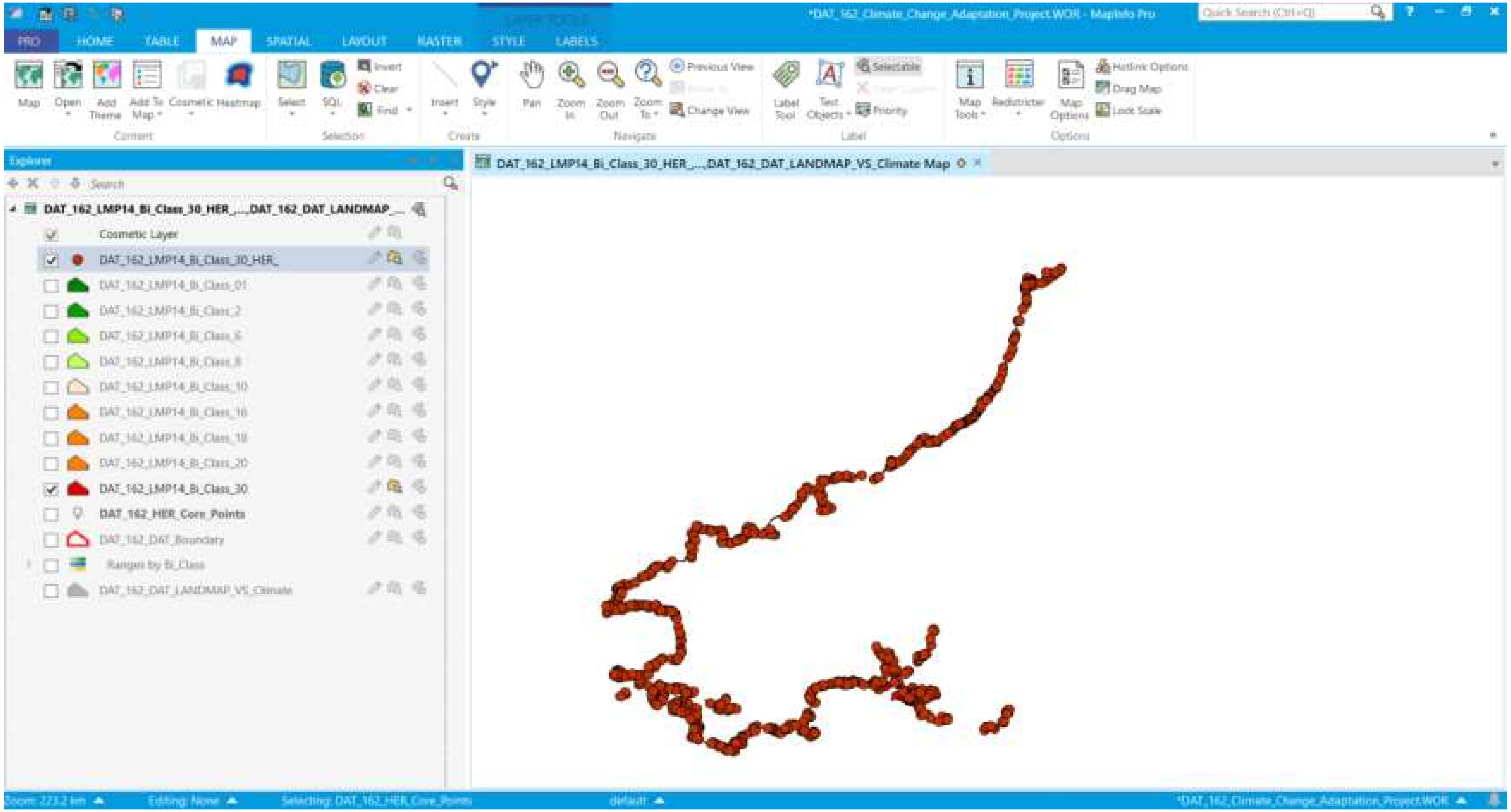
Browse the table to see that data. Hopefully, you will see that the attributes from the LMP14 table has been joined to the end of the HER Core points table.




*DAT_162_Climate_Change_Adaptation_Project.WOR - MapInfo Pro
PRO HOME TABLE MAP SPATIAL LAYOUT RASTER
New Browser Open Save Revert Close New Table Export Universal Translator
Content
Select SQL Invert Clear Find
Selection
Update Column Append Rows Add New Row
Edit
Info Hotlink Options Pick Fields Font Gridlines
Browser Tools
Filter Sort
Sort and Filter
Table Database
Maintenance
Calculate Statistics
Calculate
Explorer
Maps
DAT_162_Intersect_Parks_and_Ga
DAT_162_DAT_Cadw_SM_18_09_20
Ind. Value with Risk
High
Medium
Low
DAT_162_Sea_Flood_Risk
DAT_162_Surface_Water_Flood_Ri
DAT_162_LMP14_Bi_Class_30_HER_
DAT_162_LMP14_Bi_Class_20_HER_
DAT_162_LMP14_Bi_Class_18_HER_
DAT_162_LMP14_Bi_Class_16_HER_
DAT_162_LMP14_Bi_Class_10_HER_
DAT_162_LMP14_Bi_Class_8_HER_C
DAT_162_LMP14_Bi_Class_6_HER_C
DAT_162_LMP14_Bi_Class_2_HER_C
DAT_162_LMP14_Bi_Class_01_HER_
Ind. Value with Risk
High
Medium
Low
DAT_162_Rivers_Flood_Risk
DAT_162_Registered_Historic_La
DAT_162_LMP14_Bi_Class_30_HER_ Browser
Cadw_ListedBuildingsMPoint,...,DAT_162_DAT_LANDMAP_VS_Climate Map
Lmp14_code Lmp14_d_l Lmp14_d_s Lmp09_code Lmp09_d_l Lmp09_d_s Arch_Impact Land_Impact Var1_Class Var2_Class Bi_Class
LMP14_9 Coastal edge, cliffs and islands Coastal edge LMP9_8 Coast Coast 20 72 6 5 30
those with a coastal rat
records 1 - 28 of 1470

