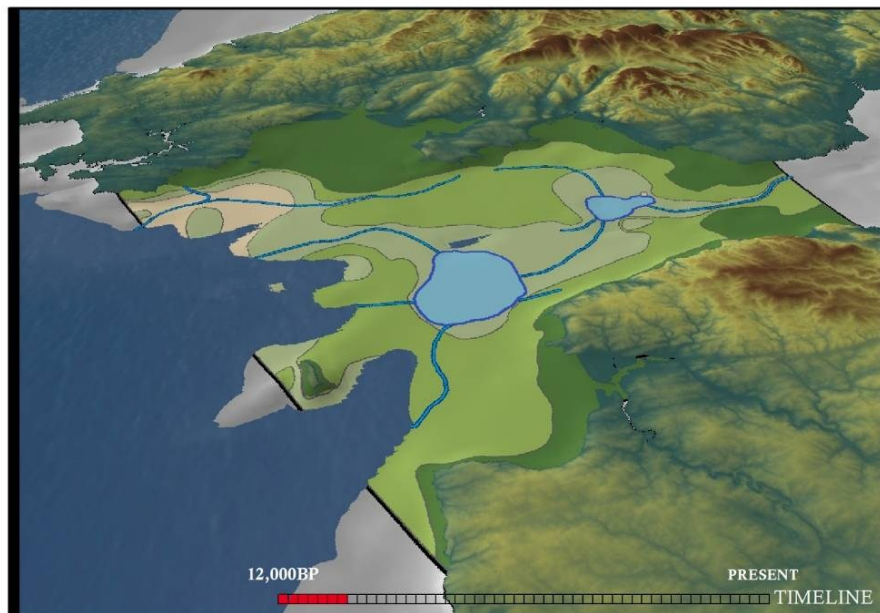


WEST COAST PALAEOLANDSCAPES SURVEY (WCPS)



2011

By

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West Coast Palaeolandscapes survey

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Summary

The West Coast Palaeolandscapes Survey builds upon the results of comparative work carried out as part of the North Sea Palaeolandscape Project (NSPP). The results of that project suggested that other areas existed within the UK where sufficient data could support similar studies. The west coast of Britain was identified as an area where information on existing palaeolandscapes would have a significant impact on our understanding of the Mesolithic and, potentially, the Palaeolithic in England and Wales. This information would also support the heritage management strategies for the region in respect to aggregates extraction. This document provides a report on the work and provides mapping relating to the prehistoric submerged landscapes in selected areas of the Bristol Channel and Irish Sea.

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Co-ordinate Systems utilised within this project.

The UTM Zone 30N Projection was utilised within the project GIS. Positions and GIS shapefiles obtained from other institutions were converted to this projection using the Geospatial tools provided within ArcGIS 9.3.

Archaeological Dates

The dates provided within this assessment are presented as either BP (Before Present), when used in reference to uncalibrated radiocarbon dates, or cal BP when the date has been calibrated

CONTENTS

1.	INTRODUCTION TO THE PROJECT	1
2	AIMS AND OBJECTIVES	2
2.1	Aims	2
2.2	Objectives	2
3	SUMMARY OF RESULTS OF PREVIOUS RESEARCH INTO THE SUBMERGED LANDSCAPE.....	4
3.1	Research frameworks.....	6
4	ARCHAEOLOGICAL BACKGROUND AND SIGNIFICANCE OF THE AREA SURROUNDING THE STUDY AREAS.....	8
4.1	Palaeolithic of the Bristol Channel and Liverpool Bay	8
	<i>Late Upper Palaeolithic (Creswellian).....</i>	8
	<i>The final Upper Palaeolithic (Federmesser culture and Long Blade Industry)</i>	9
	<i>Landscape Features of significance to this project – Caves.....</i>	10
	<i>Landscape Features of significance to this project – Rivers.....</i>	11
	<i>Landscape Features of significance to this project – Open air sites</i>	12
4.2	The Mesolithic of the Bristol Channel and Liverpool Bay	12
	<i>The Early and Late Mesolithic</i>	13
	<i>Landscape Features of significance to this project (Bristol Channel) - Riverine</i>	14
	<i>Landscape Features of significance to this project (Bristol Channel) - Cave sites</i>	15
	<i>Landscape Features of significance to this project (Bristol Channel) - High ground and dryland inland</i>	15
	<i>Landscape Features of significance to this project (Bristol Channel) -Intertidal and coastal</i>	16
	<i>Landscape Features of significance to this project (Liverpool Bay) - Riverine</i>	17
	<i>Landscape Features of significance to this project (Liverpool Bay) - Cave sites</i>	17
	<i>Landscape Features of significance to this project (Liverpool Bay) - Coastal</i>	17
5	INTRODUCTION TO THE DATA.....	19
5.1	Data holdings accessed by the project	22
5.2	3D data.....	22
	<i>An assessment of the 3D seismic survey acquired for use within the project</i>	22
5.3	2D data.....	26
	<i>Assessment of density of 2D Datasets available for study</i>	26
	<i>An assessment of the BGS 2D geophysical survey data for use within the project</i>	28
	<i>An assessment of the DTi offshore (BERR/Phoenix) 2D Data requested for use within the project</i>	28
	<i>An assessment of the speculative 2D geophysical survey data for use within the project.....</i>	31
	<i>An assessment of the available SeaZone data for use within the project</i>	32
5.4	Assessment of other information acquired for study	33
6	IMPLEMENTATION OF THE METHODOLOGY	35
6.1	Implementation of the 3D Methodology	35
6.2	Implementation of the 2D dataset methodology	38
6.3	Methodological improvements undertaken	39
7	ANALYSIS, RESULTS AND OUTPUTS.....	40
7.1	Examples of 3D features identified.....	40
7.2	Examples of 2D features identified.....	48
7.3	The integration, analysis, and interpretation of 2D and 3D seismic survey data within GIS.	52
	<i>Bristol Channel.....</i>	53

West Coast Palaeolandscapes Survey 2011

<i>Liverpool Bay</i>	60
7.4 Prehistoric Landscape Characterisation.....	70
7.5 Potential Mapping	74
7.6 Additional work by Dyfd Archaeological Trust	88
8 THE RESULTS IN CONTEXT - THE LATE PALAEOLITHIC AND MESOLITHIC LANDSCAPE.....	89
8.1 Bristol Channel – Palaeolithic (Figure 56)	89
8.2 Bristol Channel -Mesolithic (Figure 57)	91
8.3 Liverpool Bay- Palaeolithic (Figure 58)	94
8.4 Liverpool Bay – Mesolithic (Figure 59)	96
9 CONCLUSIONS	98
10 REFERENCES	99
11 Glossary.....	107
12 Appendix 1	110

LIST OF FIGURES AND TABLES

- Figure 1: Late Upper Palaeolithic landscape of the British Isles (after Coles 1998)
- Figure 2: Coverage of 3D seismic surveys in the Irish Sea region (data blocks are shown here in green)
- Figure 3: Four possible interpretations of a channel morphology (a-d)
- Figure 4: 2D seismic data density for the Irish Sea region (courtesy of BERR/DTi).
- Figure 5: 3D timeslices through datasets procured within the North Wales and English marine areas (not including the Pilot Project datasets)
- Figure 6: All 3D seismic surveys used in the project (Liverpool Bay study area)
- Figure 7: 2D lines used in the Bristol Channel study area
- Figure 8: 2D lines used in the Liverpool Bay study area
- Figure 9: A Selection of 2D Lines from the Bristol Channel, illustrating the differing sedimentological conditions across the study area.
- Figure 10: Example of scanned paper information, note the detailed metadata included in this sheet.
- Figure 11: Map of the SeaZone bathymetric data purchased for use in this project. Data © British Crown and SeaZone Solutions Limited. All rights reserved.
- Figure 12: BGS Map of the thickness of the Western Irish Sea Formation (WIS - Upper Pleistocene) from Jackson *et al* 1995
- Figure 13: 3D features exported from Kingdom as a DXF file
- Figure 14: a) High ground locations, b) 3D seismic data timeslice AMPLITUDES 0.056, c) feature outline
- Figure 15: a) Holocene estuaries and coastlines, b) 3D seismic data timeslice AMPLITUDES 0.056, c) feature outline
- Figure 16: a) Small Holocene deltaic system, b) 3D seismic data timeslice RUNSUM 0.064, c) feature outline
- Figure 17: a) End glacial channels in large floodplains, b) 3D seismic data timeslice HILBERT 0.064, c) feature outline
- Figure 18: a) Glacial tunnel valleys, b) 3D seismic data timeslice HILBERT 0.064, c) feature outline
- Figure 19: a) Holocene channels and Holocene fluvial floodplains, b) 3D seismic data timeslice AMPLITUDES 0.056, c) feature outline
- Figure 20: a) Late glacial features reused in Holocene, b) 3D seismic data timeslice HILBERT 0.064, c) feature outline
- Figure 21: a) Basin structures, b) 3D seismic data timeslice AMPLITUDES 0.052, c) feature outline
- Figure 22: Wide channels, location and example
- Figure 23: Sediment filled basin, location and example
- Figure 24: Holocene channels with infills, location and example
- Figure 25: Positive topography, location and example
- Figure 26: Glacial Lake deposits, location and example
- Figure 27: Peat/organic floodplain deposits, location
- Figure 28: Confidence map showing distance from lines in the Liverpool Bay study area
- Figure 29: Confidence map showing distance from lines in the Bristol Channel study area
- Figure 30: 2D features within the Bristol Channel study area
- Figure 31: Interpolated raster derived from the Z values of the 2D features
- Figure 32: Broad area features identified within the Bristol Channel study area
- Figure 33: Interpolated features generated within the Bristol Channel study area
- Figure 34: Relative topography within the Bristol Channel study area
- Figure 35: 2D features identified within the Liverpool Bay study area
- Figure 36: Raster interpolation derived from the Z values of the 2D features identified within the Liverpool Bay study area
- Figure 37: Features identified from the 3D dataset in the Liverpool Bay study area showing certainty of feature presence

- Figure 38: Interpretation of features identified within the 3D dataset
Figure 39: Additional 3D features identified within the Liverpool Bay study area
Figure 40: Broad area features identified within the Liverpool Bay study area
Figure 41: Relative topography within the Liverpool Bay study area
Figure 42: Prehistoric landscape characterisation of the Bristol Channel study area
Figure 43: Prehistoric landscape characterisation of the Liverpool Bay study area
Figure 44: Potential for encountering known features and deposits of archaeological significance determined by distance in the Bristol Channel study area
Figure 45: Potential for encountering known features and deposits of archaeological significance determined by distance in the Liverpool Bay study area
Figure 46: Potential survival of archaeological deposits determined by water depth in the Bristol Channel study area
Figure 47: Potential survival of archaeological deposits determined by water depth in the Liverpool Bay study area
Figure 48: Tidal stress zones within the Bristol Channel study area
Figure 49: Tidal stress zones within the Liverpool Bay study area
Figure 50: Other factors determining the presence/survival of archaeological deposits within the Bristol Channel study area
Figure 51: Other factors determining the presence/survival of archaeological deposits within the Liverpool Bay study area
Figure 52: Potential survival of archaeological deposits (combination of tidal stress, erosion, geology etc) within the Bristol Channel study area
Figure 53: Potential survival of archaeological deposits (combination of tidal stress, erosion, geology etc) within the Liverpool Bay study area
Figure 54: Potential presence/survival of archaeological features and deposits based on all contributory factors within the Bristol Channel study area
Figure 55: Potential presence/survival of archaeological features and deposits based on all contributory factors within the Liverpool Bay study area
Figure 56: The Bristol Channel during the Late Palaeolithic
Figure 57: The Bristol Channel in the Mesolithic
Figure 58: Liverpool Bay in the Late Palaeolithic
Figure 59: Liverpool Bay in the Mesolithic

- Table 1: Areas covered by 3D seismic data
Table 2: 2D lines used in the project
Table 3: Features identified within the Bristol Channel study area
Table 4: Features identified in the 2D seismic datasets within the Liverpool Bay study area
Table 5: Features identified within the 3D seismic datasets
Table 6: Landscape characterisation of the Bristol Channel study area
Table 7: Landscape characterisation of the Liverpool Bay study area

1. INTRODUCTION TO THE PROJECT

1.0.1 In 2009 a pilot study for the West Coast area (Appendix 1) was commissioned by English Heritage building on the results of the North Sea Palaeolandscape Project (NSPP). It sought to investigate the methodology of utilising a wider variety of seismic data sources to determine the extent and nature of the submerged landscapes contained within an area of the Irish Sea.

1.0.2 The results of the pilot project identified several areas within the UK where sufficient data, albeit often in the form of older 2D survey, would support comparative work. The west coast of Britain was identified as a particularly interesting area, both archaeologically and methodologically, and the Irish Sea and Bristol Channel areas were highlighted for further study. Any information gleaned on the palaeolandscape here would inform our understanding of the development of the Mesolithic and, potentially, the Palaeolithic, in both England and Wales. Information gained would also have considerable value for our understanding of the archaeological records of Ireland, Scotland and the Isle of Man. In addition any knowledge provided would assist heritage and mineral management strategy of offshore development control within these areas.

1.0.3 The West Coast Palaeolandscapes Survey therefore sought to investigate the potential for submerged landscapes within the Irish Sea and Bristol Channel.

1.0.4 The specific outcomes of the project are:

- To exploit the methodology developed during the pilot study to utilise existing 2D seismic and related data to improve the understanding of the submerged prehistoric resource of study areas in the Irish Sea and Bristol Channel and to integrate the data with that from the Pilot study.
- To apply the existing methodology for 3D datasets (where available) to assist in the provision of extensive landscape data for the Irish Sea.
- To use these generated datasets to investigate and explore the Late Palaeolithic and Mesolithic Landscapes within the study areas, and where possible map these landscape features to assist heritage management strategy with respect to marine aggregate extraction and development.
- To disseminate the results as a technical report and popular bilingual publication for Wales.

2 AIMS AND OBJECTIVES

2.1 Aims

2.1.1 The overall goal of this study was to utilise available information to generate a baseline interpretative data set for the maritime areas of the outer Bristol Channel and south-east Irish Sea that is compatible with that provided for the North Sea but utilising data from 2D seismic lines in the manner suggested by the commissioned pilot project (Appendix 1).

2.1.2 The principal aims of the project were therefore:

Aim 1: To use the available existing 2D and 3D seismic and related datasets to explore the Late Quaternary and Holocene landscape and to enhance exploration through any available, additional data.

Aim 2: To provide a map of the topographic features of the region which have archaeological relevance. Resolution of mapping was enhanced through additional data procurement.

Aim 3: To provide a map of survival potential for archaeological deposits within the study area and, as above, to use additional data to enhance the results.

Aim 4: To use data on environmental and archaeological potential to provide an extensive landscape characterisation map of the two areas for use for development control purposes.

Aim 5: (Dyfed) To use the results of the project and disseminate these to the wider public in Wales.

2.2 Objectives

2.2.1 The aims defined above may be formulated as a series of objectives that were addressed through the application of specific methodologies.

Aim 1: To use the available existing 2D and 3D seismic and related datasets to explore the Late Quaternary and Holocene landscape and to enhance exploration through any available, additional data.

Objective 1.1: To locate and obtain appropriate seismic and related datasets, where available, for utilisation within the project.

Objective 1.2: To assess the density of 2D and 3D seismic coverage and to identify any gaps of coverage within the study area and to assess the impact of such gaps upon the production of continuous landscape mapping.

Objective 1.3 To identify any additional data and material that may be required to support the use of the seismic data in mapping the submerged archaeological landscape.

Aim 2: To provide a map of the topographic features of the region which have archaeological relevance. Resolution of mapping was enhanced through additional data procurement.

Objective 2.1: To utilise the available 2D seismic information to provide landscape data for the study area

Objective 2.2: To utilise the available 3D seismic information to provide landscape data for the study area

Objective 2.3: To analyse the information resulting from Objectives 2.2 and 2.3

Objective 2.4: To produce appropriate mapping from the results of 2.1 to 2.3

Aim 3: To provide a map of survival potential for archaeological deposits within the study area and, as above, to use additional data to enhance the results.

Objective 3.1: To assess and identify areas where archaeological deposits may exist through the use of 2D and 3D seismic data, available bathymetric data and additional data sets.

Objective 3.2: To identify areas where the potential for prehistoric archaeological preservation may be minimal due to erosional processes.

Object 3.3: To map the resultant outputs of Objective 3.1 and 3.2 in a manner that reflects the data available

Aim 4: To use data on environmental and archaeological potential to provide an extensive landscape characterisation map of the two areas for use for development control purposes.

Objective 4.1: To utilise the results from Aims 1 and 2 to generate a broad scale landscape interpretation, the resolution of which could be enhanced through the provision of additional data as part of the project variation.

Objective 4.2: To produce a characterisation of the data that could be utilised to assist planning and development within these regions.

Objective 4.3: To disseminate this information via agreed outputs

Aim 5: (Dyfed) To use the results of the project and disseminate these to the wider public in Wales.

Objective 5.1: To produce a popular bilingual (Welsh/English) booklet on the project - *The lost lands of our ancestors/Tiroedd coll ein cynadadau*

Objective 5.2: To create a bilingual website (part of Dyfed Archaeological Trust's website - www.dyfedarchaeology.org.uk) outlining results of the project.

Objective 5.3: To create a bilingual education resource on the project website

3 SUMMARY OF RESULTS OF PREVIOUS RESEARCH INTO THE SUBMERGED LANDSCAPE

3.0.1 The Liverpool Bay study area (which included the initial pilot study area) was identified by Coles (1998) as part of the palaeolandscape that facilitated the connection of the Isle of Man to the British mainland. However, the lack of detailed information prevented a more detailed assessment of the potential and significance of the area. Despite this, Coles produced a series of extensive, but speculative maps that included the area (Figure 1). These clearly indicate the region as an extensive emergent landscape well into the early Holocene.

3.0.2 The Bristol Channel study area was also identified as significant during these periods, and the area suffers equally from a lack of direct information.

3.0.3 Attempts to rectify this situation have frequently involved the use of isostatic rebound models to provide outline representations of the former landscape in the Liverpool Bay area, and examples include those produced by Shennan *et al* 2000 and Lambeck and Purcell (2001). Unfortunately, the scales at which these models operate make them unsuitable for archaeological interpretation. Even though higher resolution local models are utilised in other areas of the British Isles, the analytical cell size (1.2km x 1.2km, Shennan and Horton 2002: 513) is still too large for the majority of archaeological analyses. This, combined with the exclusion of important oceanographic and geological factors, including burial and erosion, make these models far from ideal (Bell *et al* 2006, Box 1, 14). Essentially, the issues associated with isostatic modelling, and its use in archaeological research, demand that novel methodologies must be developed if the marine prehistory of this region is to be interpreted and protected adequately.

3.0.4 In January 2005, Wessex Archaeology undertook to produce a pilot study of the 'seascape' within part of the Liverpool Bay area (extending to the 12 nautical mile limit). Mapping, themed by period and broad headings reflecting modern use of the region, defined a series of polygons representing 'Character Areas'. However, it is important to note that the lack of detailed information concerning the submerged landscape in the region meant that this study was obliged to use a model of coastal change to provide an assessment of potential for the presumed, submerged prehistoric landscape. Whilst such observations do not invalidate the larger rationale of such a project it still remains true, for the reasons highlighted by Bell (2006) and those cited above, that the method is less than ideal if the intention is to understand these early, inundated landscapes. The need to provide further, detailed mapping of the actual landscape and any surviving features is clear if we wish to enhance the results of these earlier projects and to assist strategic marine planning.

3.0.5 Seascape characterisation projects are ongoing in the study areas (Irish Sea/ Severn Estuary), however the data from these projects was not available prior to the conclusion of this project. Integration with these projects must occur at a later date.

3.0.6 The potential for petroleum industry data to inform submerged archaeological prospection has been noted for some time (e.g. Kraft *et al* 1983; Coles 1998). However, the methodologies and the technology needed to implement such studies have been unavailable until relatively recently. The use of extracted datasets for archaeological purposes was pioneered by Birmingham University for the palaeolandscapes of the southern North Sea (Gaffney *et al*

2007) as part of the MALSF-funded North Sea Palaeolandscape Project. The project employed the latest computing and visualisation techniques available to both the archaeological and petroleum industries to explore a 3D dataset provided by PGS UK Ltd. This revealed a submerged Mesolithic landscape in unprecedented detail. The resolution was sufficient to perform a detailed analysis using the data to reveal the presence of the coastlines, estuaries and major fluvial features active in prehistory.

3.0.7 A Pilot Project to test the methodological application of these techniques in the Irish Sea area was completed by Birmingham University in 2009 (Appendix 1). This study revealed that legacy 2D data could, where sufficient density existed, provide extensive landscape information. This is significant as it facilitates investigation into submerged prehistoric landscapes beyond the existing extent of 3D survey. The current project therefore is derived from this work and was undertaken to implement the results of the pilot project.

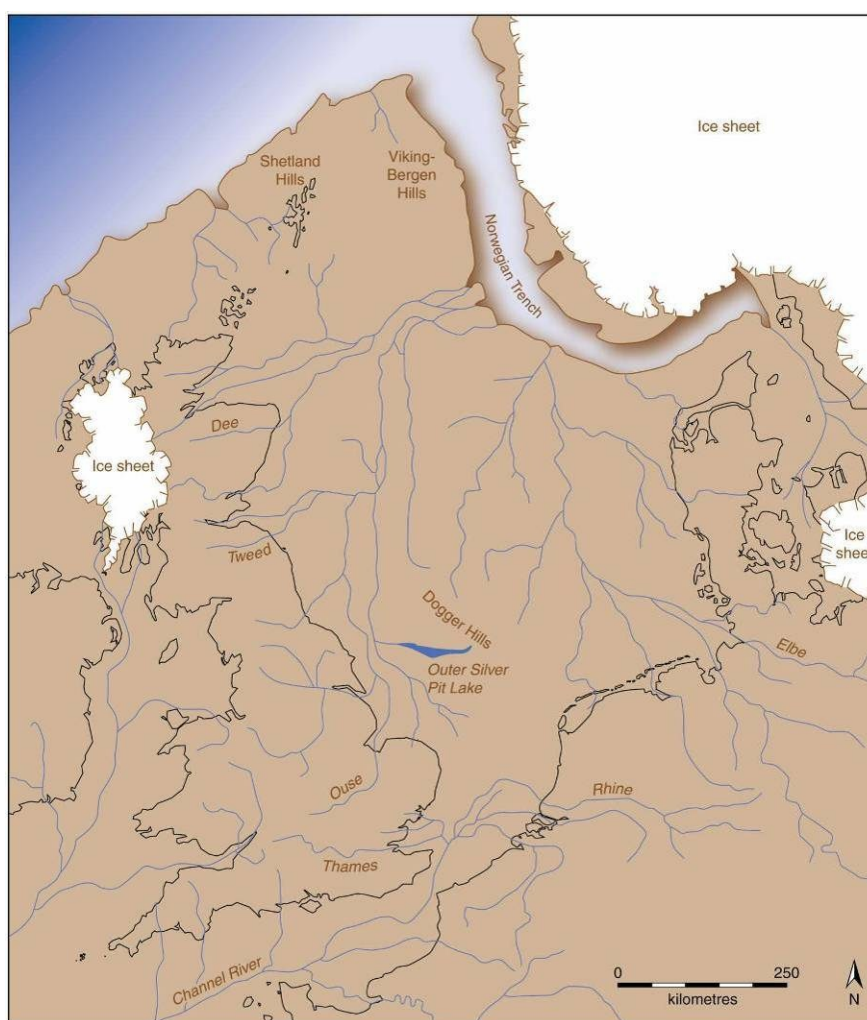


Figure 1: Late Upper Palaeolithic Landscape of the British Isles (After Coles 1998)

3.1 Research frameworks

3.1.1 Since the initial publication of Roberts and Trow's work in 2002, considerable change has occurred in the way marine archaeology is assessed within the British Isles, particularly in respect to submerged prehistory. This change has in part driven by recent research that has been supported by English Heritage using funds from the ALSF (e.g. Gaffney *et al* 2009, Wessex Archaeology 2008.) Additionally, the ALSF has also funded the development of a Maritime and Marine Research Framework in England - which should be published shortly (Ransley *et al* forthcoming). This identifies both the Palaeolithic and the Mesolithic as areas where further research is required, particularly with respect to the impact of landscape change and sea-level rise on populations (Bell *et al* forthcoming.) In addition, the recent international research framework for the North Sea demonstrates how international collaboration is required to fully understand and interpret submerged landscapes which cross national boundaries (Peeters *et al* 2009).

3.1.2 In the terrestrial sphere, there are several relevant regional frameworks. In the South West region, which bounds the Bristol Channel, there is the South West of England Archaeological Research Framework (SWARF, Webster 2007). This research framework notes the importance of improving our understanding of past climate and sea-level change (Aim 23, Webster 2007), especially in relation to the prehistoric period. The framework also notes the importance of considering the continuation of the Palaeolithic and Mesolithic landscapes in the current offshore areas and the need for topographic, deposit, and site modelling for these submerged areas.

3.1.3 The North West Archaeological Research framework takes a similar position in relation to Liverpool Bay (Brennand *et al* 2006). In particular the framework notes that the maritime and coastal resource contains potential wealth of information, however it notes that "Patterns of past sea-level rise and coastal change are understood only at a broad scale" (Brennand *et al* 2006). In addition the framework also notes that the offshore and intertidal areas that potentially contain prehistoric land surfaces, and observes the recorded occurrence of submerged forest beds at several intertidal locations. The North West framework records that these resources are under threat from natural forces, and that tidal currents are known to have destroyed sites.

3.1.4 Period specific frameworks also exist. In particular the Prehistoric Society has published two frameworks of relevance. One, published in 1999, covered both the Palaeolithic and Mesolithic (Prehistoric Society 1999), but was revised during 2008 and focused on the Palaeolithic. The 2008 revised framework includes several themes that touch on research issues associated with submerged landscapes (Prehistoric Society 2008). In particular, Theme 1 (Hominin Environments and Climate Drivers) emphasises the importance of studying sea-level change and the significance of the marine transgression after the Last Glacial Maximum (LGM) in changing patterns of landscape use. The local Palaeolithic framework for the Bristol area also highlights these objectives (Bates and Wenban-Smith 2005).

3.1.5 Although the 1999 Palaeolithic and Mesolithic research framework covers the Mesolithic period, the framework noted a divergence in themes associated with period research. This resulted in the 2008 publication only covering the Palaeolithic. A current research framework for the Mesolithic has yet to be published.

3.1.6 One significant research question associated with early Mesolithic archaeology concerns the establishment of annual territorial movement. It has been suggested this occurred early in the Mesolithic. Early Mesolithic sites may be associated with both early and late lithic industries (David and Walker 2004). This suggests that the same locations were used in both periods and that the formation of seasonal movements within a set territory emerges at an early date. This indicates that we may expect similar use of the landscape and resources throughout this period. Evidence to substantiate this hypothesis is likely to be located in areas that were coastal areas and wetlands in the early Mesolithic. However, as there is a lack of early Mesolithic coastal material, following isostatic change and sea-level rise (Milner 2006, 68), it is important to consider if it is applicable to extrapolate the results from terrestrial areas into the offshore region. Until material is recovered from the offshore region, there is insufficient data to resolve this issue.

3.1.7 The study of subsistence economies, seasonality, and territorial movements have traditionally been at the forefront of Mesolithic archaeological research, and whilst these are important, recent work has sought to place emphasis upon on understanding how hunter-gatherers lived in their landscape and how they may have modified their world (Gaffney *et al* 2009). The clearest evidence for landscape modification are burning events, recorded both in the upland and coastal fringes. Burning within the landscape would improve visibility for hunting, produce new vegetation growth to attract grazing ungulates, and encourage the growth of woodland edge plants such as blackberries (Bell 2007).

3.1.8 Recent research in and around the Severn Estuary has produced evidence of repeated reed-bed and woodland burning episodes associated with Mesolithic artefacts, suggesting anthropogenic activity (Bell 2007; Timpany 2005; Brown 2005.) This is most evident at Goldcliff where charcoal spreads compare well to pollen diagrams highlighting vegetation disturbance over a wider local and regional scale (Bell 2007). There has been some debate regarding the nature of burning in this period. It is argued that wildfire may be accountable for the charcoal spreads located on sites and in the micro-charcoal record (Rackham 1980). However, there are marked regularities in burning events, including their cyclical nature at specific locations. Most vegetation and reed burning events fall between 6000-4000cal BC and are associated with the Late Mesolithic. However some are almost two millennia earlier and Star Carr demonstrates that such modification is possible even in the early Mesolithic (Mellars and Dark 1998). Whilst much of the evidence for the region relates to the late Mesolithic age, this may suggest evidence for early Mesolithic modification of the landscape should be anticipated within the submerged landscapes of the Bristol Channel and Liverpool Bay.

3.1.9 Significant new information regarding the Mesolithic has been derived from the examination of drowned landscapes in intertidal and off-shore locations. Submerged landscapes provide the ideal context for the examination of Mesolithic archaeology as the level of preservation is rarely encountered elsewhere.

3.1.10 Excavations in Denmark have demonstrated the potential archaeological richness of submerged landscapes. Recovered organic artefacts have included dugout canoes, decorated paddles, and fish traps (Andersen 1987). Alongside the material culture, waterlogged sites preserve an array of organic biological evidence such as pollen, plant macrofossils and microfossils and, indeed, submerged forests, all of which help interpret changing environmental and social dynamics. Although Britain currently only possesses one major submerged site of this period, Bouldner (Momber 2004), this and evidence from elsewhere in Europe

illustrates the potential of, currently unknown, sites of this period to add significantly to our regional and national understanding of the archaeology of the period.

4 ARCHAEOLOGICAL BACKGROUND AND SIGNIFICANCE OF THE AREA SURROUNDING THE STUDY AREAS

4.1 Palaeolithic of the Bristol Channel and Liverpool Bay

4.1.1 The Palaeolithic record of Britain is summarised as a series of intermittent periods of human activity with intervals of abandonment or very low levels of activity (Barton 1999). These occupation cycles are in direct relation to glacial periods, when the climate of Britain was too harsh to support settlement. Whilst the period under study by the project starts with the last glacial maximum (LGM) at c. 18,000BP, it is important to note that there is the potential for earlier archaeological deposits within this region. At the start of the LGM at 18,000BP the ice sheets of the Dimlington stadial covered the majority of Britain until their retreat at approximately 13,000BP (Lowe and Walker 1997).

4.1.2 Interglacial warming began after 13,000BP (Bell and Walker 2005) and it is shortly after this date that the first evidence for human recolonisation of Britain is found close to the research area, at Gough's Cave in Somerset. The modified red deer bone dating to 12,800+-150BP, suggests the landmass was recolonised rapidly by human and animal communities (Richards *et al* 2000). It is suggested that groups accessed Britain through the landscapes that connected it to central Europe (Barton 1999).

4.1.3 The final phases of the Palaeolithic are subdivided into two broad periods, defined in part by the climate, environmental conditions in Britain and human adaptive strategies (Barton 1999). The main periods are, the Late Upper Palaeolithic, which is represented by the Creswellian culture (12,900BP to 12,000BP), and the Final Upper Palaeolithic which is associated with the Federmesser culture (12,000BP to 10,500BP) and a Long Blade Industry (10,300BP to 10,000BP) (Pettitt 2008). A brief introduction to these periods and cultures are provided below.

Late Upper Palaeolithic (Creswellian)

4.1.4 In Britain the first lithic industry associated with the upper Palaeolithic period is the Creswellian and is characterised by trapezoidal-backed blades known as Cheddar points. The debitage of this industry is also distinctive with longer, curved, faceted flakes (Jacobi and Roberts 1992). The Creswellian is regarded as late British variant of the European Magdalenian culture, and there is a convincing case for an association with this European Culture (Barton and Dumont 2000).