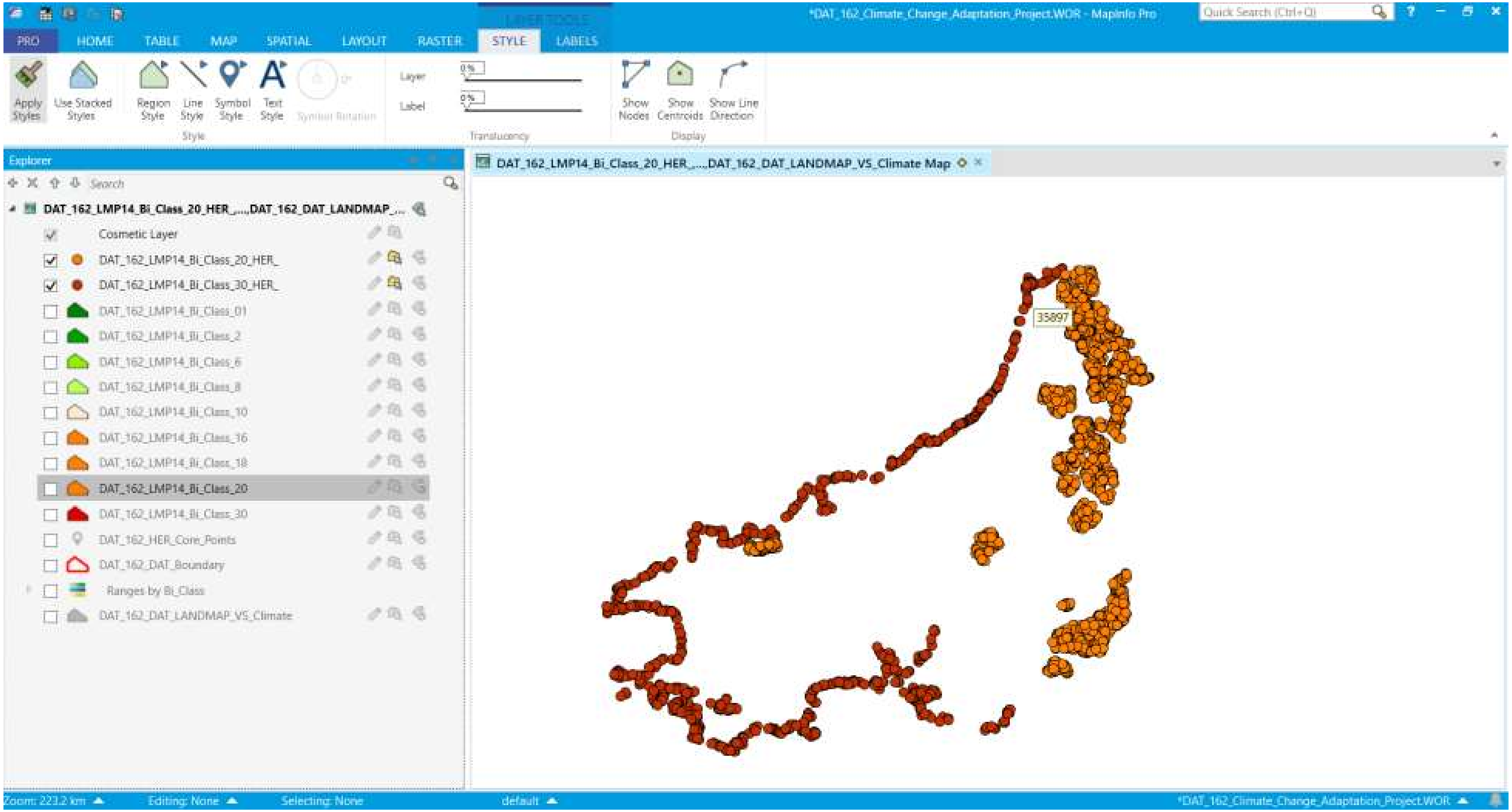
STEP 49

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



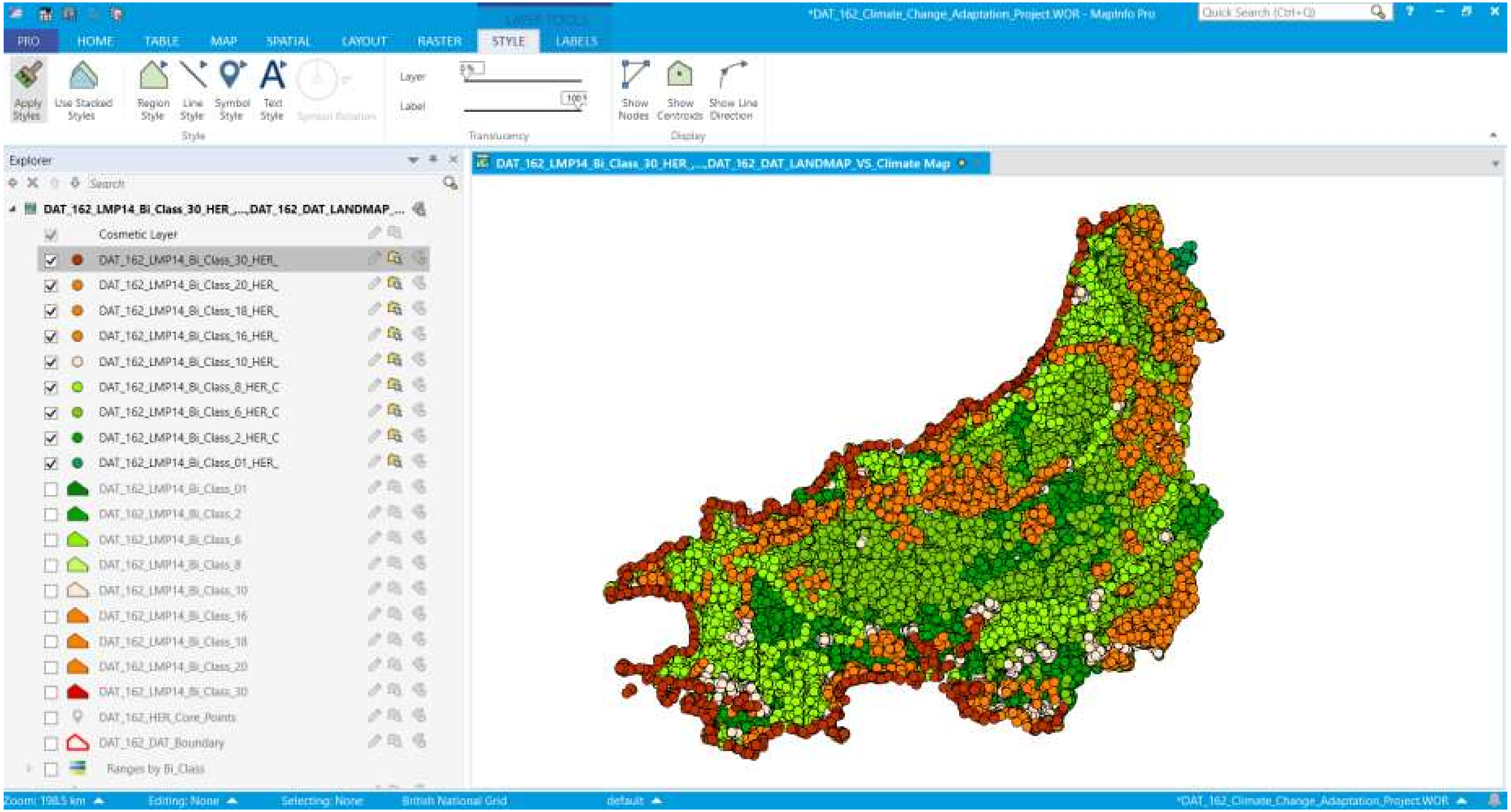
STEP 50

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



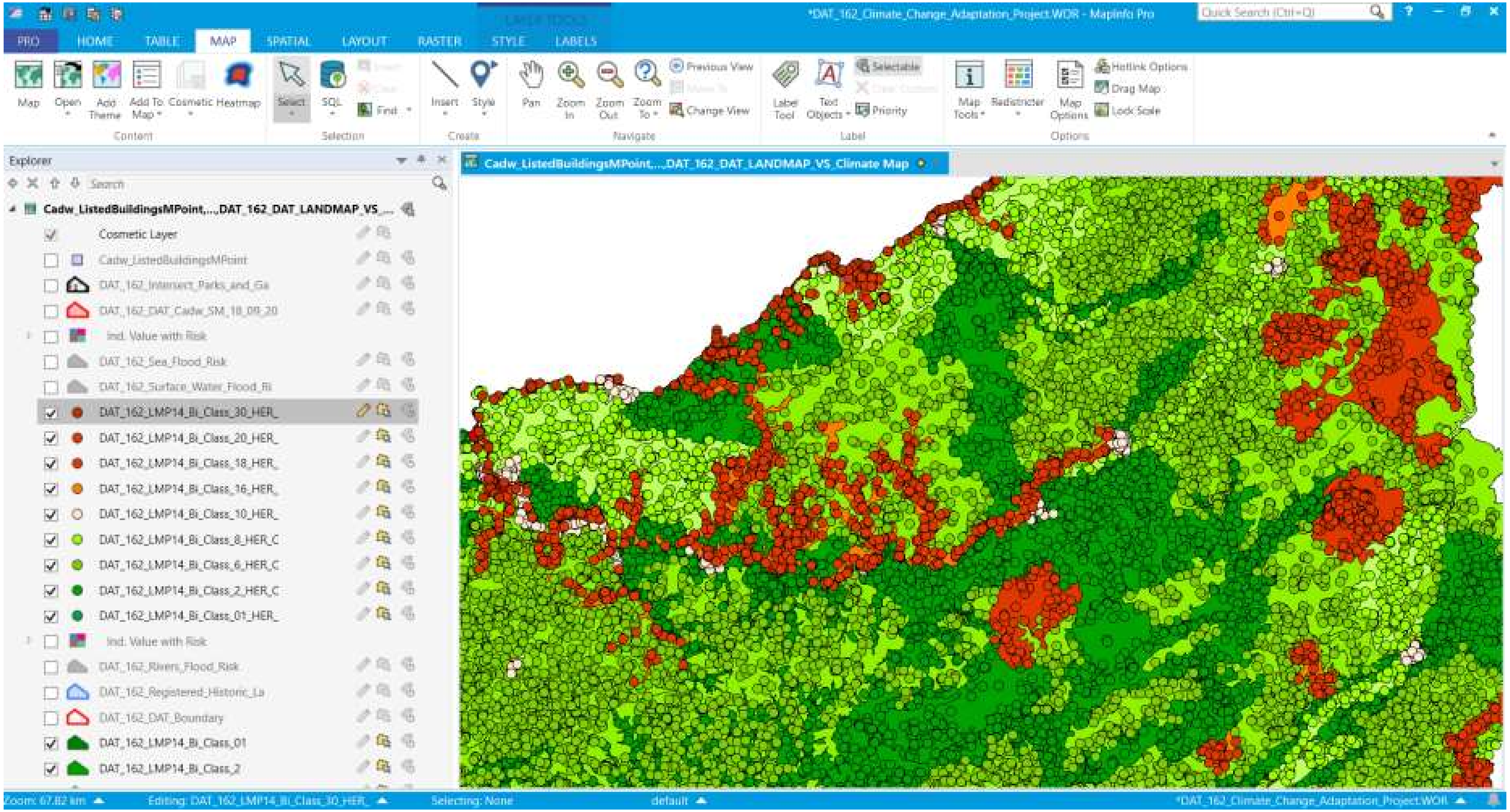
STEP 51: Classified HER data

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):



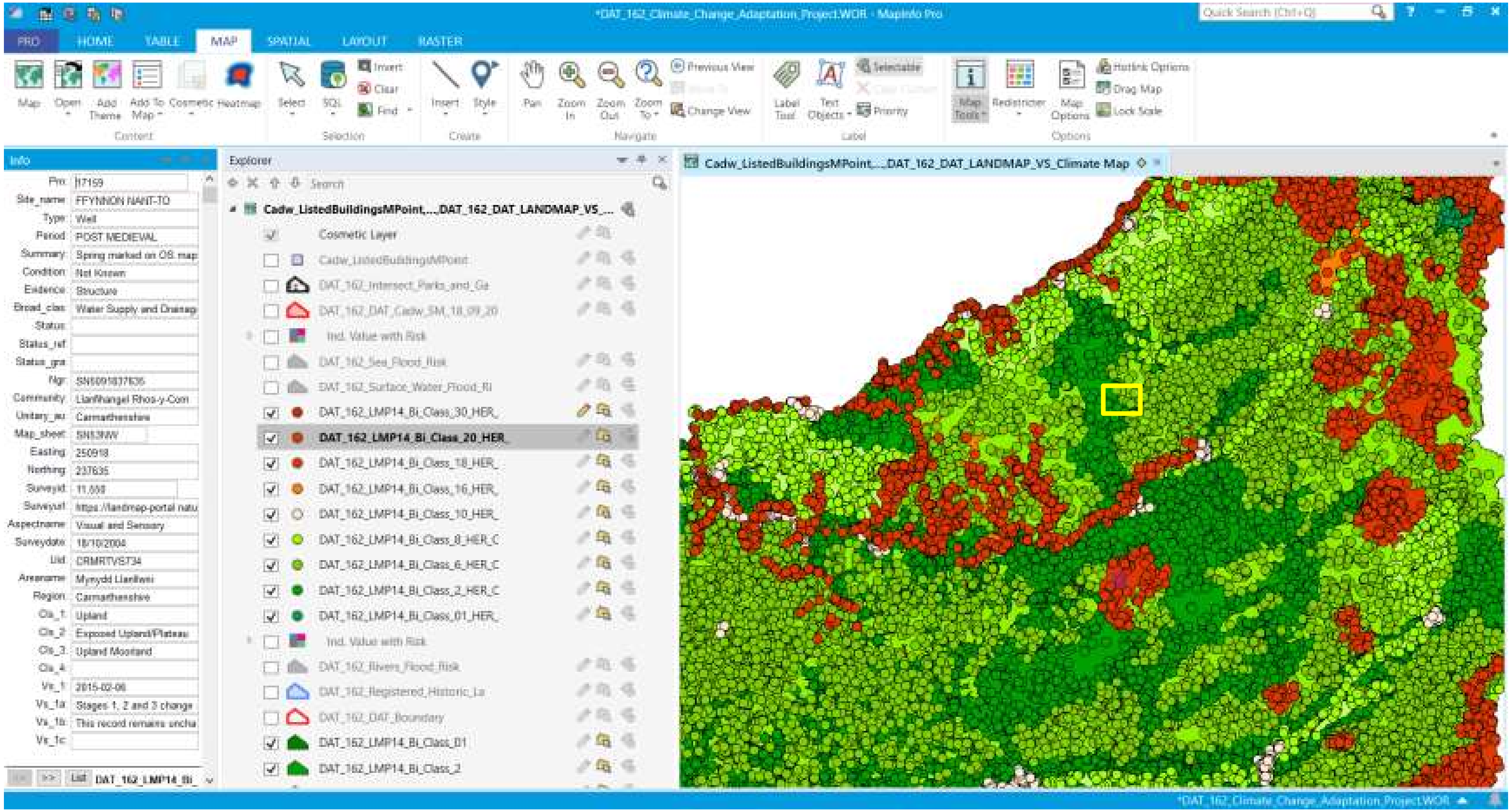
STEP 52: the baseline data

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.