4.1.5 The evidence for a hunting economy is based upon evidence from findspots, such as the Gough's Cave, where points have been interpreted as spear or projectile points used for hunting game (Jacobi and Roberts 1992,). *In-situ* lithics are rare for this period, instead evidence of imported flints are found, which has given rise to the hypothesis of long distance community movement with high residential mobility. The finds within Britain suggest the potential geographical range of these populations could be very large (Barton 1999)

4.1.6 The isotopic evidence from some human bone assemblages also shows a high degree of reliance on hunting herbivores, specifically horse and reindeer (Richards *et al* 2000). The landscape would have provided excellent hunting and opportunities resource exploitation. Species hunted by communities include arctic hare, arctic fox, mammoth, reindeer, bear and other species such as wild cattle and wild horse (Barton 1999). The hunting of these mobile prey species and the preference for procuring good quality flint for making tools suggests that the culture was mobile within the landscape.

4.1.7 Environmentally the climate was slightly warmer than today but would have demonstrated greater continentality and with colder winters (Barton 1999). Within this arctic landscape the vegetation would have taken some time to re-establish and thus an open tundra landscape with increasing levels of sedges and herbs dominated the landscape until c.12,500BP (Walker and Harkness 1990), when slow recolonisation of birch took place, leading to an overall expansion of woodland around 12,000BP (Barton 1999).

The final Upper Palaeolithic (Federmesser culture and Long Blade Industry)

Federmesser

4.1.8 Following the Creswellian Culture, the appearance of Federmesser culture at around 12,000BP is thought to relate to changes in the environment during the interstadial (12,000-11,000BP) (Barton 1999). The lithic assemblages of this period demonstrate the adaptation to new hunting conditions demonstrated through a change in tools and raw material procurement. Assemblages of this period, within the study area, are associated with the Mendips and caves on the southern Gower peninsula (Jacobi in Barton *et al* 1991), and with exceptional bone and antler finds at Kendrick's cave in Llandudno (Sievekin 1971).

4.1.9 It is suggested that these new industries are associated with the afforestation of the landscape (Walker *et al* 1993, Walker and Harkness 1990), and different techniques for hunting in closed woodland (Barton and Dumont 2000). Jacobi (1997) also suggests that the characteristic Federmesser (or "Penknife points" in Britain) show damage which is consistent with them being utilised as archery projectile tips. Given the size of the lithic materials used, it has been tentatively suggested that there is a smaller landscape range than in the Creswellian (Barton 1999).

Long Blade Industry

4.1.10 With the onset of the Younger Dryas (10,800-10,000BP) Britain experienced climate deterioration. The GISP-2 ice-core data suggests a rapid fall in mean temperatures of up to 7 degrees C (Barton 1999; Atkinson *et al* 1987). This cold, wet climate would have led to significant snow falls which fed localised glaciers in Scotland and north Wales (Alley *et al* 1993). There is limited evidence of human activity for this period, and it is possible that Britain was abandoned for a period around this time (circa 10,500BP).

4.1.11 Reoccupation of Britain appears to occur around 10,300BP (Cook and Jacobi 1994), at the end of the Younger Dryas. This period is marked by rapid climatic warming. Lithic assemblages are characterised by the production of long blades with a length greater than 12cm. Most finds are located in sites that are closely associated with flood plains and low river terraces, and are thought to be associated with the working of antler (Barton 1999).

4.1.12 Typologically there are no distinct assemblages associated with this period, however the material shows differences to that of the preceding Federmesser and Creswellian. Recently the site of Launde in Leicestershire has provided material which shows remarkable parallels to material from Belgium (Prehistoric Society 2008). Thus this material has been suggested to be related to the Epi-Ahrensbergian of the European low counties. The lithics are, however, sufficiently different to suggest that the reoccupation of Britain after 10,500BP was undertaken by groups different to those previously occupying the landscape prior to 10,500BP. In archaeological terms the long blade material shows great similarity to some aspects of material from the early Mesolithic. The distinctions between the Long Blade Industry and the early Mesolithic are such that these two periods can be considered together (Prehistoric Society 2008, 3).

Landscape Features of significance to this project – Caves

4.1.13 The main depositional locations associated with Palaeolithic archaeology are within caves and rock shelters, interstratified fluvial deposits such as travertines, river terraces gravels, alluvial red beds, lake muds and beach deposits, and within aeolian sediments such as loess (Gamble 1987). Cave sites within the Bristol Channel and Liverpool Bay, have produced some of the best and earliest evidence for late Upper Palaeolithic activity in Britain.

4.1.14 There is potential for a network of subterranean caves to be found in the limestone formation present within the submerged landscape of both Liverpool Bay and the Bristol Channel. It is difficult to assess if these caves will have buried Palaeolithic sediment sequences and artefacts, especially as tidal activity may have scoured out any deposits. However, given the rapid sea-level rise and the extent of Holocene sediment deposition, it is possible that some Palaeolithic evidence will remain in such sites.

4.1.15 Caves around the Bristol Channel have produced evidence for Palaeolithic occupation, including finds of human bone and evidence for mortuary practice. Important coastal cave sites are located within the immediate research area of the Bristol Channel, on the southern tip of the Gower Peninsula, at Paviland's Cave (Aldhouse-Green 2000), Worms Head Cave (Bell 2007) and the caves on Caldey Island (Bell 2007). Burials are not a common feature during this period for Europe as a whole (Gamble 1987) and the discovery of human remains, as at Caldey Island (Bell 2007), makes this an internationally important area for study of Creswellian mortuary practices. Evidence from the analysis of human bones has demonstrated the skinning of individuals, with the tongue removed in some contexts. The defleshing of individuals has suggested cannibalism although ethnographic parallels for ritual defleshing have been observed in other contexts, and may be more appropriate for the evidence. Ritual consumption to honour the dead might also be considered (Barton 1990).

4.1.16 Another concentration of Palaeolithic cave finds occur further inland in the Mendips. Gough's cave is a site of international importance and has the largest assemblage of Upper Palaeolithic artefacts and faunal remains of any Upper Palaeolithic site in Britain. Alongside evidence of human defleshing, at both this site and nearby Sun Hole, faunal remains indicate that red deer and horse were butchered both for meat and the removal of tendons. Analysis suggests that occupation at the site may have occurred in both summer and winter (Richards *et al* 2000). This evidence suggests a meat based subsistence strategy. Stable isotope analysis has shown that protein sources in human diets at these sites came mainly from herbivores such as *Bos* sp (cow) and *Cervus elaphus* (red deer)

(Richards *et al* 2000). Opportunities to develop stable isotope work in the region would enrich our concepts of Pleistocene hunting and subsistence strategies.

4.1.17 The rich organic assemblage at Gough's cave suggested a full range of activities within such locations and illustrated the diversity of materials used for tools. Rare examples of worked bone and ivory were located, including a significant number of bone needles, double-bevelled mammoth ivory rods and a range of pointed awls made from reindeer antler and arctic hare bone.

4.1.18 The assemblage in Gough's Cave contained, in addition to flints from Salisbury Plain (Jacobi in Fagnart and Thevenin 1997), non-local seashells and Baltic amber, presumably procured from the North Sea coast. This suggests the people using the cave were either very mobile or had extensive exchange networks. Assemblages from sites elsewhere in the UK, including Kent's Cavern in Torquay and Robin Hood Cave at Creswell Crags, are similar in composition and it has been suggested they may be associated with the same group (Jacobi and Roberts 1992). Further work on assemblages from the study region and its hinterland, using potentially undiscovered cave sites, might provide new insights into exchange networks or group mobility.

4.1.19 It is difficult to determine, using available evidence, if sites such as Gough's cave were task sites or occupied as residential sites (Barton 1997). The range of activities and material remains highlight the multifunctionality of these locations but new sites, within the submerged landscape, might provide important comparative data to test such suggestions.

4.1.20 Evidence for art, especially mobile art forms, is widespread across the continent and examples are found in the north-west and north-east provinces. Gough's Cave provides an example of a fine engraving on a bovine tibia (Richards *et al* 2000). Cave art itself is present in continental Europe, but relatively rare in Britain. Recent discoveries of a series of incised images at Creswell Crags suggests that art may have been more widespread within Britain and that the extensive cave networks in the region might provide further evidence for such activity.

4.1.21 The study area around Liverpool Bay does not provide such a comprehensive record in comparison to the Bristol Channel. However, the regional Historic Environment Records record finds of Late Upper Palaeolithic artefacts from Badger Hole Cave, overlooking Morecambe Bay (HER 512). The nearby Dog Holes Cave has produced a Pleistocene animal bone assemblage (HER 511), but this has not been associated with human activity.

4.1.22 In Kendricks Cave, Llandudno, important finds include a horse jaw with incisions patterns and beads manufactured from perforated badger and deer teeth. This is an important site as it provides some of the only evidence for occupation of this area during the Younger Dryas, and highlights that there may be further evidence of human activity in the area.

Landscape Features of significance to this project – Rivers

4.1.23 Rivers are a focus for human activity throughout most archaeological periods. However, there are no finds adjacent to existing rivers within the research areas. However lack of evidence does not suggest absence. Rivers are agents of transport, they pick up and carry objects and deposited artefacts may have been carried downstream. On the other hand, items found in palaeochannels may be from sites further inland. Little work has been carried out on the movement of lithics in river systems, but research by Cropper (2009) has

demonstrated that hand axes can move significant distances in rivers, especially in times of increased dynamic fluvial activity. The palaeochannels within the Bristol Channel and Liverpool Bay would have been highly active during the later Palaeolithic, carrying large quantities of melt water and sediment; especially in Liverpool Bay which drained the Welsh mountains. Thus it is likely that evidence for activity may have been washed downstream. Moreover, sites at the side of rivers may have been buried and exist, protected, under deposits within the mapped, submerged landscape.

4.1.24 Within the research area two possible Upper Palaeolithic pebble flint scrapers were found at Illfracombe (HER 64413) and a, possible. Palaeolithic or Mesolithic worked flint at Barnstaple Bay (HER 58259). These finds may suggest transport by river.

Landscape Features of significance to this project – Open air sites

4.1.25 Although we have no evidence of open air sites within either study area, examples elsewhere in Britain include Hengistbury Head (Barton 1992). Given the effects of erosion on open air sites, especially on the coastline, and the potential low visibility of such sites, due to burial by later sediments, such a lack of evidence is perhaps unsurprising. Therefore, although no evidence for such sites exists at present in these areas, it is possible that they exist within offshore environments.

4.2 The Mesolithic of the Bristol Channel and Liverpool Bay

4.2.1 The Mesolithic period, between 9600BC and 4000BC, is also characterised by a hunter-gatherer subsistence economy. Communities are thought to have moved around the landscape in a seasonal pattern, exploiting the abundance of natural resources. A variety of different site types have been identified, with large home bases and smaller specialised sites for manufacture of tools, or accessing particular food opportunities, including seasonal fish runs.

4.2.2 Evidence for the Mesolithic in Britain is relatively sparse; non-utilitarian and organic artefacts are rare, as is evidence for built structures. Death and mortuary practice is also little understood. Commonly, Mesolithic sites are discovered as unstratified, undated flint scatters (Bell 2007). As a consequence, our understanding of the period is dominated by our knowledge of a few sites where exceptional preservation has enabled a more detailed reconstruction of site use and activity from evidence as analysis of shells, animal bones and lithic scatters (Clarke 1954; Coles 1971).

4.2.3 The Mesolithic has, in the past, been viewed as a period of dynamic environmental change and cultural transition (Gaffney *et al* 2009). However, sites, such as Gough's Cave in Somerset have produced evidence of burial practice and associated grave goods which are clearly associated with the early Mesolithic (Richards *et al* 2009),.

4.2.4 Within Mesolithic archaeology there has been a significant focus on seasonality studies. These studies have utilised a range of environmental indicators to assign season of use to archaeological sites. A number of studies have produced excellent results, detailing the seasonal timings of repeated visits to specific sites (eg Goldcliffe, Bell 2007), while other sites such as Star Carr (Clarke 1954) have produced a more complex picture, and have been the subject

of reinterpretation (Legge and Rowley-Conwy 1988; Mellars and Dark 1998; Conneller *et al* 2009; 2010).

4.2.5 Ultimately, while it is possible to suggest the season of use on select sites, linking these with other areas of Mesolithic activity in the adjacent wider landscape, and thus defining an annual territory, has been less successful.

The Early and Late Mesolithic

4.2.6 The Mesolithic is often associated with the onset of the Holocene, and is roughly subdivided into the early (9600-7600BC) and late Mesolithic (7600-4000BC).

4.2.7 The early Mesolithic is separated from the late Mesolithic on the basis of a number of characteristics. The lithic assemblages assigned to this period have a similarity with earlier Palaeolithic industries (David and Walker 2004, cited in Bell 2007). Later Mesolithic industries are quite heterogeneous (Bailey and Parkington 1988).

4.2.8 The post-glacial landscape of the early Mesolithic was climatically and ecologically different to the later Mesolithic. Post-glacial temperatures in the early Mesolithic gradually rose to average winter temperatures of 0 degrees and summer temperatures of 17 degrees (Bailey and Spikins 2008). The rise in temperatures created the conditions to establish forests of pine and birch in some areas and then to incorporate hazel, oak and elm. There were also dramatic changes in the species of animals located in the country, with the loss of large herds of arctic Late Pleistocene species (Lowe and Walker 1997).

4.2.9 The general topography of the UK changed dramatically between the early and late Mesolithic landscapes. Global temperature rise saw the melting of large ice sheets in the northern hemisphere. This process initiated a significant and rapid rise in sea-levels from 35m below present at the start of the Holocene to a relic Mesolithic coastline corresponding roughly to that of the present day, at 7500cal BC (Bell 2007).

4.2.10 The rapid sea-level rise pushed coastlines inland and submerged previously dry terrain, flooding the land-bridge connecting the United Kingdom to mainland Europe, and making Britain an island for the first time in modern human history. The submergence of large areas around Britain would have had significant and dramatic impacts on the ecological diversity of both plant and animal species. Areas including the Bristol Channel and Liverpool Bay were quickly submerged. Between 9500 and 4000cal BC the rivers running into Liverpool Bay and the Bristol Channel would have suffered a great reduction in length. Bell (2007) has suggested that the river Severn lost 50% of its main channel length. Such dramatic environmental, topographic, and relief changes would have been apparent to the local communities and would have impacted on territory size and the potential exploitation areas available to them (Bell 2007).

4.2.11 In contrast, ecologically speaking, the later Mesolithic was much more stable, with the relict late Mesolithic coastline in the south west being roughly comparable to the present day (Bell 2007). The forests established in the early Mesolithic thickened and diversified, and the continental climate developed into a warmer maritime climate (Bailey and Spikins 2008). Climatically the period was stable, although environmental dynamism would have still been visible to the communities on the coast of Britain, as the landscape was subjected to smaller, yet still significant, cycles of marine transgression and regression (Shennan and Horton 2002; Allen 1990 and 2000; Bell 2007). These transgression episodes

were pronounced, and are recorded as interleaved peat and silt sequences on coastal sites throughout the Severn Estuary and Bristol Channel. These deposits contain many examples of well-preserved archaeological sequences and offer a glimpse of what could be buried underneath the Bristol Channel and Liverpool Bay.

4.2.12 A final distinction between the early and late Mesolithic is in terms of archaeological visibility. Evidence for activity of late Mesolithic communities is more prominent in comparison to earlier periods. Early Mesolithic activity seems to be associated with lowland, lacustrine and riverine sites such as Starr Carr (Clarke 1954) and the Kennet Valley (Ellis *et al* 2003). However, the absence of evidence for early Mesolithic coastal archaeology in the study area is most likely due to the fact that the contemporary coastline lies a considerable distance away from the present coastline. This situation is not unique to the area and has been identified as being an issue throughout the United Kingdom (Bailey and Milner 2002; Milner 2006). From the late Mesolithic, there is a clear association between human activity and coastal locations. This coastal focus is argued to be a response to increased population or community displacement caused by high levels of environmental dynamism (Bell 2007), but could equally be associated with increased visibility of these areas due to their location within modern intertidal areas.

Landscape Features of significance to this project (Bristol Channel) - Riverine

4.2.13 Rivers are an obvious focus for prehistoric human communities. The palaeochannels buried under the waters of the Bristol Channel would have been a vital source of food and fresh water for both animal and human communities, and they are also likely to have served as corridors of movement (e.g. Waddington 2007; Schulting and Richards 2000). It is likely that the rivers located in the areas neighbouring the Bristol Channel, were originally tributaries of the River Severn before the Holocene sea-level rise.

4.2.14 17 sites have been located adjacent to the major rivers, Parrett, Torridge and up to 50km inland, (Bell 2007), and the presence of both early and late Mesolithic sites indicates the continued use of riverine locations throughout this period.

4.2.15 There are more Mesolithic sites located in a riverine context on the English side of the Channel than the Welsh (Webster 2007), although this is arguably a product of research bias. Therefore we could expect to see the continuity of the pattern established on the English side of the channel, in the submerged landscape of the Bristol Channel, with perhaps intensification as the tributaries converged into the main fluvial channel of the Severn.

4.2.16 Mesolithic activity can also be observed in other fresh water contexts. Further inland at the Mendips, the Burtle Beds of Chedzoy have produced significant quantities of lithics. Early communities were attracted to these features, which, in the early Mesolithic, would have been high points against the surrounding topography and channels of brackish and fresh water. If we extend this into the Bristol Channel, we might expect any positive topography to be a focus for human activity, especially when the landscape transitioned into a brackish wetland dominated area.

Landscape Features of significance to this project (Bristol Channel) - Cave sites

4.2.17 Cave sites within the south-west region have produced one of the best collections of Mesolithic human bone in the country (Conneller 2006). Four of these major cave sites, are located within a roughly 10km distance of each other within the Mendip Hills, approximately 15km from the Bristol Channel. With the exception of a small area of Silurian volcanic rocks, the Mendips are made up of sedimentary rocks ranging in age from Late Devonian to Mid Jurassic, dominated by Carboniferous Limestone (Tappin *et al* 1994). This Carboniferous Limestone formation, which has often been uplifted, faulted, folded and eroded to produce unconformities, continues into the Bristol Channel and finishes roughly before Ilfracombe and Swansea.

4.2.18 Caves are a typical landform within Carboniferous Limestone formations, and are a substantial feature of the Mendip Hills. Limestone is predominantly composed of calcium carbonate (CaCO_3), which when in contact with water, especially rainwater (due to its weak acidic properties), becomes soluble. This chemical weathering is responsible for the erosion of the rock and, over many years, creates caves.

4.2.19 Although not fully explored, we could expect to see the continuity of cave formations within the limestone rock outcrop in the Bristol Channel, represented as part of a subterranean, submerged cave network. Although now submerged, and dependent on the erosional properties of tidal currents, the deposition of Holocene sediments may have sealed and protected any archaeology present. The excavated cave sites present in the south-west area of Britain, such as Gough's Cave (Stringer 1986), Hay Wood Cave (Everton and Everton 1972) and Aveline's Hole (Tratman 1977), have illustrated the archaeological potential of cave sites. Aveline's Hole in particular has been a very important site for conveying demographic information and much needed cultural evidence about early Mesolithic burial practice. 50-100 individuals, adults, children and adolescents, were originally reported to be found buried in the cave (Davies 1921). The skeletal and dating evidence produced an array of important information, including the age at death, individual's diets with focus on marine contributions to diets, information about nutritional stresses during childhood and internal parasites (Schulting and Wysocki 2002; Schulting *et al* 2005).

4.2.20 Apart from skeletal evidence and its associated research implications, cave sites produce other important evidence of flint knapping, hunting and in some locations cave art. On the south Welsh coast Mesolithic flints, blades and penknife points have been found in caves in the Gower and on Caldey Island (Lacaille and Grimes 1955). During the early Mesolithic the caves on Caldey Island would have been on a hill in the middle of the Bristol Plain, offering not only shelter but also vistas over the valley floor.

Landscape Features of significance to this project (Bristol Channel) - High ground and dryland inland

4.2.21 Within the research area, concentrations of Mesolithic artefacts are located on hill top locations (Webster 2007). Many of these assemblages are found as unstratified flint scatters (Bell 2007). High points in the landscape would have provided excellent vantage points to observe the valley below, especially useful for tracking both animal and human movements. After rapid sea-level rise, these locations became cliff tops overlooking the sea.

4.2.22 One of the most significant sites within this category is at Hawcombe Head (Riley and Wilson-North 2001). This site dominates the coast from a more upland elevation than those sites adjacent to the modern day coastline. The site produced a very large number of worked flints, and was interpreted as a late Mesolithic hunting site. A comparable site on the Welsh side of the Channel is at Nab Head in Pembrokeshire (Smith 1992). This occupies a similar cliff top location, and produced a range of lithic tools.

4.2.23 From the present evidence, we can expect evidence for human activity on almost any prominent landscape feature located within the Bristol Channel, especially around the edges of the Welsh coast, where the submerged landscape has an elevated position overlooking the valley bottom.

Landscape Features of significance to this project (Bristol Channel) -Intertidal and coastal

4.2.24 Research over the last 15 years on the intertidal sites around the Bristol Channel and Severn Estuary, has demonstrated the area was subject to inundation during the early Mesolithic, but during the later Mesolithic the coastal area was impacted by a number of smaller episodes of marine transgression and regression. These are recorded as interleaved peat and silt sequences. The archaeology within these sequences occurs at the beginning of grey clay-silt deposition, and as such suggests that human activity was most pronounced in times of extreme environmental dynamism (Bell 2007; Timpany 2005; Brown 2005). Thus we can expect to see an intensification of human activity in those areas most affected by sea-level rise, namely the submerged areas.

4.2.25 The coastal and intertidal shores of the Bristol Channel and Severn Estuary have produced quite a significant number of Mesolithic sites preserved along with well preserved environmental evidence. Intertidal sites, which are accessible during low tides, are often associated with submerged forests and reed beds which were exploited by Mesolithic communities. Submerged forests and peat shelves are frequently located along the coastline on both the English and Welsh coasts. Examples include Blue Anchor Bay, Minehead, Porlock, Magor, Goldcliff and Uskmouth, and further details can found in the resource assessments of the area (Webster 2007).

4.2.26 The submerged forests are defined as assemblages of ancient tree remains that are located in their growth position, and are regularly covered by tides. The forests are usually discovered in peat beds which have stumps and fallen trunks out-cropping onto the foreshore (Heyworth 1985). The majority of submerged forests in this area produce a mid-Holocene date falling between 5000- 2900 cal BC (Bell 2007).

4.2.27 One of the most significant forms of evidence in the Bristol Channel intertidal area is the footprints left by the human and animal communities who were exploiting the wetland resources. So far footprints have been found at Magnor, Uskmouth, and at the Severn Estuary. Investigations at Goldcliff have demonstrated that a significant number of the prints belonged to children, and this has been important in addressing the role of children in hunter-gatherer societies (Bell 2007).

4.2.28 Shell middens are another important form of evidence found in such locations and Westwards Ho! provides a good example (Palmer 1977). If these structures are located within the Bristol Channel, they offer the opportunity to

reveal subsistence information on foodstuffs, their contribution to diet and the seasonality of use.

Landscape Features of significance to this project (Liverpool Bay) - Riverine

4.2.29 A number of Mesolithic sites have been discovered adjacent to rivers flowing into Liverpool Bay. The River Alt in Merseyside provides a good example of the frequency of Mesolithic sites located in these contexts (Hodgson and Brennand 2006). Similar rivers in Lancashire such as the River Lune (Penney 1978) and the River Wyre (Middleton *et al* 1995) have also produced assemblages of flints and antler mattocks utilised by early communities. In Cumbria, this pattern is repeated along the River Crake.

4.2.30 On the north Wales coastline, at Rhuddlan, a significant early Mesolithic site has been identified adjacent to the River Clyde (Bell 2007). The lithic assemblage and associated artefacts suggest that a broad range of tasks took place here, and it has been identified as a potential base camp site. The area at the time of the early Mesolithic would have been approximately 10km from the coast, and the site would have been able to maximise resources from a number of different environmental contexts.

4.2.31 The site at Rhuddlan highlights the attractiveness of riverine locations to Mesolithic communities, especially those placed within reasonable access to coastal and wetland resources (Quinnell *et al* 1994). There is significant potential for palaeochannels within the submerged landscape to support comparable sites during the early Mesolithic. Within these sites the levels of preservation are likely to be high and evidence for organic material culture may be preserved.

Landscape Features of significance to this project (Liverpool Bay) - Cave sites

4.2.32 Evidence for Mesolithic occupation of caves in the area has been identified in Southern Cumbria (Salisbury 1997; Young 2002). Liverpool Bay contains carboniferous strata which sub-crop beneath quaternary deposits around areas adjacent to the present coast. Consequently, there is a possibility that submerged caves containing archaeological deposits exist in a small belt of submerged land. This is located, almost running parallel to the coast to a 10 km distance in a seaward direction, from the western tip of Anglesey roughly to the Clywdin platform.

Landscape Features of significance to this project (Liverpool Bay) - Coastal

4.2.33 The area around Liverpool bay has been a focus for Holocene sea-level research for some time (e.g. Zong *et al* 1996 and 1999; Lambeck 1996; Annan 2001; Wilson *et al* 2005). However the level of archaeological research is not comparable to that completed in the landscape surrounding the Bristol Channel and Severn Estuary. The North West research framework notes that the literature is heavily influenced by the concentration of fieldwork in particular areas (Hodgson and Brennand 2006). However survey along the coast (e.g. Cowell and Innes 1994; Middleton *et al* 1995) has helped to highlight the presence of Mesolithic settlement in this area.

4.2.34 Martin Bell (2007) has indicated that during the Holocene, rising sea-levels would have flooded the deep valley in Merseyside created during the Pleistocene.

This would suggest that, for the last two thousand years of the Mesolithic, the marine influence in this area would have extended further inland and that would provide much larger ecotonal areas than today. These areas would have provided a rich array of resources for exploitation by human communities.

4.2.35 Archaeological sites located in, or near to, the intertidal zone are mostly represented as sequences of inter-layered silts, and peats. The peats often include significant areas of submerged forest, preserved under thick deposits of protective estuarine silts, and associated with episodes of marine transgressions. Peat shelves and submerged forests are common around the coastline of Liverpool Bay, but it is difficult to gauge the distance in which they reach out into the submerged landscape. If they are protected by a significant Holocene and modern day sediment cover, and not eroded by wave action, then there may be significant areas of buried forests within the bay.

4.2.36 Two of the most significant archaeological sites found within this context are at Prestatyn and Rhyl, both which are protected by coastal dunes (Bell 2007). Evidence from these locations included antler mattocks, flint tools and, most importantly, shell fish middens. Middens in these contexts are well preserved and have afforded detailed data on seasonal exploitation.

4.2.37 During the late Mesolithic, there is increasing evidence for the use of coastal resources. Examples of this can be seen at Goldcliff (Bell 2007) and Trevoise Head (Johnson and David 1982). However, this evidence does not necessarily mean that the coastline was used more in the late Mesolithic. Rather, given the proximity of the late Mesolithic coastline to the modern coastline, this reflects an increase in visibility and contemporary accessibility to the areas which contain this evidence.

5 INTRODUCTION TO THE DATA

5.0.1 In 2007 a methodology was pioneered by Birmingham University, as part of the MALSF funded North Sea Palaeolandscape project, which derived landscape information from large scale 3D petroleum industry datasets (Gaffney *et al* 2007). The methodology utilised 3D reflection seismic data acquired through the use of multiple streamers. These data were then placed into a binned dataset with, in the case of data acquired for hydrocarbon exploration, a spacing of 12.5m x 12.5m x 4 milliseconds, or multiples thereof. However, 3D seismic is versatile and can be interrogated in a number of ways. Instead of relying on vertical profiles, the volume can be sliced in any direction. Of particular importance to the North Sea Palaeolandscape Project was the utilisation of horizontal slices (timeslices) through the data to produce an image of relatively shallow, and flat, Holocene features (Thomson *et al* 2007). The image, in many cases, could be interpreted as a map showing a range of sedimentary features and, subsequently, a map of the inundated landscape.

5.0.2 Given that the methodology had been so successful, it is appropriate to consider why this was not applied directly to the data contained in the study areas. The simple answer is that there is considerably less 3D seismic data located around the west coast of England. Whilst the southern North Sea represents an ideal situation, with "wall to wall" coverage of 3D datasets, the situation in the Irish Sea, and indeed the whole of the west coast is less satisfactory. Large blocks of data, covering the main reservoirs and prospects can be found; they are however often unlinked and large areas remain without coverage (see Figure 2). For example, the archaeologically significant Severn Estuary area contains no 3D seismic coverage at all. Application of the North Sea Palaeolandscapes methodology to available datasets could provide valuable landscape information only for isolated areas. However, their use would be limited as they would effectively be islands against a background of limited or no data. This situation would therefore be of limited use to strategic marine planning, as the significance of the landscape as a whole, and that of the features identified, would remain to be fully determined.

5.0.3 Clearly it would be advantageous to utilise the available 3D datasets to provide landscape data whilst using some other means to determine the background landscape information between the 3D surveys. The most obvious source of useable data are the standard petroleum industry 2D seismic datasets which cover much of the area. These seismic reflection surveys are usually referred to as 2D. This is because the data is collected via a single cable or streamer and the information displayed is effectively a vertical slice through the earth. Consequently, specific features, such as river channels, may be located with a vertical profile. Shallow 2D seismic surveys, therefore, aid the detection of palaeogeographic features, which may possess archaeological potential.

5.0.4 The use of such surveys can permit the location and mapping of buried Holocene landscape features. Traditional 2D seismic reflection data is often acquired as a series of discrete vertical profiles using a single streamer towed behind the vessel. This acquisition pattern results in the collection of several profiles with the spacing between profiles being several orders of magnitude greater than the trace spacing (i.e. the horizontal sampling interval along the profile).

5.0.5 This method of acquisition has two main disadvantages. Firstly, the reflected seismic energy is assumed to have originated from a point directly

beneath the profile even though it could have originated from a point laterally offset from the profile. The result of this aliasing is that the location of a feature cannot be accurately constrained, as the spacing between lines is too wide to correct this error. Secondly, the spacing between lines is sufficiently wide that it can be difficult to map the position of a morphological feature across the region of interest. For example, Figure 3 (a-d) demonstrates how wide line spacing can lead to several equally valid interpretations. It is important to consider therefore that whilst these datasets could provide the structural framework of the interpretation, other datasets may be required to provide additional data in areas where the 2D data coverage is insufficient to resolve interpretation issues.

5.0.6 The value of 2D seismic data to map buried palaeochannels has long been understood, however this has tended to focus on the utilisation of data from higher resolution 2D seismic systems (e.g. Velegrakis *et al* 1999). However, if such data could be utilised the relative density and spatial coverage of these 2D datasets (see Figure 4) may offer a potential solution to the issues of developing an archaeological landscape understanding of the submerged areas of the West Coast.