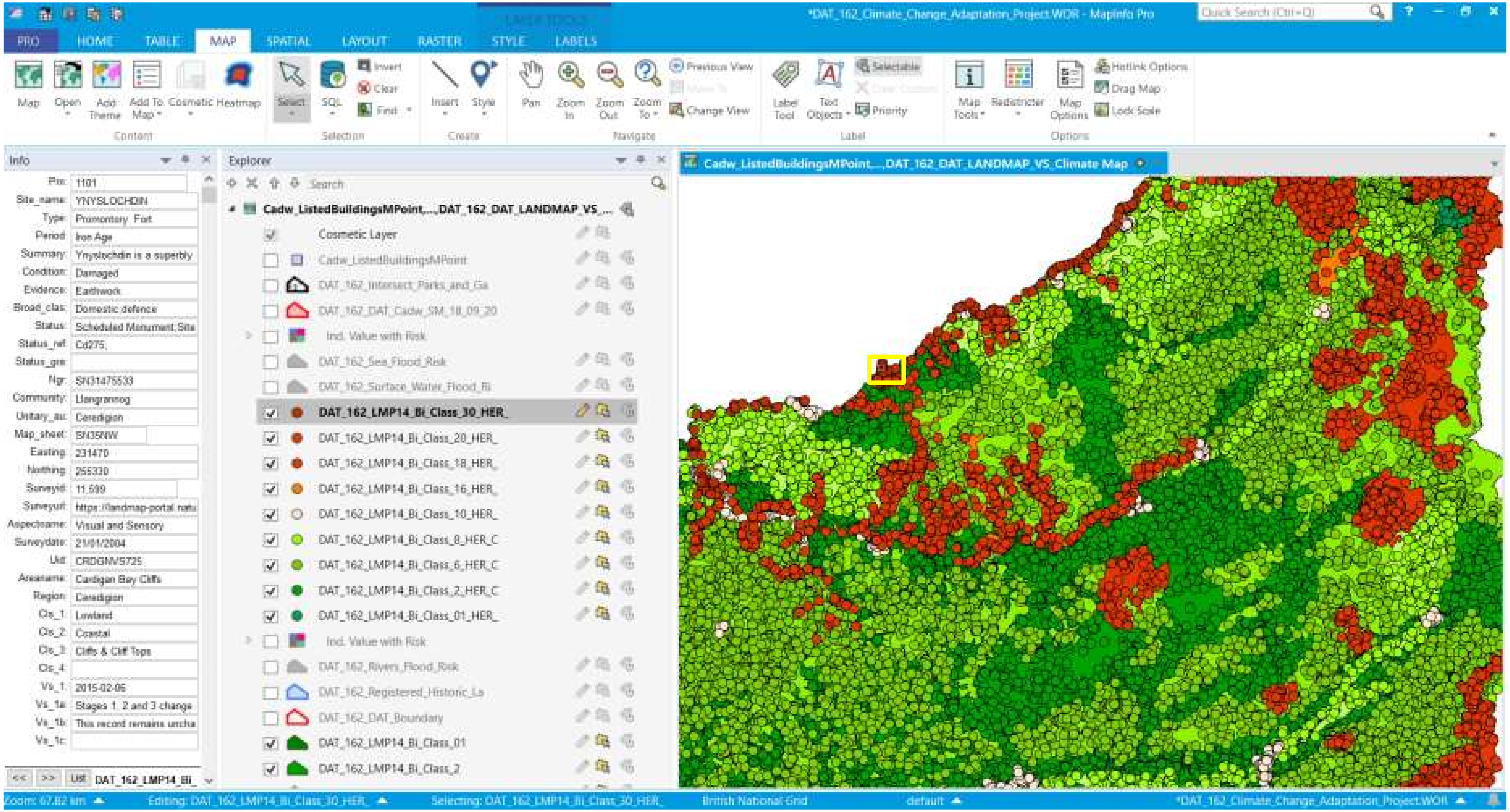


STEP 53

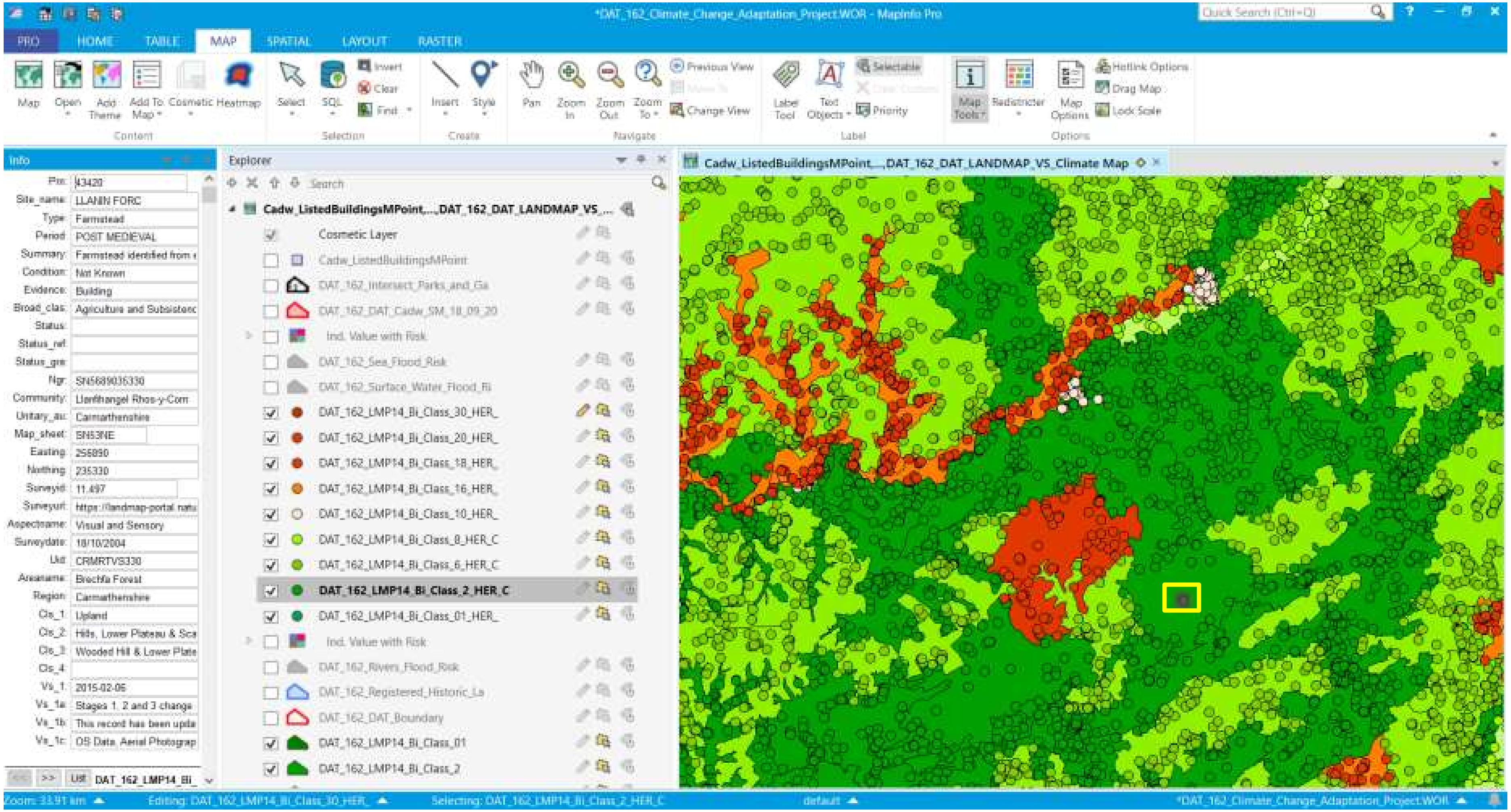
We can assess a population of a certain Bi_class and address the points on an individual basis, applying the susceptibility criteria of the historic environment assets categories provided in the HEG Sector Adaption plan to attribute the true vulnerability of the sites. For example, in the image below shows a point in the High risk group Bi_class 20 (in yellow rectangle) which is a post-medieval well. What is the true risk for this structure? Its located in a land class which has been evaluated as being vulnerable to high, negative impacts of climatic change. It also broadly falls into the HEG's "Buildings and Settlements" category which are also considered to be particularly vulnerable to the impacts of climatic change.



This promontory fort has been classified with the highest risk Bi_class:



Conversely however, this farmstead (a building) has been classified with a low Bi_class. It falls within a low risk land class but the HEG criteria suggests that it is of greater vulnerability. Its true risk level is probably greater than this Bi_class model but lower than the well in the first example.



v

STEP 54: NRW Flood Risk Assessment data

This baseline data can also be overlain with other data such as NRW's latest Flood Risk Assessment data which is available to download in shapefile format from http://lle.gov.wales/catalogue/item/FloodRiskAssessmentWales/?lang=en The following is taken from the metadata:

Flood Risk Assessment Wales provides a national assessment of risk flooding from Rivers, the Sea and Surface Water and Small Watercourses.

The assessment takes into account flood defences and combines new, national-scale modelling with detailed local-scale models to categories risk into 3 bands, labelled 'High', 'Medium' and 'Low' risk.

For Rivers and Surface Water and Small Watercourses:

'High' risk means that each year, this area has a chance of flooding of greater than 1 in 30 (3.3%)

'Medium' risk means that each year, an area has a chance of flooding of between 1 in 100 (1%) and 1 in 30 (3.3%).

'Low' risk means that each year, an area has a chance of flooding of between 1 in 1000 (0.1%) and 1 in 100 (1%).

For the Sea:

'High' risk means that each year, this area has a chance of flooding of greater than 1 in 30 (3.3%)

'Medium' risk means that each year, an area has a chance of flooding of between 1 in 200 (0.5%) and 1 in 30 (3.3%).