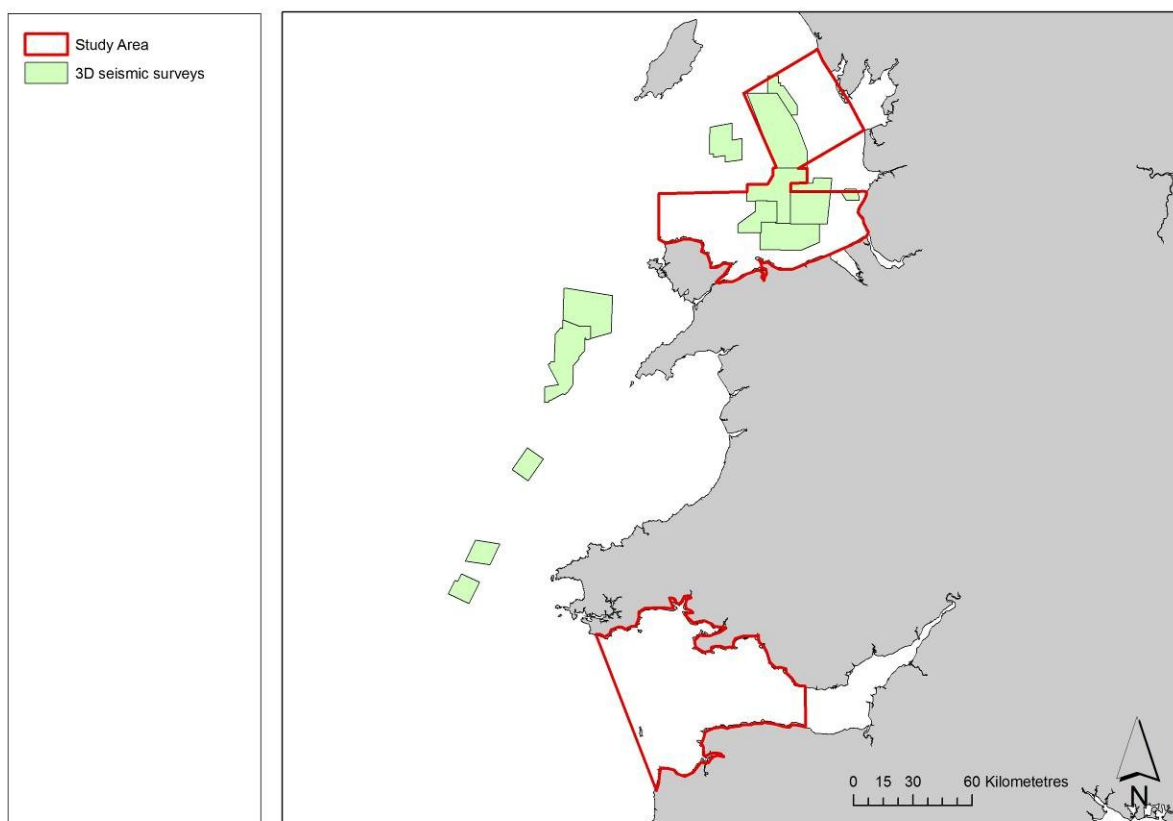


Figure 2: Coverage of 3D seismic surveys in the Irish Sea region (data blocks are shown here in green)

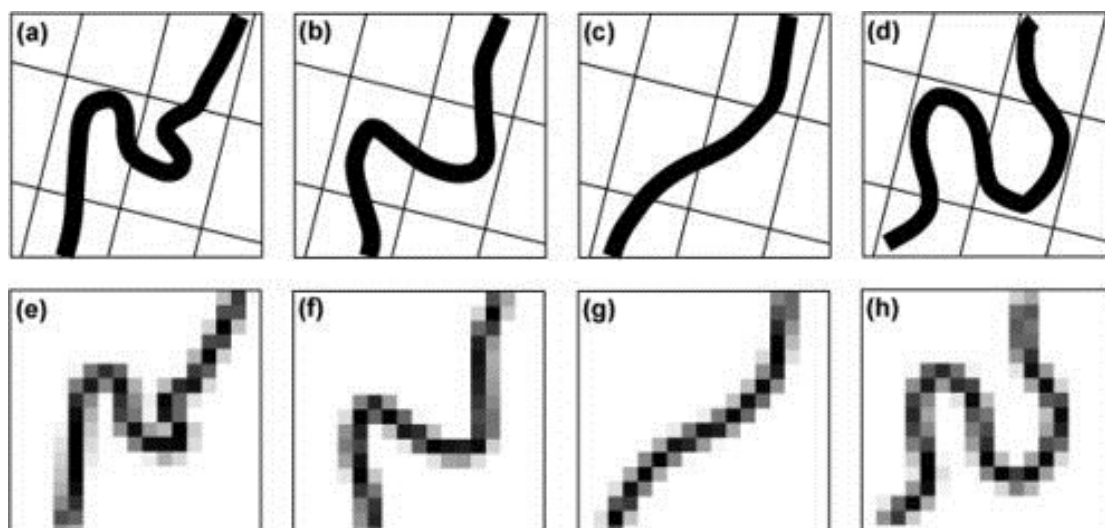


Figure 3: (a-d) Four possible interpretations of a channel morphology based on a coarse 2D seismic grid. Each interpretation is equally valid. (e-h) Schematic illustrations of how each of the interpretations shown in a-d would appear on a timeslice from a laterally continuous, binned 3D seismic volume. This demonstrates that additional information, such as 3D seismic data would be required to distinguish between the possible alternatives (after Thomson and Gaffney 2007).

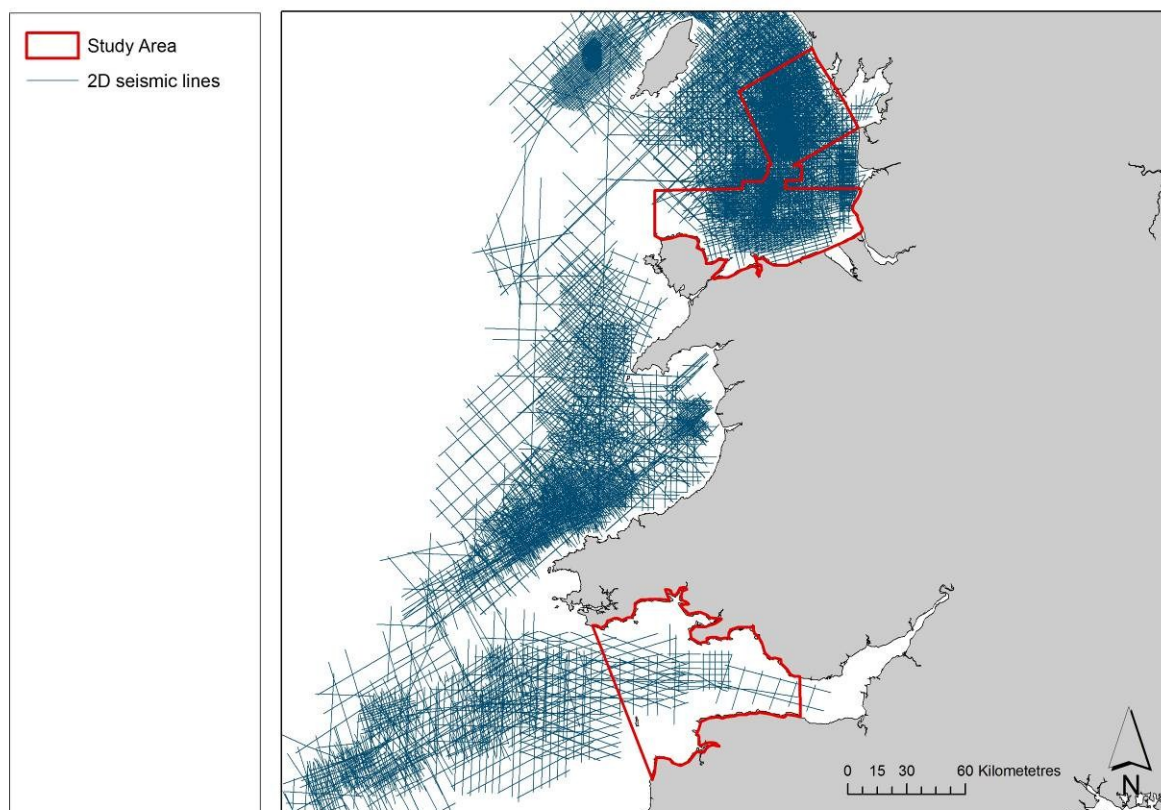


Figure 4: 2D seismic data density for the Irish Sea region (courtesy of BERR/DTI). The pilot project area is outlined here in red.

5.1 Data holdings accessed by the project

5.1.1 The data required for this project was held in a number of locations and reflects the various requirements for which the data was acquired. For example, high-resolution data of the nearshore zones is held by the UK onshore geophysical data library: even though it is located well within the marine zone. This is due to the data being acquired by the now defunct British Coal Board, and more recently for onshore oil and gas installations and pipelines.

5.1.2 The main datasets used for the project were acquired for the energy industry and reside within three main data libraries. The largest of these is the UK offshore geophysical data library (DTi/BERR) which holds released 2D seismic survey derived from a variety of sources. The British Geological Survey holds smaller quantities of data of various vintage. Other commercial bodies also hold data and information on owners can be obtained online from the UK offshore geophysical library (DTi/BERR).

5.1.3 SeaZone, as commercial wing of UK Hydrographic Office, holds the digital data of the seabed and produces commercial bathymetry products.

5.2 3D data

An assessment of the 3D seismic survey acquired for use within the project

5.2.1 The main bulk of the available 3D seismic data is found in the Liverpool Bay area. The project was extremely fortunate that the entire coverage of 3D seismic data within the area was provided to the University of Birmingham for the purposes of this research. For this the University would specifically like to thank the following companies; Centrica UK Ltd, BHP, Conocco Phillips, NDA. We would also like to thank Fugro for assisting prompt data delivery.

West Coast Palaeolandscapes Survey 2011

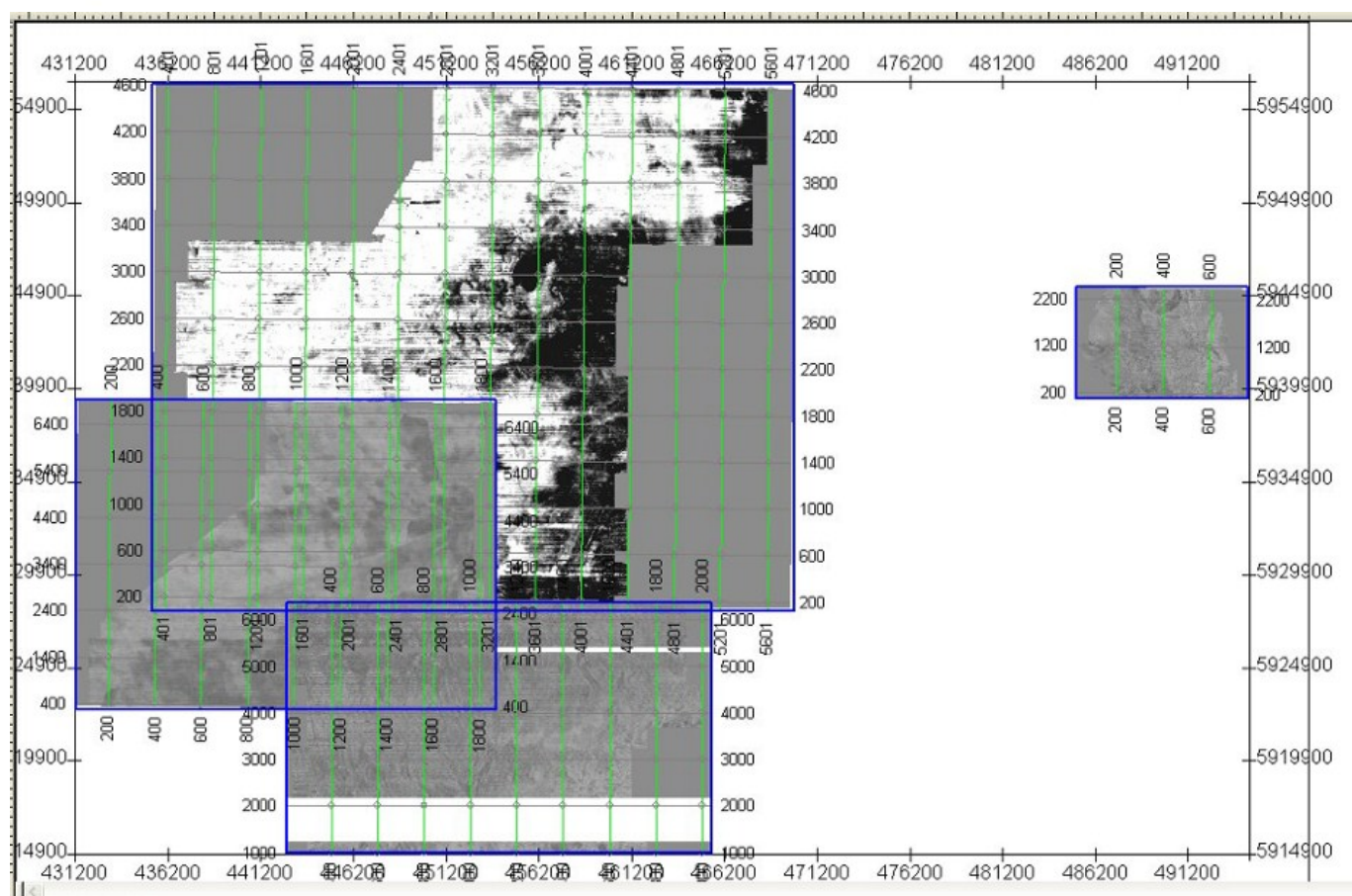
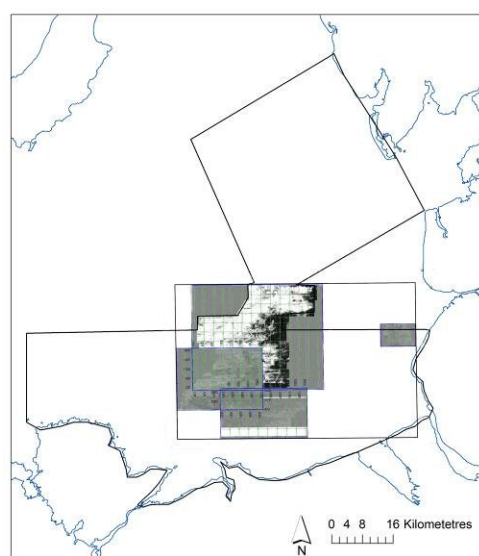


Figure 5: 3D timeslices through datasets procured within the North Wales and English marine areas (not including the Pilot Project datasets)

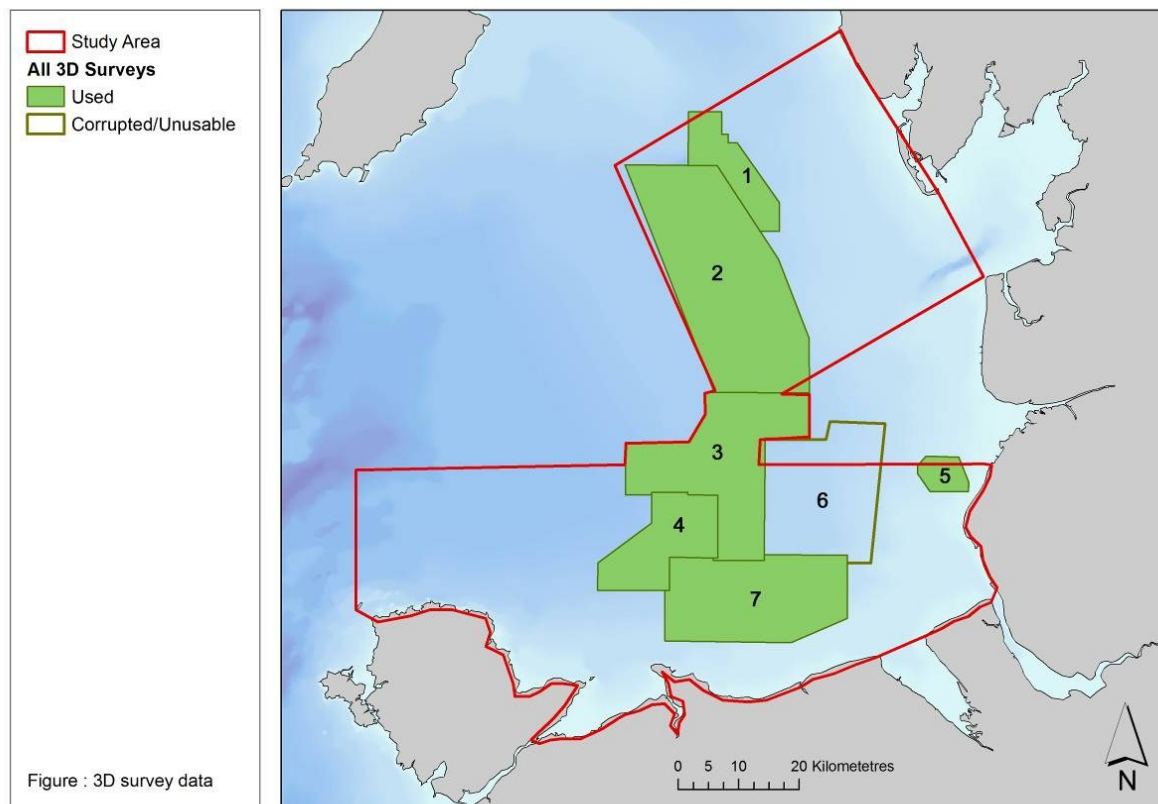


Figure 6: All 3D seismic surveys used in the project (Liverpool Bay study area)

Number	Project	Survey Name	CS9NAME	Useable/corrupted	Area (square km)
1	Pilot	EIS1137	AT973F0003	Useable	153.44
2	Pilot	Morecambe and Satellites	BG943F0001	Useable	685.72
3	Main	Q110-3D	ET953F0003	Useable	438.81
4	Main	LiveFMS	BH953D2001	Useable	201.40
5	Main	WiseFMS	BH953D2002	Useable	41.44
6	Main	SY444	BH923D2001	Unrecoverable	426.71
7	Main	CV933F0001	CV933F0001	Useable	417.34
TOTAL AREA (useable) = 1938.15 STUDY AREA = 5823.65 Percentage Study Area covered by 3D surveys = 33.28%					

Table 1: Areas covered by 3D seismic data

5.2.2 Survey 1 also known as "**EIS1137**" is a 3D seismic reflection survey acquired using standard airgun technology. The resulting digital survey has a bin spacing of 12.5 metres. The seismic data was made available in digital SEG-Y format and this, with associated survey information, was provided on DVD to VISTA for research purposes. This data may not be generally available for study.

5.2.3 Quality of the data was good and it responded well to serial timeslicing. The data also proved suitable for full processing and archaeological interpretation.

5.2.4 **Survey 2** also known as "**Morecambe and Satellites**" is a 3D seismic reflection survey acquired using standard airgun technology. The resulting digital survey has a bin spacing of 12.5 metres. The seismic data was made available in digital SEG-Y format and this, with associated survey information, was provided on DVD to VISTA for research purposes. This data may not be generally available for study.

5.2.5 Quality of the data was good and it responded well to serial timeslicing. The data also proved to be of adequate quality for full processing and archaeological interpretation. Initial results suggest that the main limitation of this dataset for archaeological research resulted from the relatively ephemeral characteristics of the strata of archaeological interest - represented by terrestrial Holocene deposits.

5.2.6 **Survey 3** (Q110-3D) is a 3D seismic reflection survey acquired using standard airgun technology. The resulting digital survey has a bin spacing of 12.5 metres. This survey was provided by ConocoPhillips. The seismic data was made available in digital SEG-Y format and this, with associated survey information, was provided on DVD to VISTA for research purposes. This data may not be generally available for study.

5.2.7 Quality of the data was good; it responded well to processing and is suitable for archaeological interpretation.

5.2.8 **Survey 4** (LIVEFMS) is a 3D seismic reflection survey acquired using standard airgun technology. The resulting digital survey has a bin spacing of 12.5 metres. This survey was made available by BHP in digital SEG-Y format and was provided on DVD to VISTA for research purposes. This data may not be generally available for study. However, the data obtained from BHP was problematic. The metadata for the reconstruction of this survey was lost during storage. Fortunately, sufficient data was gleaned by the project team from the labels on the original data tapes, in association with the processed header information, to allow the survey to be reconstituted. This situation highlights the issues of the recovery of data stored for long term (Bunch *et al* 2007), and the need for appropriate metadata for geophysical surveys.

5.2.9 Once reconstructed the data repaid the required effort and was seen to be of good quality and responded well to the processing. The data is suitable for archaeological interpretation.

5.2.10 **Survey 5** (WISEFMS) is a 3D seismic reflection survey acquired using standard airgun technology. The resulting digital survey has a bin spacing of 12.5 metres. This survey was made available by BHP. As with **Survey 4**, the data obtained from BHP was problematic due to the available metadata being lost during its time in storage. Again, after much effort it was possible to use the processed header information in addition to line information that was sufficient to allow the survey to be rebuilt. This situation highlights the need to preserve appropriate metadata for geophysical surveys.

5.2.11 Quality of the data was good and it responded well to the project methodology. When processing is applied to the data is seen to respond adequately. The data is therefore amenable to archaeological interpretation.

5.2.12 **Survey 6** (SY444) is a 3D seismic reflection survey acquired using standard airgun technology. The resulting digital survey has a bin spacing of 12.5 metres. This survey was made available by BHP. As with **Survey 4** and **Survey 5**, the data obtained from BHP was problematic due to the available metadata being lost during its time in storage. Unlike the other two surveys, insufficient information remained to allow the reconstruction of this survey. As such this information was not used in this project. However, should this metadata be located in the future, it should be processed for archaeological purposes. This result again highlights the differing storage standards that exist for geophysical data, and the problems associated with their recovery.

5.2.13 **Survey 7** (CV933F0001) is a 3D seismic reflection survey acquired using standard airgun technology. The resulting digital survey has a bin spacing of 12.5 metres. This survey was acquired from NDA. The seismic data was made available in digital SEG-Y format and this, with associated survey information, was provided on DVD to VISTA for research purposes. This data may not be generally available for study.

5.2.14 Quality of the data was very good, especially considering its acquisition in shallower, near shore contexts. Indeed it is surprising that it responded so well to processing. After study the data is observed to have suitable definition for archaeological interpretation.

5.3 2D data

Assessment of density of 2D Datasets available for study

5.3.1 The initial assessment of the availability of 2D datasets was comparatively easy as the two main data repositories provide web portals which allow a visual inspection of the data holdings. These are located at

1. UK DEAL - <http://www.ukdeal.co.uk/>
2. The British Geological Survey - <http://www.bgs.ac.uk/>

5.3.2 GIS information on available BGS GIS data can also be made available to appropriate projects upon request. GIS data for the BERR surveys is available from UK DEAL although a registration and subscription fee to the resource is required.

5.3.3 Based upon the available information and the current web resource it was determined that the study area contained a significant coverage of 2D data, a suitable selection of which could be utilised within this study.

5.3.4 Not all the lines were useable, some of the data was unusable and, of the paper lines, the pinger-only lines were determined not to be of sufficient quality to pick up archaeological features.

5.3.5 The table below shows the length of the lines that intersected both of the study areas. Where lines extended beyond the study area, they were also checked for features present in the dataset, but not included in the line length statistics.

West Coast Palaeolandscapes Survey 2011

Area	Data Type	Useable/Unusable	No of Lines	Total Length of Lines (km)
Bristol Channel	Digital	Useable	59	1024.34
	Digital	Unusable	30	530.07
	Paper	Useable	31	981.88
	Paper	Unusable (pinger only)	9	366.20
Liverpool Bay	Digital	Useable	171	2947.35
	Digital	Unusable	60	911.79
	Paper	Useable	85	2181.36
	Paper	Unusable (pinger only)	14	160.15
Bristol Channel		Total Useable Lines		2006.22
		Total Unusable Lines		896.27
Liverpool Bay		Total Useable Lines		5128.71
		Total Unusable Lines		1071.94
Bristol Channel		Total of all lines		2902.49
		Useable lines as percentage		69.12%
Liverpool Bay		Total of all lines		6200.65
		Useable lines as percentage		82.71%

Table 2: 2D lines used in the project

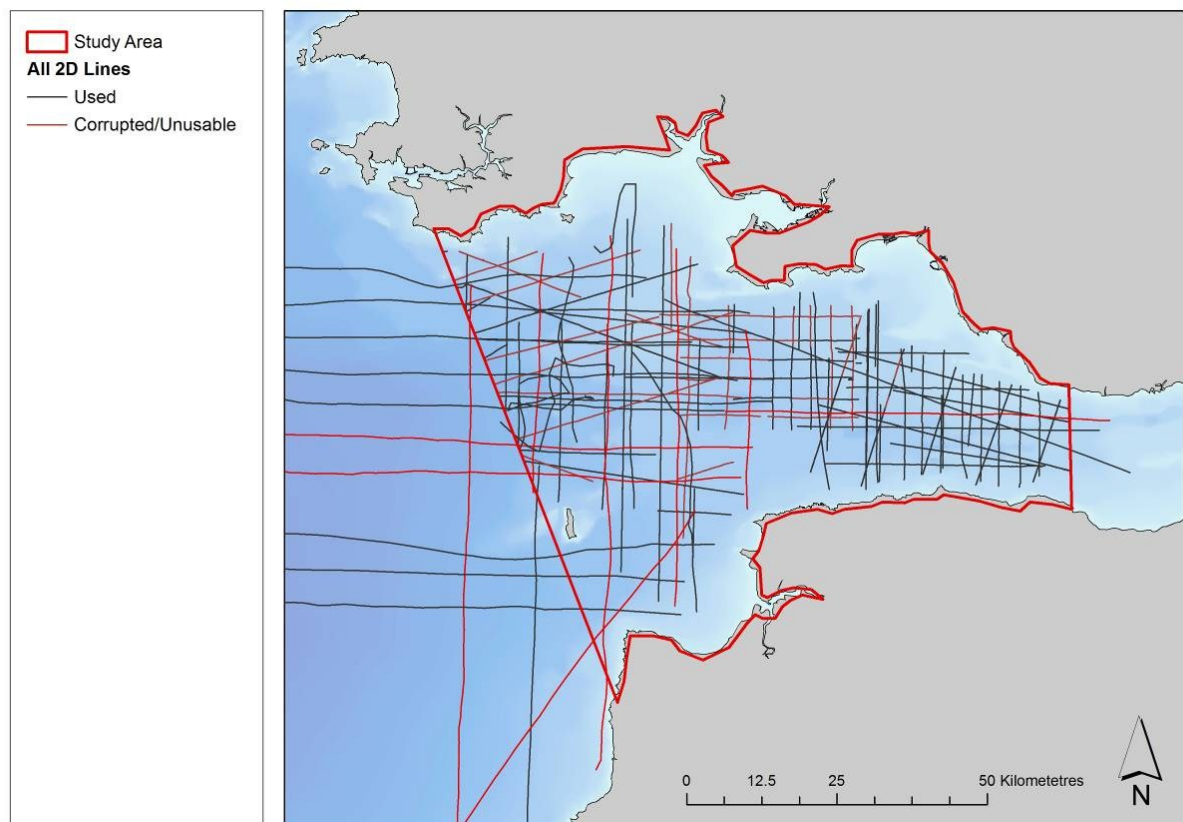


Figure 7: 2D lines used in the Bristol Channel study area

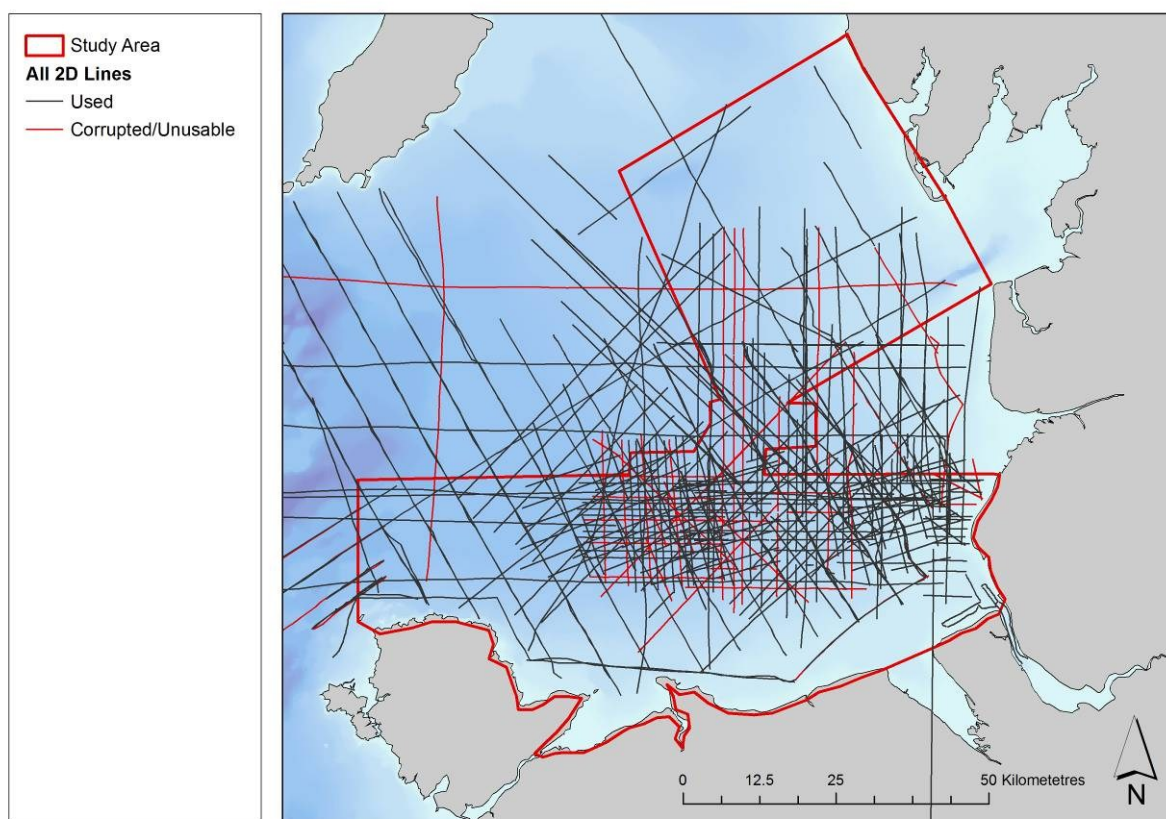


Figure 8: 2D lines used in the Liverpool Bay study area

An assessment of the BGS 2D geophysical survey data for use within the project

5.3.6 The selected geophysical dataset consisted of several shallow seismic surveys comprising a series of lines which covered extensive sections of the study area and which were obtained by the British Geological Survey from the 1960's until recently. For these surveys multiple lines of data were available derived from a combination of common seismic sources (sparker and pinger). The seismic data was made available in the form of scanned paper rolls in TIFF format and the corresponding survey track plots were available on DVD. A fee was charged by the BGS for access and reproduction costs associated with retrieving these images. All available BGS data for the study area was requested.

5.3.7 Although there was some variability in quality, the BGS datasets were adequate for archaeological interpretation. These data were digitised into SEG-Y files through the use of the ImagetoSEG software created by Chesapeake.

An assessment of the DTi offshore (BERR/Phoenix) 2D Data requested for use within the project

5.3.9 The selected geophysical dataset included a series of traditional petroleum industry 2D seismic surveys comprising a series of intersecting lines coincident with several of the most significant features within the study area. They therefore possessed the greatest potential for study and validation. These data were selected on the following basis. Due to the low line density, all of the BERR 2D seismic data for the Severn Estuary was sought for acquisition. However due to the number of lines and surveys in the Irish Sea and the available budget, a

selection process was required to maximise cost effectiveness. The GIS was used to facilitate selection based upon the premise of producing the best possible use of the funding available whilst maximising data availability. Selection was restricted to a minimum request of 10 lines per CS9 name. This reduced the licensing costs to a level which could be sustained by the budget.

5.3.10 The original data were obtained from BERR/Phoenix (representing the DTi's data store), which holds a significant number of surveys from this area. However, it was discovered that some of the speculative surveys undertaken in the Bristol Channel were not held at this store due to licensing issues. These data were obtained directly from the original survey company as part of an agreed research agreement and are discussed separately.

5.3.11 The data held by BERR is stored on the original paper survey rolls, which were subsequently scanned by Phoenix Data Solutions Ltd. for conversion to SEG-Y files. The corresponding spatial information relating to the survey was also provided on DVD. This data is not freely available for academic or research study. A significant fee had to be paid, and a potentially complex licence agreement agreed to facilitate access to the data. This agreement does not limit the use of the resulting interpretation of the data, which would in this case be used for archaeological purposes. Rather the agreement limits copying and distribution of the original survey data as provided by the agreement.

5.3.12 The data was of variable quality even when the selected lines originated from the same survey.

5.3.13 However, the digital nature of the data allowed application of a range of processing techniques to optimise the data output. Unsuitability of the remaining lines resulted from poor response and reflectors in the top sections of the datasets, as well as poor data resolution. The scanning/conversion of the paper records into digital data can also potentially introduce an unknown element of error into the process of interpretation.