'Low' risk means that each year, an area has a chance of flooding of between 1 in 1000 (0.1%) and 1 in 200 (0.5%)

The risk assessment takes into account the effect of any flood defences that may be in the area. Flood defences reduce, but do not completely stop the chance of flooding as they can be overtopped or fail. Flood risk information for each source has been created as 'onion-skins', i.e. with no overlapping data between individual risk bands. These risk bands should be combined and displayed a single layer for each flood source.

If data is displayed in map form to others, it should be shown with a maximum zoom scale of 1:5,000 and that base mapping of 1:10,000 is used to give context. Viewing at more detailed scales may not be appropriate given the indicative nature of national-scale modelling.

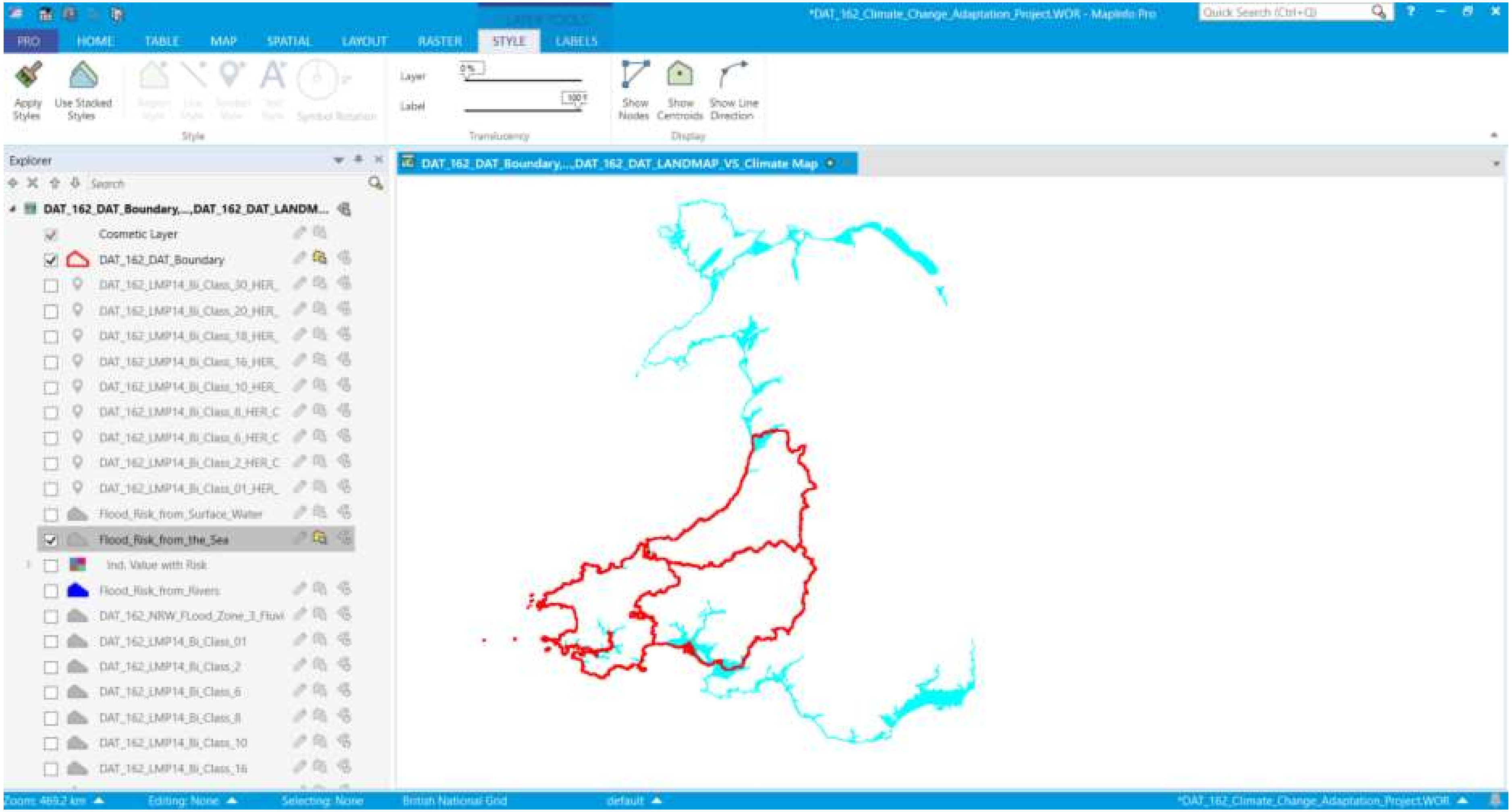
The maps are not property specific and show risk for a general area. National scale modelling undertaken at 2m grid resolution. Local scale modelling undertaken at different resolutions, typically between 2m – 10m.

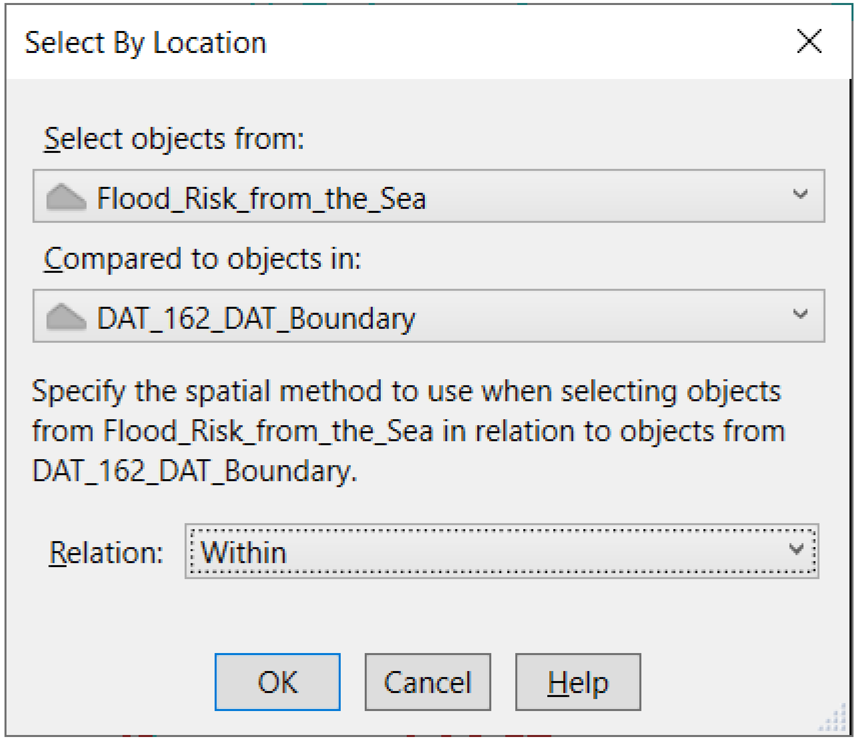
****

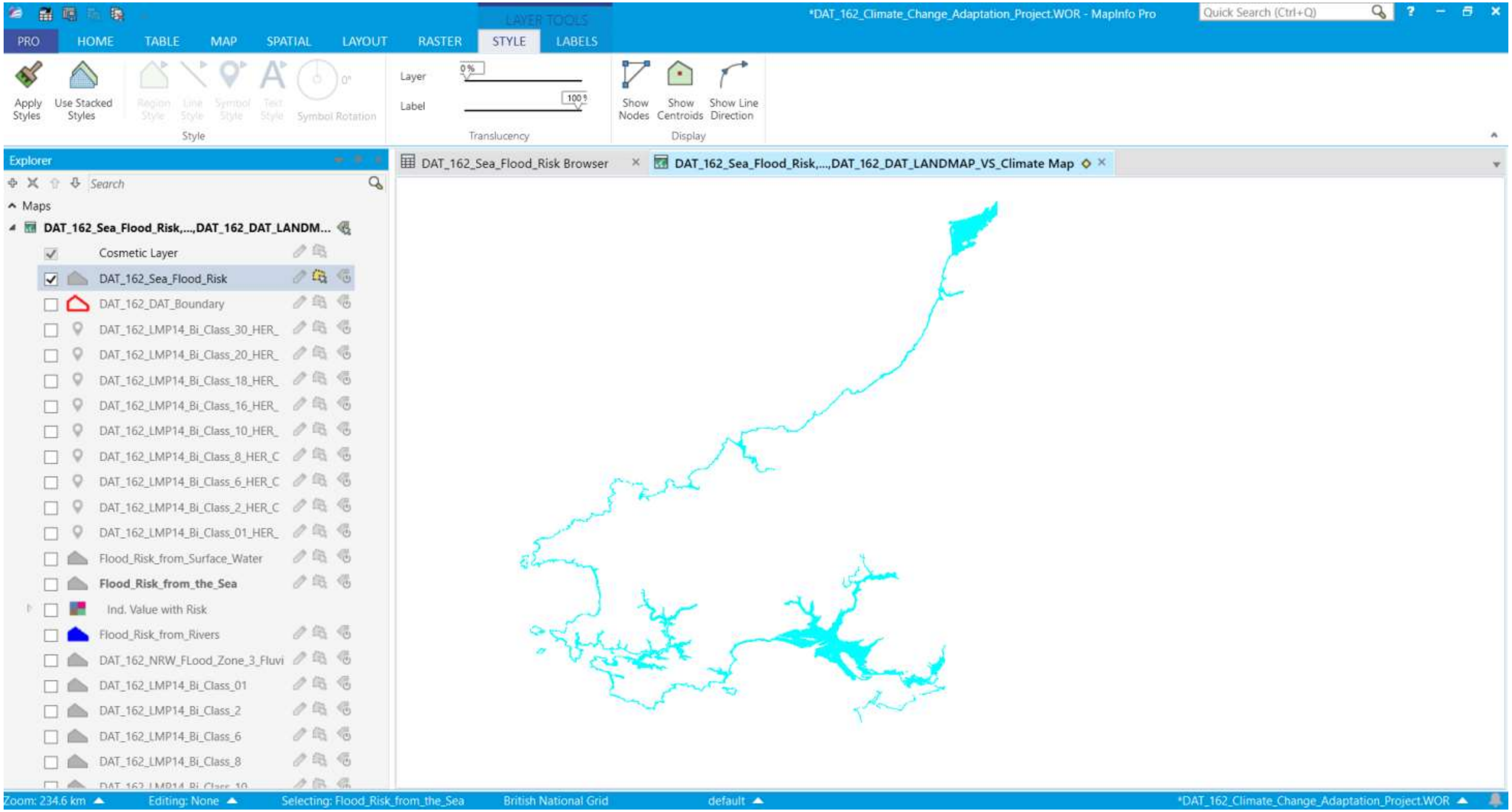
These are huge vector files and require much more processing and patience. In my experience, these data took a long time to load and process and upset MapInfo quite frequently. When the “wheel of doom” appears get up and put the kettle on! The surface water data is the densest dataset to process and perhaps, isn’t necessary at this stage.

In this instance I think it would be most useful to clip the data using the same methodology as the HER data where by the WAT boundary attributes are joined with the Flood Risk attribute tables.

Repeat the process undertaken in steps 43 to 46 and shown in the following pages for the risk of flooding from the sea data.

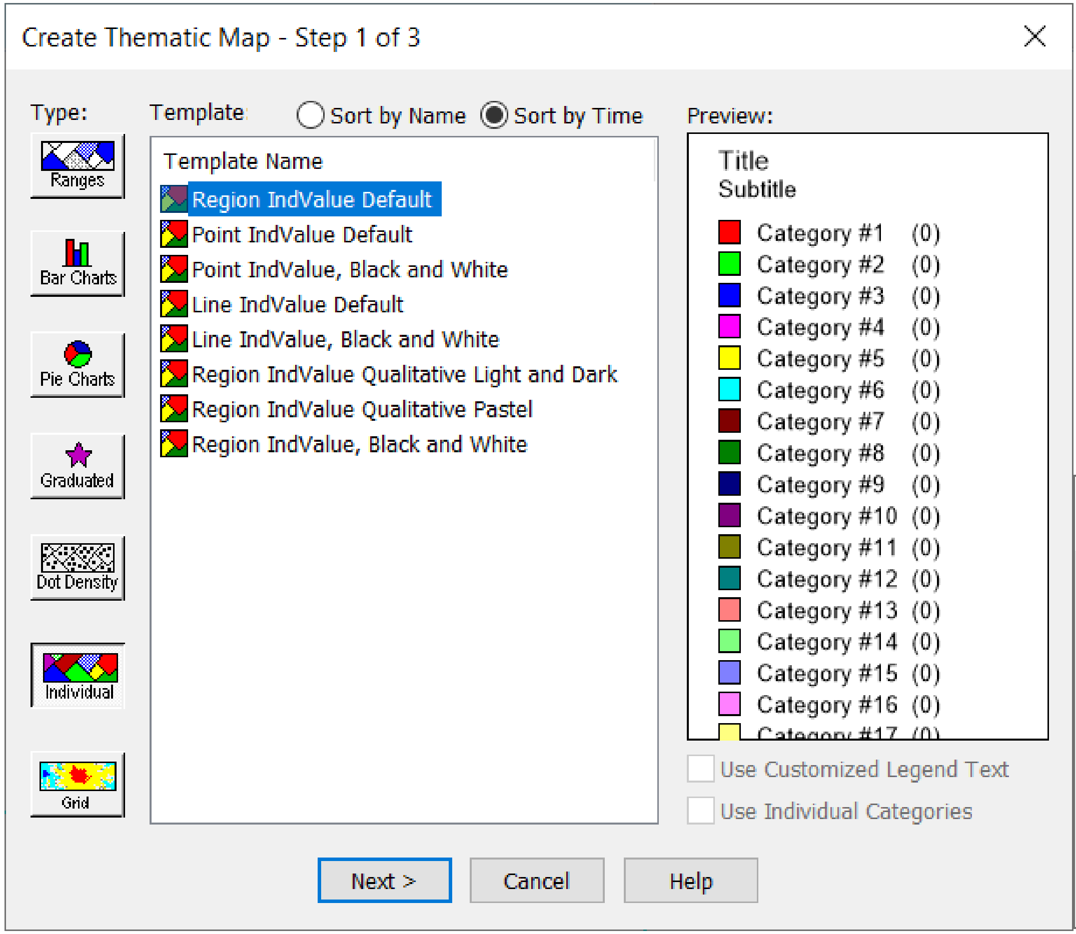

*DAT_162_Climate_Change_Adaptation_Project.WOR - MapInfo Pro
PRO
HOME
TABLE
MAP
SPATIAL
LAYOUT
RASTER
STYLE
LABELS
Apply Styles
Use Stacked Styles
Style
Layer
Label
Translucency
Show Nodes
Show Centroids
Show Line Direction
Display
Explorer
Search
DAT_162_DAT_Boundary,...,DAT_162_DAT_LANDM...
Cosmetic Layer
DAT_162_DAT_Boundary
Flood_Risk_from_Surface_Water
Flood_Risk_from_the_Sea
Ind. Value with Risk
Flood_Risk_from_Rivers
DAT_162_LMP14_Bi_Class_01
DAT_162_LMP14_Bi_Class_2
DAT_162_LMP14_Bi_Class_6
DAT_162_LMP14_Bi_Class_8
DAT_162_LMP14_Bi_Class_10
DAT_162_LMP14_Bi_Class_16
DAT_162_DAT_Boundary,...,DAT_162_DAT_LANDMAP_VS_Climate Map
Editing: None
Selecting: None
British National Grid
default

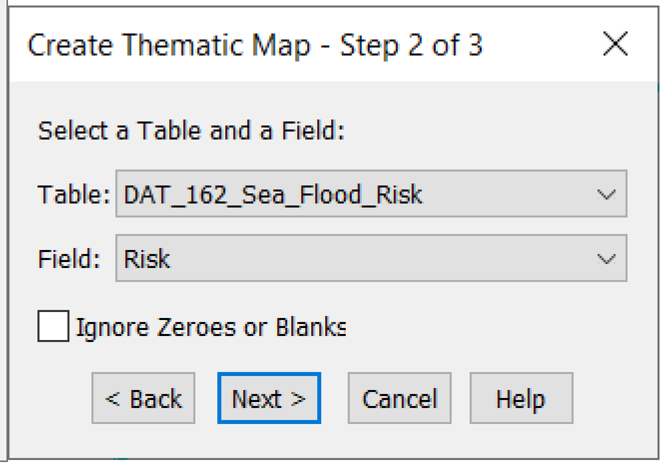

Select By Location
Select objects from:
Flood_Risk_from_the_Sea
Compared to objects in:
DAT_162_DAT_Boundary
Specify the spatial method to use when selecting objects from Flood_Risk_from_the_Sea in relation to objects from DAT_162_DAT_Boundary.
Relation:
Within
OK
Cancel
Help


*DAT_162_Climate_Change_Adaptation_Project.WOR - MapInfo Pro
Quick Search (Ctrl+Q)
PRO
HOME
TABLE
MAP
SPATIAL
LAYOUT
RASTER
STYLE
LABELS
Apply Styles
Use Stacked Styles
Style
Layer
Label
Translucency
Show Nodes
Show Centroids
Show Line Direction
Display
Explorer
Search
Maps
DAT_162_Sea_Flood_Risk,...,DAT_162_DAT_LANDM...
Cosmetic Layer
DAT_162_Sea_Flood_Risk
DAT_162_DAT_Boundary
DAT_162_LMP14_Bi_Class_30_HER_
DAT_162_LMP14_Bi_Class_20_HER_
DAT_162_LMP14_Bi_Class_18_HER_
DAT_162_LMP14_Bi_Class_16_HER_
DAT_162_LMP14_Bi_Class_10_HER_
DAT_162_LMP14_Bi_Class_8_HER_C
DAT_162_LMP14_Bi_Class_6_HER_C
DAT_162_LMP14_Bi_Class_2_HER_C
DAT_162_LMP14_Bi_Class_01_HER_
Flood_Risk_from_Surface_Water
Flood_Risk_from_the_Sea
Ind. Value with Risk
Flood_Risk_from_Rivers
DAT_162_NRW_FLood_Zone_3_Fluvi
DAT_162_LMP14_Bi_Class_01
DAT_162_LMP14_Bi_Class_2
DAT_162_LMP14_Bi_Class_6
DAT_162_LMP14_Bi_Class_8
DAT_162_Sea_Flood_Risk Browser
DAT_162_Sea_Flood_Risk,...,DAT_162_DAT_LANDMAP_VS_Climate Map
Zoom: 234.6 km
Editing: None
Selecting: Flood_Risk_from_the_Sea
British National Grid
default
*DAT_162_Climate_Change_Adaptation_Project.WOR

STEP 55: thematic mapping of the flood risk data

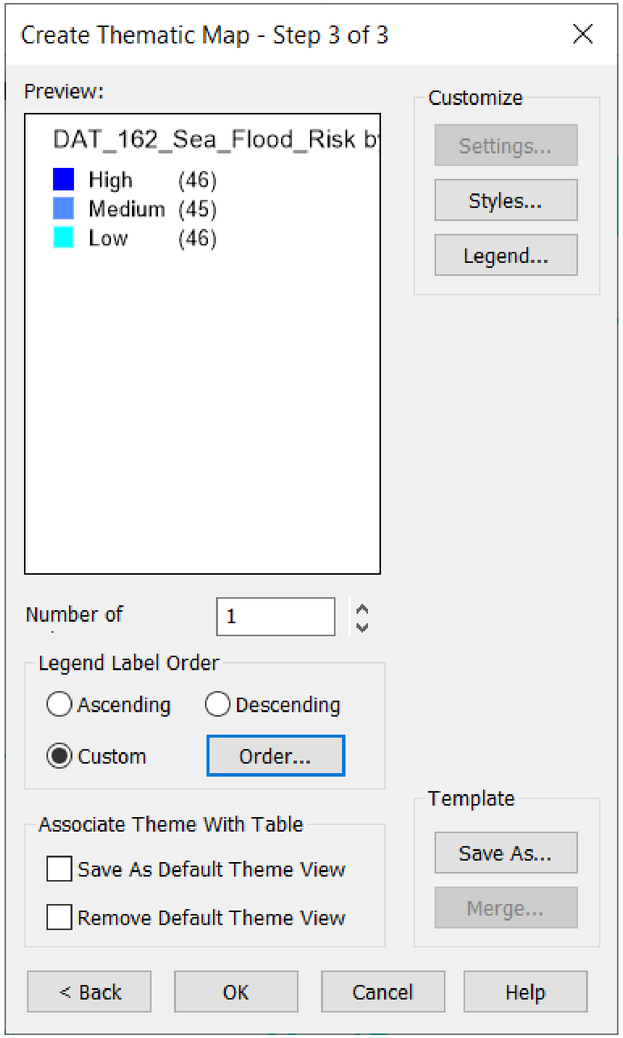
Its useful to create a thematic map based on the “Risk” field of the flood risk data. In this instance we can use the “Individual” thematic template:





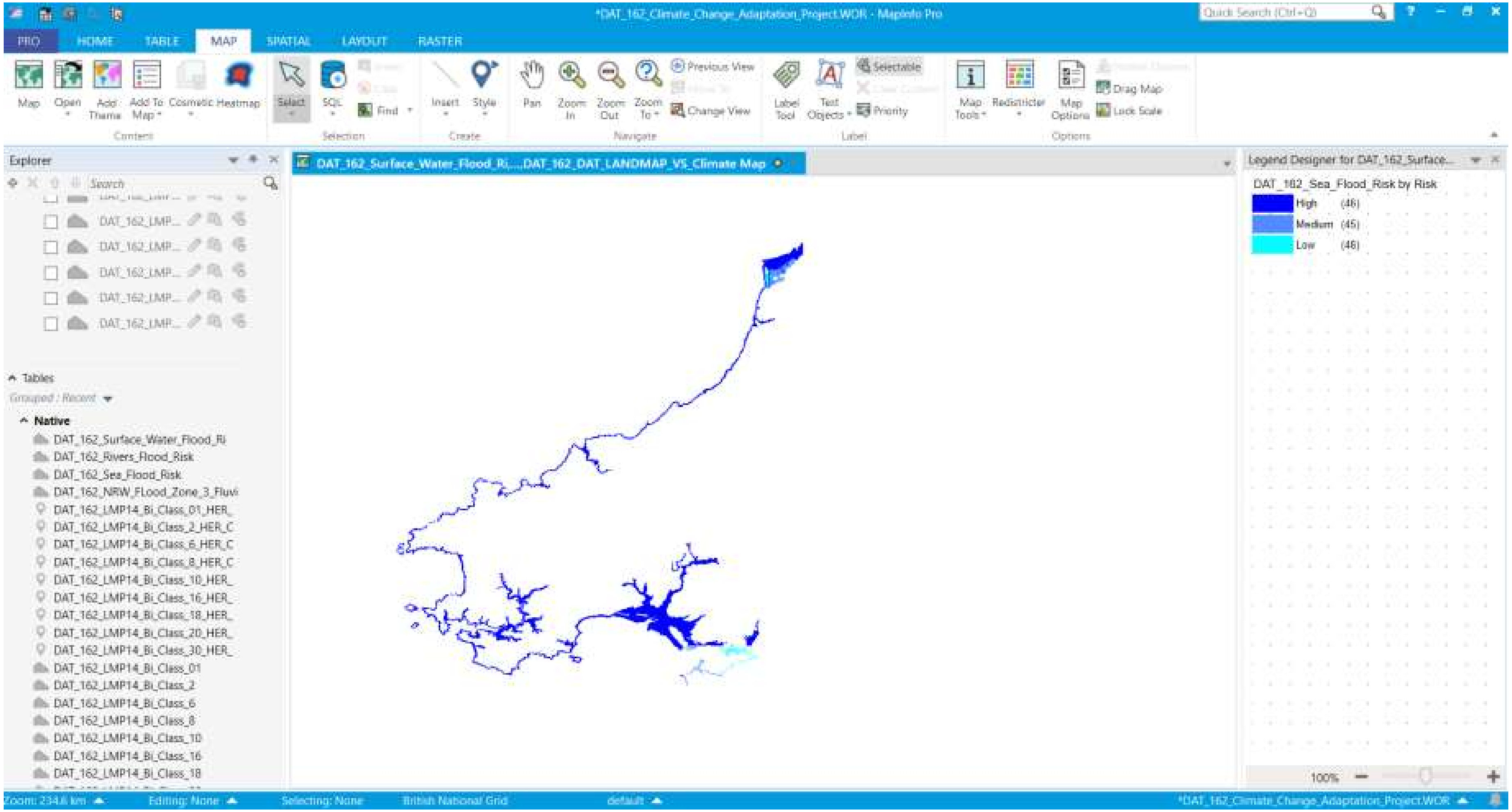
STEP 56

Change the region styles as by clicking on the “Styles” tab and using the process outlined in step 19



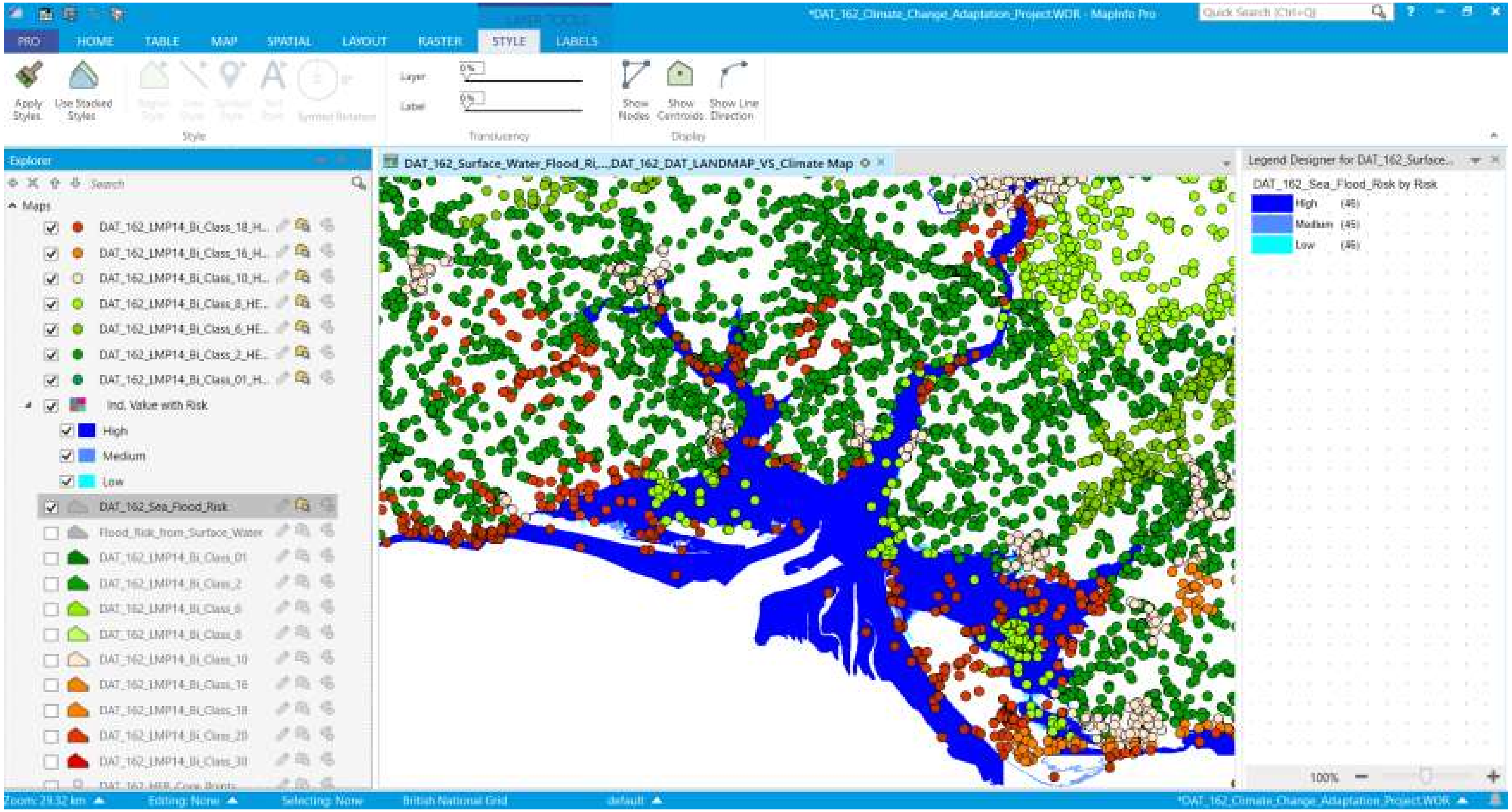
STEP 57

The resultant map could look something like this:

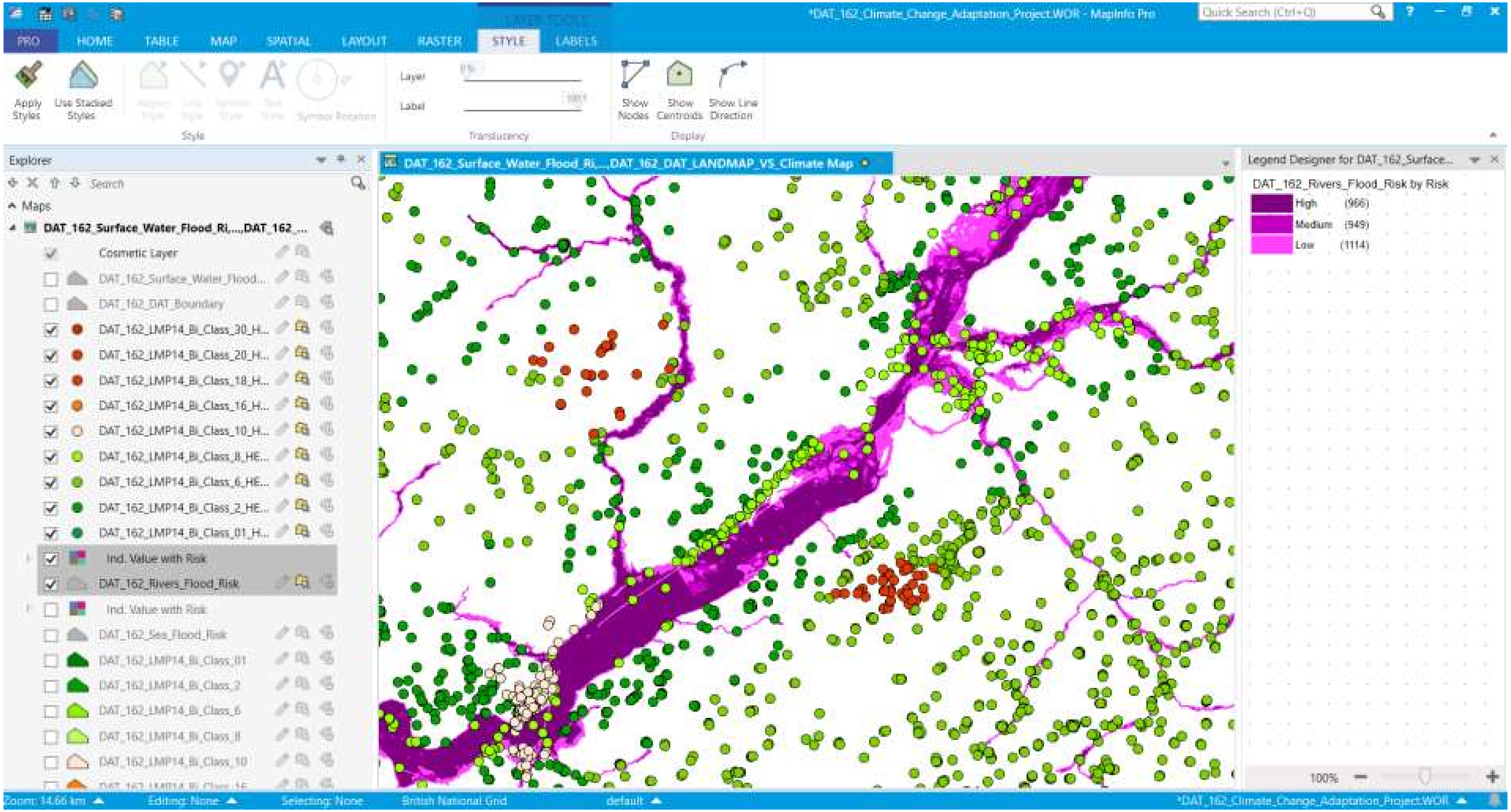


STEP 58

It is then possible to overlay the classified HER Core point data to see which intersects and falls within the flood risk data. Immediately it possible to see that this has thrown some considerable implications for evaluating the vulnerability of these sites. In the example below you can see that there are a number of low risk Bi_class points that are at high risk of flooding from the sea (having already been assessed as pertaining to land classes with little or no risk from rising sea levels according to the NRW Flood Zone 3 data). It would also be useful to apply a buffer to these flood zones e.g 150m

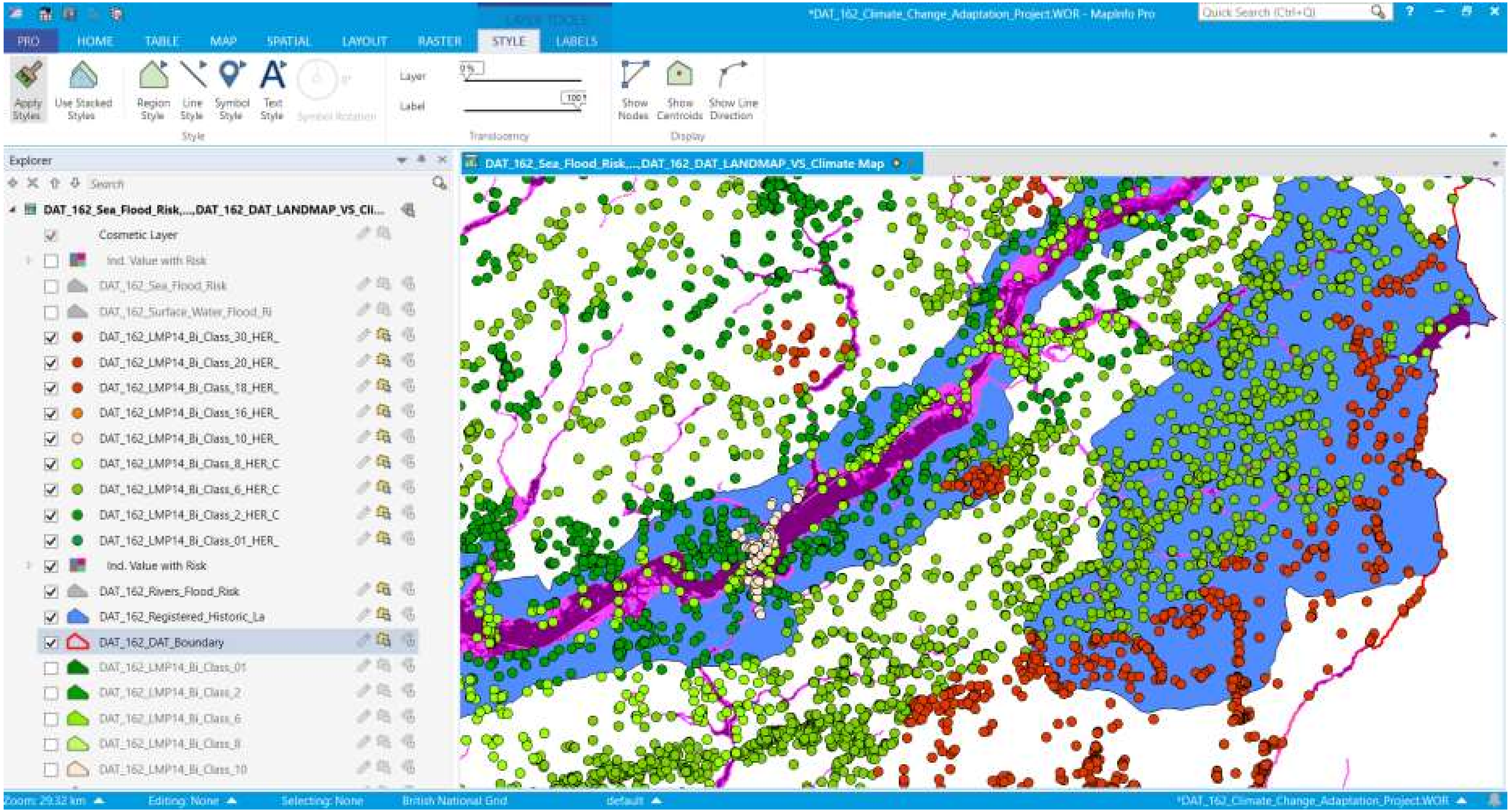


The example below shows the same problem for the risk of flooding from rivers:



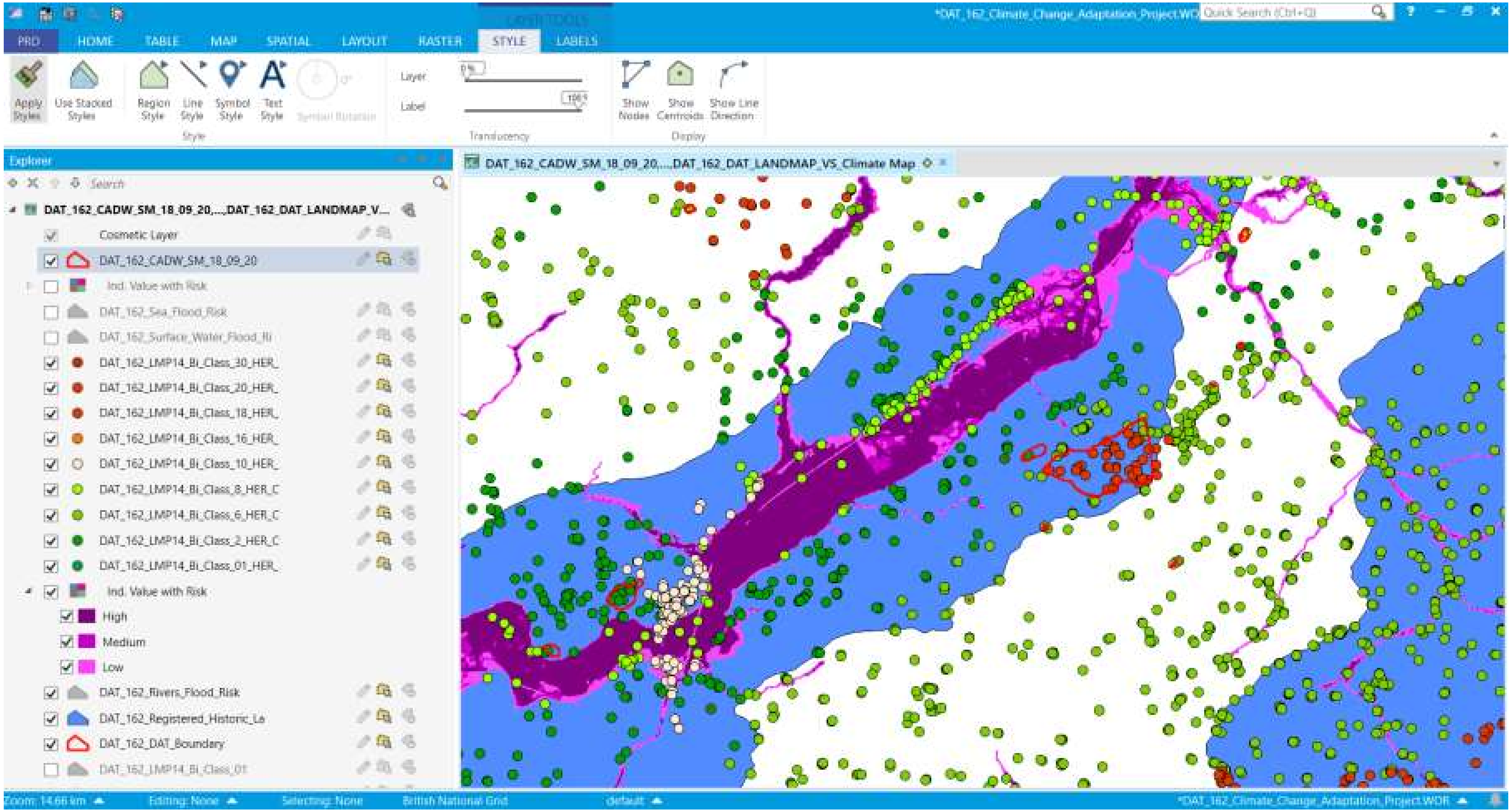
STEP 59

We can now add other historic environment data to the mapping. Below shows to Registered Historic Landscape polygons. We can use these polygons to calculate very quickly the count and density of the HER points and Bi_classes and to evaluate the risks and implications presented by the flood data.