West Coast Palaeolandscapes Survey 2011

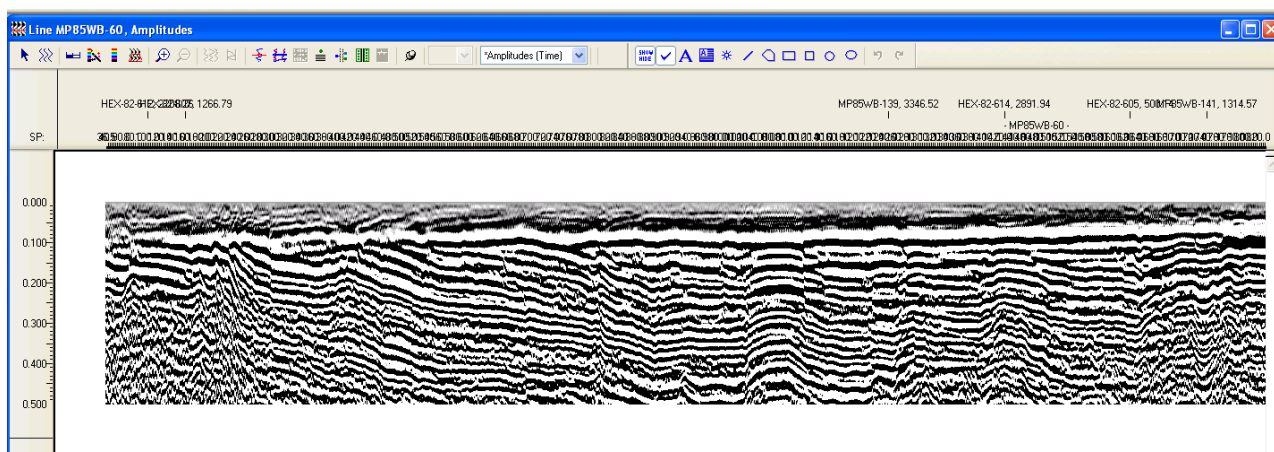
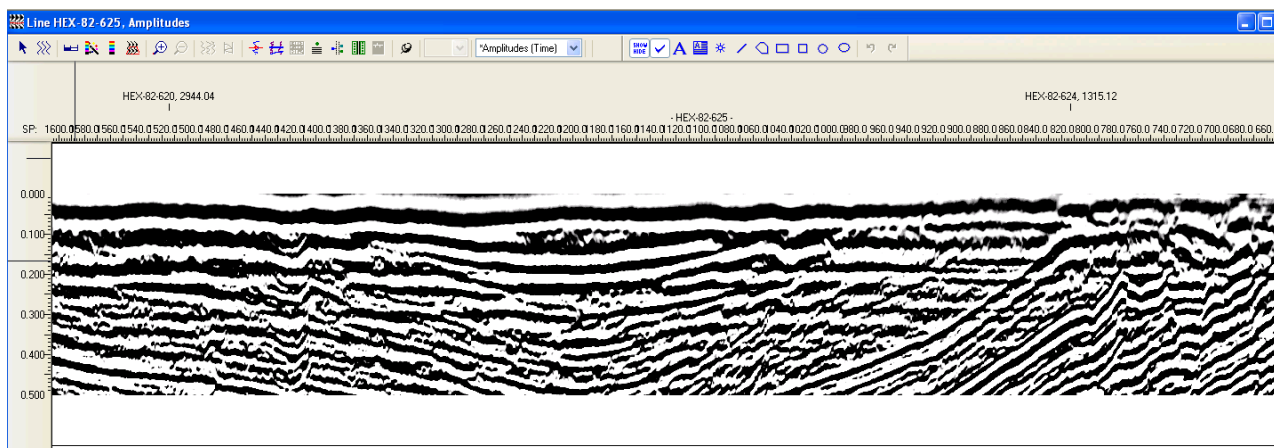
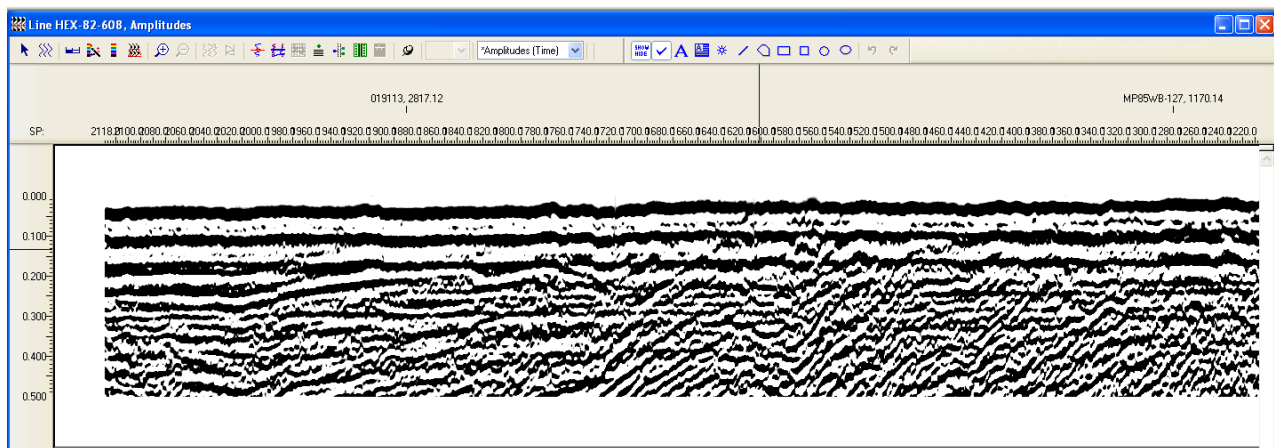


Figure 9: A Selection of 2D Lines from the Bristol Channel, Illustrating the differing sedimentological conditions across the study area.

An assessment of the speculative 2D geophysical survey data for use within the project

5.3.14 The selected speculative geophysical dataset consisted of several seismic surveys which were acquired by Fugro-Robertson in 1982. For these surveys multiple lines of data were available the majority being outside the study area. However, a significant proportion is contained within the west of the Bristol Channel study area. Given the low line density in the Bristol Channel section of the survey, it was decided to approach Fugro-Robertson for assistance. The seismic data was made available to Birmingham University for the purposes of research. The University would like to thank Fugro-Robertson for their assistance in this matter. The survey data was made available in the form of scanned paper rolls in TIFF format and the corresponding survey track plots available on DVD. The original digital survey data was also made available.

5.3.15 This information was observed to contain data that was characterised by some of the best reflector quality seen in the Bristol Channel study area. The data also responded very well to processing. Early topographic features were observed following processing and the remaining data provided an invaluable cross correlation source with the BERR data. This was especially useful in areas where noise issues reduced the line density.

5.3.16 These data, therefore, were of considerable value in assisting the project.

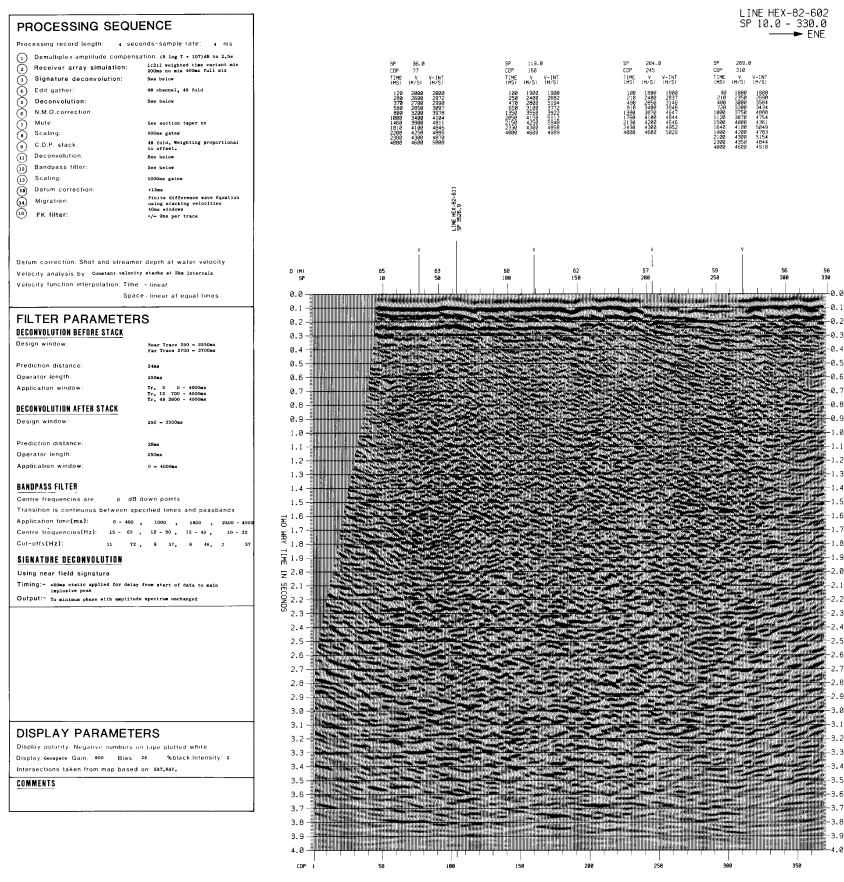


Figure 10: Example of Scanned Paper information, note the detailed metadata included in this sheet.

An assessment of the available SeaZone data for use within the project

5.3.17 A series of SeaZone datasets were selected to represent the range of data products potentially available for analysis in comparable projects. Digital bathymetry provided a good image of the current seabed over the entire study area (Figure 11).

5.3.18 The original data were obtained from SeaZone Solutions. The information relating to data was supplied to VISTA on DVD, and provided in a variety of formats. This data is not freely available for academic or research study and a fee, and licence agreement, is required to gain access to the information. For this project, data were provided in ArcGIS shape file format and ESRI compatible grid formats. These were all contained within a pre-generated ArcGIS project which was projected into GCS WGS 1984 co-ordinates.

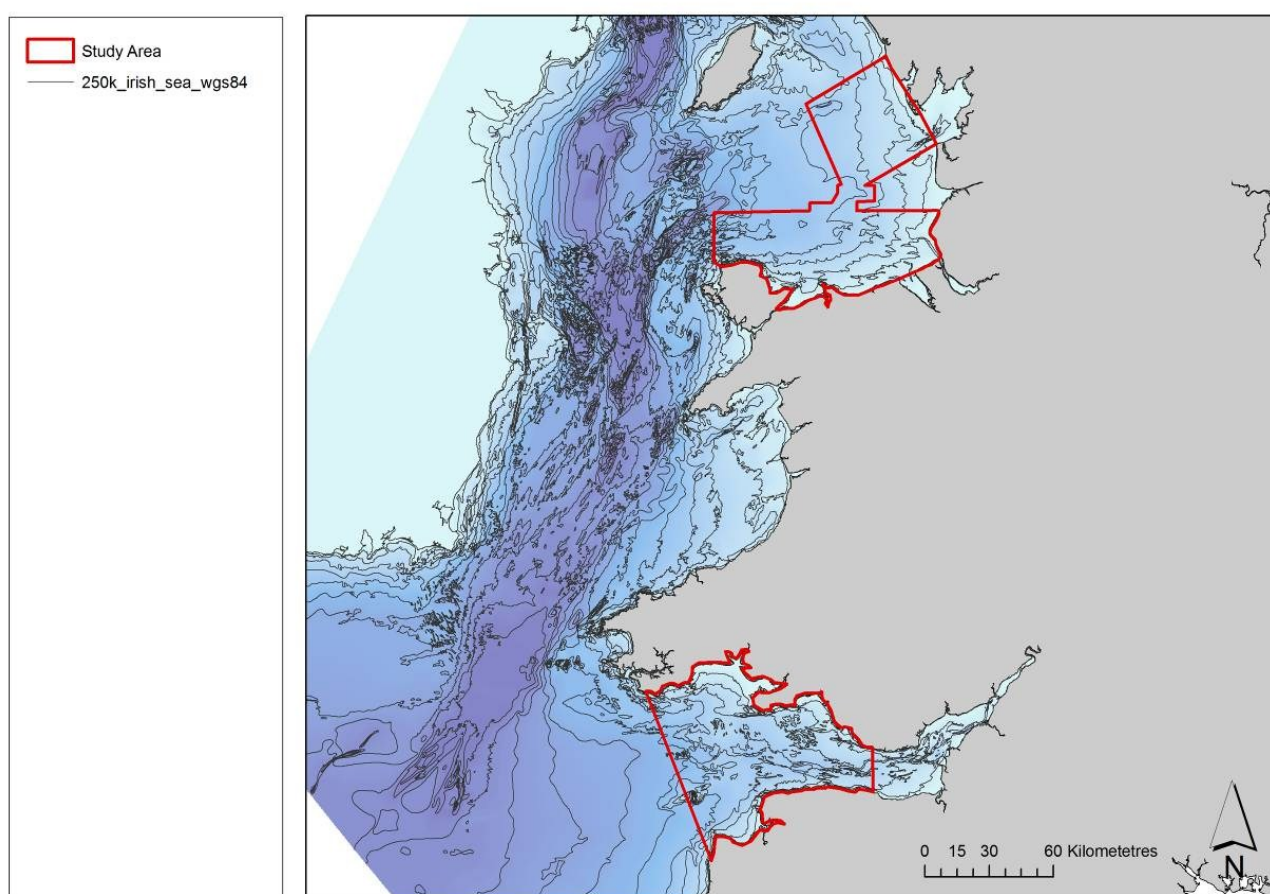


Figure 11: Map of the SeaZone bathymetric purchased for use in this project. Data © British Crown and SeaZone Solutions Limited. All rights reserved.

5.4 Assessment of other information acquired for study

5.4.1 The distribution and depth of Late Pleistocene and Holocene sediments in the UK sector of the Irish Sea Basin have been mapped by the BGS on the basis of seismic-stratigraphic analyses and integrated with lithological and biostratigraphic data from sediments retrieved from shallow boreholes or vibrocores. Unlike the 3D seismic volumes used in the majority of the North Sea Palaeolandscape Project, the seismic data employed in the BGS's seismic-stratigraphic mapping campaign are 2D line profiles totalling a length in excess of 23,000 km. These comprise a combination of low-frequency sparker and air-gun sourced data which achieve local penetration of greater than 800 m. However, resolution decreases with depth, and sedimentary units less than 5m in thickness cannot generally be resolved. Higher frequency sources, such as boomer data, offer significantly improved resolution of shallow seismic reflection events, but often cannot penetrate more than 20m within the Irish Sea. Following established seismic-stratigraphic procedures (Mitchum 1977) the 2D seismic data are used to identify a sequence of seismic-stratigraphic units which, individually, are termed as formations separated from their preceding and succeeding units by unconformable surfaces. Each formation is characterised by one or more distinctive seismic facies type, which, in the absence of direct stratigraphic data, are often used to infer the ages of undated seismic units.