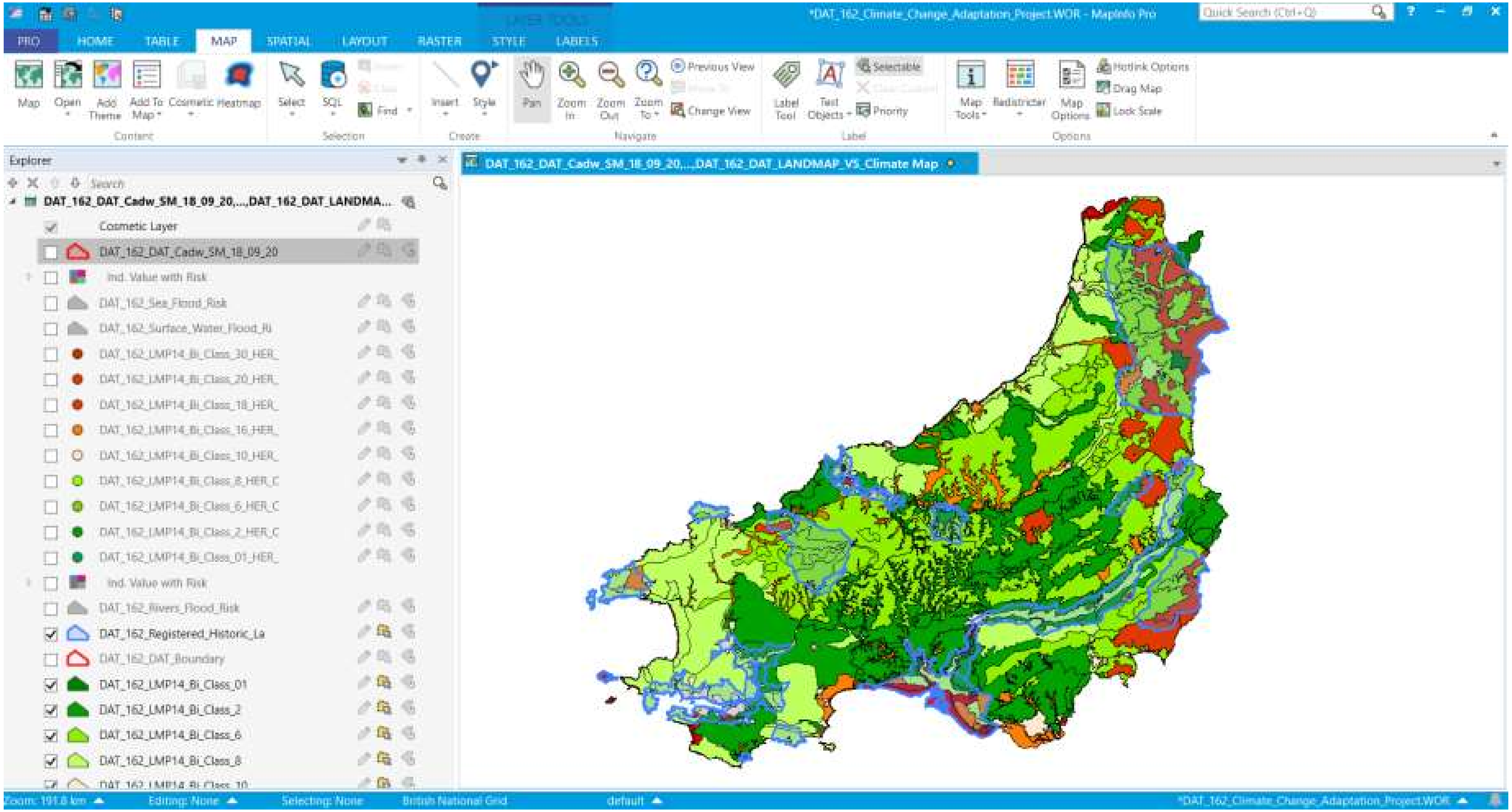
STEP 60: Cadw polygons

We can also add the Cadw Scheduled monument polygons to the mapping. An immediate assessment shows that one of the SMs comprises of potentially high risk sites. Two smaller SMs towards the SW corner of the map shows that these potentially low risk sites are in close proximity and/or at direct high risk of river flooding.



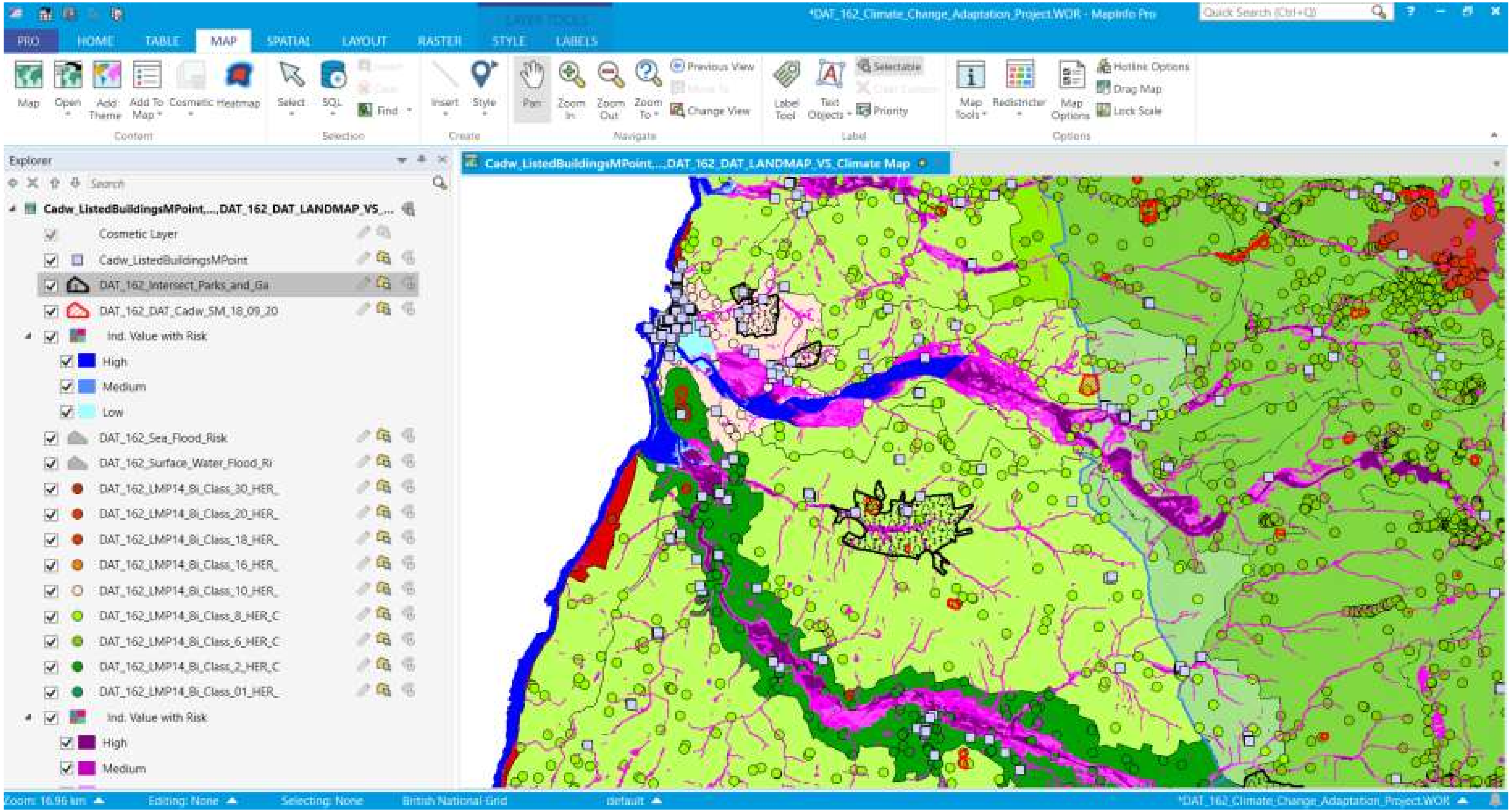
STEP 61

The Bi_class land class base mapping data is also useful to characterise and evaluate the risk of larger polygonal dataset such as the Registered Historic Landscapes (outlined and hachured in blue):



STEP 62

We can continue to add point and polygonal data to the mapping. Below shows Listed Buildings (grey squares) and the Registered Parks and Gardens polygons (outlined in black, tree in fill) over laid the classified (Bi_class) land classes and HER points, sea and river flood risk data and registered Historic Landscapes polygons (outlined and hachured in blue). We could add woodland, blanket bogs and the RCAHMW maritime assets data to this.



CONCLUSIONS

This methodology is just one example of how spatial modelling can quickly produce a baseline dataset to evaluate the risks of climatic change on the historic environment at a national, regional and site scale.

The principle underpinning this methodology is that historic environment assets should be evaluated by ***where*** they are, not ***what*** they are in the first instance. This has been possible by using NRW LANDMAP's Landscape and a Changing Climate project data impact metrics. This method removes the problem of categorising historic environment typologies.

The archaeology and land class impact scores from this data have been converged to produce a bivariate base map showing the areas calculated has having the greatest to lowest negative impacts of climate change. The historic environment data can be overlaid, and it is possible to see where this data intersects or falls with in the risk classified areas. HER core point data has been attributed an initial risk level based on this classified base map.

The true vulnerability of these sites can be assessed at a site level by sampling these populations. The application of NRW's latest Flood Risk Assessment data has significant implications on the classified data and requires an independent, systematic evaluation.

The classified point and polygon data can be imported into the regional HERs as standalone tables (converted first into zipped shape files). Indeed, it may even be possible to convert this data into an additional child table within the Core records.

An important caveat is that the classified data is a result of this modelling methodology. Different processing and classification will produce different results. Irrespective of the methodology undertaken, spatial modelling allows for a rapid coherent and repeatable processing and evaluation of the data.

Finally, this methodology has demonstrated that it is possible to apply many levels of data interrogation to identify a number of possible lines of further enquiry and study. This baseline data has satisfied the remit of the scoping study and enables the HEG Sector Adaptation Guidance's risk criteria and adaptive techniques to be applied practically and consistently. We can use this baseline data to identify the opportunities to;

- Increase our knowledge
- Increase our capacity
- Increase resilience

My initial recommendations from this exercise is that the NRW Flood Risk Assessment data and its implications on the historic environment is a study in itself. The LANDMAP project and HEG project used the Flood Zone 3 data. As we have seen, the latest flood risk data shows that there is flooding risk where there has not previously been identified. Secondly, that whether it is possible using the data available and building on this spatial modelling, to undertake a triage of loss in the historic environment. This would necessitate the integration of Cadw's Schedule Monument condition monitoring data.