5.4.2 Additional information is located within the BGS regional report for the Irish Sea. This is derived from interpretation of scientific seismic lines acquired across the region as well as an extensive seabed sampling program. The mapping contains not only useful information pertaining to the stratigraphy of the region, but also includes mapping of relic bedforms located during survey. Unfortunately, all of the relic bedforms are located outside of the project area and it was not possible to cross calibrate this information with the bathymetric data obtained by the project

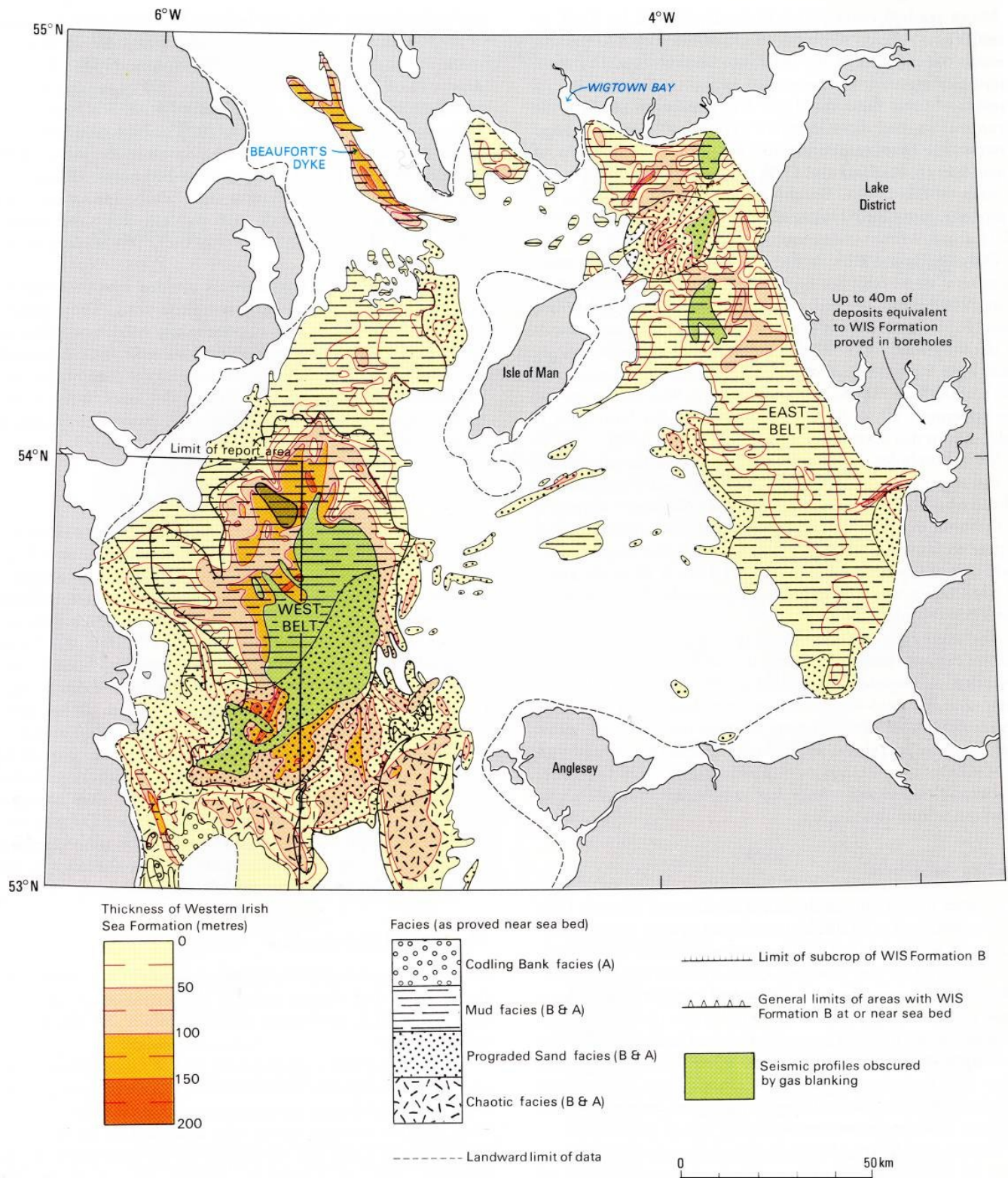


Figure 12: BGS Map of the thickness of the Western Irish Sea Formation (WIS - Upper Pleistocene) from Jackson *et al* 1995

6 IMPLEMENTATION OF THE METHODOLOGY

6.0.1 The project undertook to utilise the improved methodologies as developed by the West Coast Palaeolandscapes Pilot (Fitch and Gaffney 2009)

6.1 Implementation of the 3D Methodology

6.1.1 The technique of timeslicing is the first step in 3D interpretation of seismic data. This is achieved by dividing the 3D seismic data volume into a series of horizontal slices of equal time. In this project the 3D data volume was sliced into a series of horizons at 0.004 of a second intervals, starting at 0.06 seconds where the first post seabed multiple was imaged, through to the first clearly resolvable glacial features. The seabed was poorly resolved in the study area and so, in this region, multiples were used in the timeslicing to gain a full understanding of the features at or near the seabed.

6.1.2 The approach provided clear images of the depositional features, but the thin Holocene cover in this region resulted in limited vertical and hence temporal separation of features (Jackson *et al* 1995). It was observed from the initial investigation of this dataset, and the BGS report for this region, that the elements of stratigraphy of archaeological interest were considerably thinner than in the North Sea, but were comparable to that observed in the WCPP Pilot. This was supported by analysis of the slices, which suggested a relatively shallow region of interest within the data, thus the end time utilised was set at 0.15s. This means that in the 3D seismic data for the study area the depositional systems tended to be better interpreted in timeslices rather than profiles.

6.1.3 Timeslices were generated automatically within the available seismic interpretation packages. However, other methods were required to export the timeslice information to facilitate GIS display. The export of planar data from a seismic interpretation package is usually facilitated through horizon export. If a perfectly flat horizon is generated within the interpretation package, and associated amplitude data is extracted, it can be utilised as a pseudo timeslice, with identical properties to a timeslice. This pseudo slice information can be exported to an external package in a range of formats suitable for GIS import. Through mathematical manipulation it becomes possible to generate a series of pseudo slices which can be utilised in a GIS in a similar manner to timeslices within an interpretation package. After careful consideration, it was considered that output as a simple ASCII text file, in the format X,Y, attribute was the most appropriate given its simplicity, transferability and its non-proprietary format. This ASCII information was then converted to a raster image in ArcGIS and subsequently interpreted.

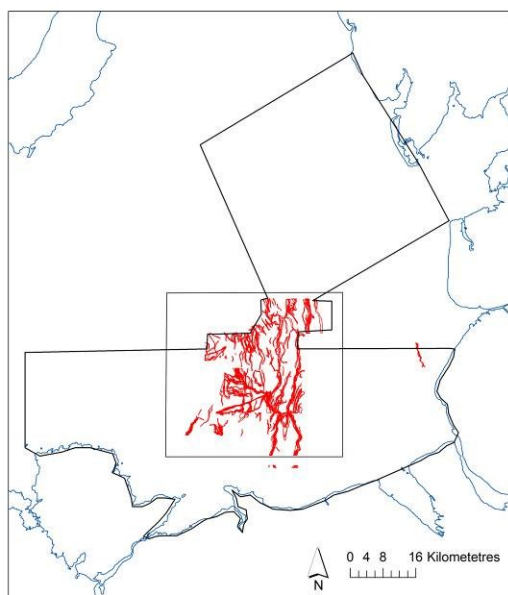
6.1.4 In order to enhance the features seen in the time slices, several industry standard techniques were employed to improve the visualisation and interpretation. The first of these techniques is opacity rendering (Kidd 1999). This technique converts conventional 3D seismic data into a voxel volume, with each voxel containing the information from the original portion of the 3D seismic volume that it occupies together with an additional (user-defined) variable that controls its opacity. The opacity of individual voxels can therefore be varied as a function of any of their seismic attributes, which thereby allows the user to explore only those voxels that fall within their particular attribute range of interest (usually amplitude). This method permits a clearer solution of the

interpretation, and thereby allows a relative dating of the observed structures to be assigned.

6.1.5 Alongside this attempt to improve the definition of the features, a series of standard seismic attributes were also serially timesliced to assist analysis. These attributes included Envelope extraction, Automatic Gain Control, Running Sum. Minor improvements in the definition were realised utilising Running Sum and Automatic Gain Control. However whilst no new features were visualised beyond that observed within the standard amplitude datasets, the increased definition of features was of great assistance in affecting effective landscape feature recognition within the study.

6.1.6 Within the Liverpool bay area, 3D seismic data was imported into Kingdom and then processed in a variety of ways in order to generate 'timeslices' through the dataset. Each of the timeslices, for each of the surveys, were analysed for archaeological landscape features, which were then digitised within Kingdom.

6.1.7 These features were then exported as a DXF, and imported into ArcGIS. Some features had very strong signals and were visible in many of the timeslices. Some features were more ephemeral and were only visible within one of the timeslices (Figure 13).



3D features
exported from Kingdom

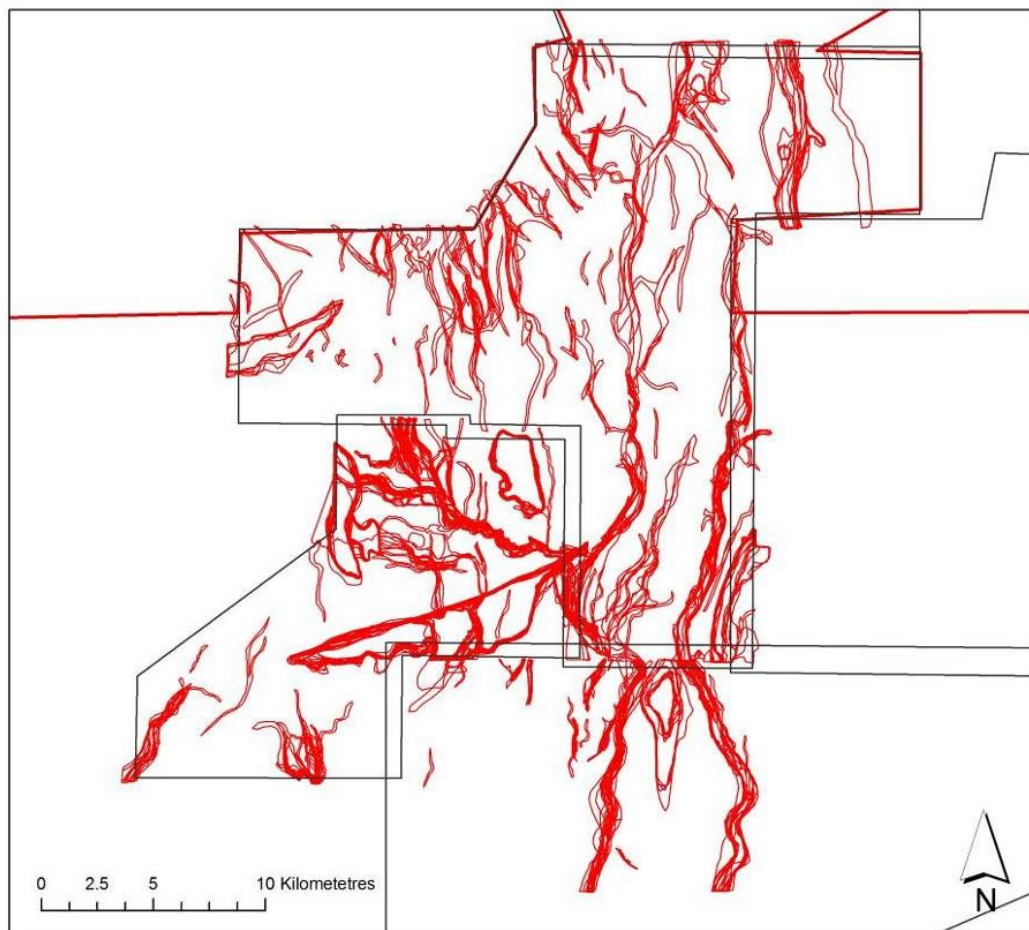


Figure 13: 3D features exported from Kingdom as a DXF file

6.2 Implementation of the 2D dataset methodology

6.2.1 After detailed examination of the 2D seismic lines it was decided that a combination of standard interpretation procedures coupled with associated GIS recording would be employed during analysis.

6.2.2 Initially, the seismic data was examined utilising standard seismic-stratigraphic procedures (Mitchum 1977). Digital 2D data, provided as SEG-Y data, was imported directly within SMT Kingdom 8.2 (64bit) seismic analysis software. As the data was provided digitally, it was possible to perform seismic attribute analysis upon these 2D datasets utilising the same suite of attributes as described for the 3D methodology. Generation of this information, however, failed to identify any new features and there was only minor clarification of the identified features. Once completed, interpretation of the features was undertaken directly within the seismic analysis software and recorded as a series of culture files. As well as recording the locations of identified features within point files, possible landscape features were also recorded. This information was exported directly into the project GIS for further analysis.

6.2.3 Once the 2D data was imported into Kingdom, individual lines were analysed for landscape features, and these features were digitised. The resultant dataset was a point shapefile with X and Y (spatial), and Z (time/depth) attributes at regular intervals along each of the features. Where multiple feature types were identified within the lines, multiple features in the same spatial position were created, although sometimes with a different Z value. For instance, a particular line might have channel features overlain by organic or floodplain deposits. Both features would be identified in the same geographical location, but with different time/depth attributes.

6.2.4 These features were classified within Kingdom into groups or types. Each individual feature type was exported as a CSV file, which was then merged together as a database. The point shapefile with features types was then imported into ArcGIS and in turn was converted into a line shapefile denoted each of the individual features. This was buffered at 100m to create a polygon shapefile which could be amalgamated with other 3D features. Each feature has attributes of source, certainty, and description based on the initial interpretation from the 2D lines.

6.2.5 The scanned analogue (paper) data was converted to digital format utilising Chesapeake's ImagetoSEG-Y program to facilitate a direct analysis within the main geophysical software. This facilitated the utilisation of the standard 2D processing and interpretation techniques.

6.2.6 This was achieved through the identification of the nearest fix (or shotpoint) location to the identified feature and then subsequently locating the appropriate record within the GIS. The data within the point file marker table was then populated to provide the necessary supporting data. It is important to note that this method does not provide precise locations for these features as achieved with the other methods. This information was recorded within the shapefile table. Despite this, the error margin likely to be associated with the locations is estimated at +/- 50m, which would permit future investigations to target these areas with relative accuracy.

6.2.7 Within Kingdom, the Z attributes of the points were also used to interpolate between the features using the flex-grid method. This created a second point shapefile.

6.2.8 The second point shapefile generated from the grid was imported into ArcGIS and interpolated into a continuous raster layer. The values of the Z (time/depth) attribute are relative to the underlying topography, but not exact depth values, and so can only be used to interpret relative topography not absolute depths.

6.3 Methodological improvements undertaken

6.3.1 Given the extensive nature of the 2D seismic data, and the limited time available, it was not appropriate to consider or undertake major methodological changes. Therefore the methodology as outlined in the "West Coast Palaeolandscapes – Pilot Study" was undertaken (Fitch and Gaffney 2009), see Appendix 1.

6.3.2 However, after consideration it was deemed useful and possible to include the bathymetry as a pseudo horizon within the 2D seismic datasets to assist in interpretation in very shallow or noisy datasets. This methodological refinement was extremely useful in the Bristol Channel area where line density was low.

7 ANALYSIS, RESULTS AND OUTPUTS

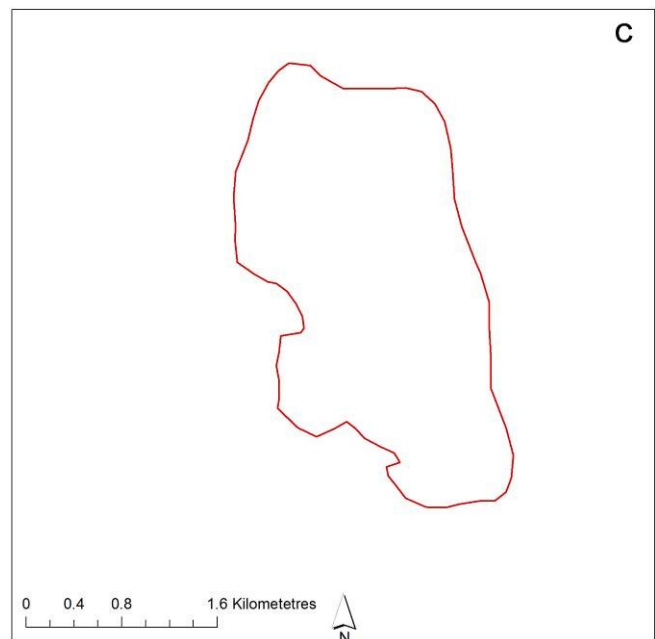
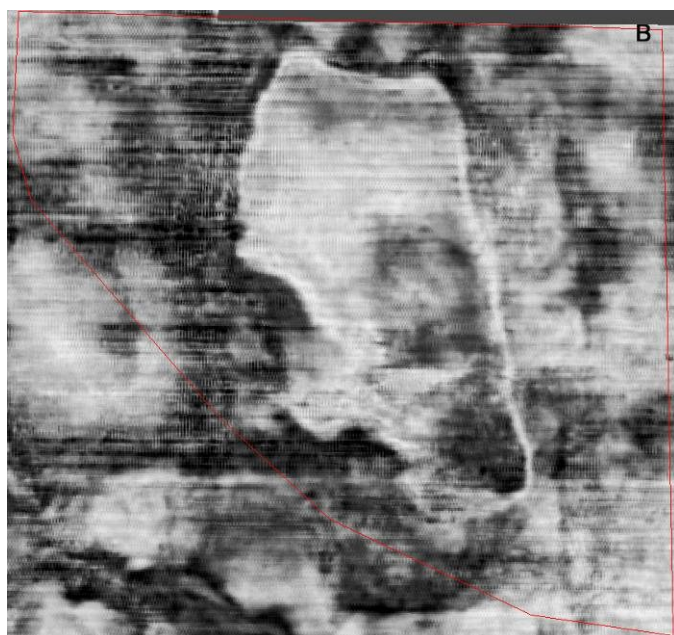
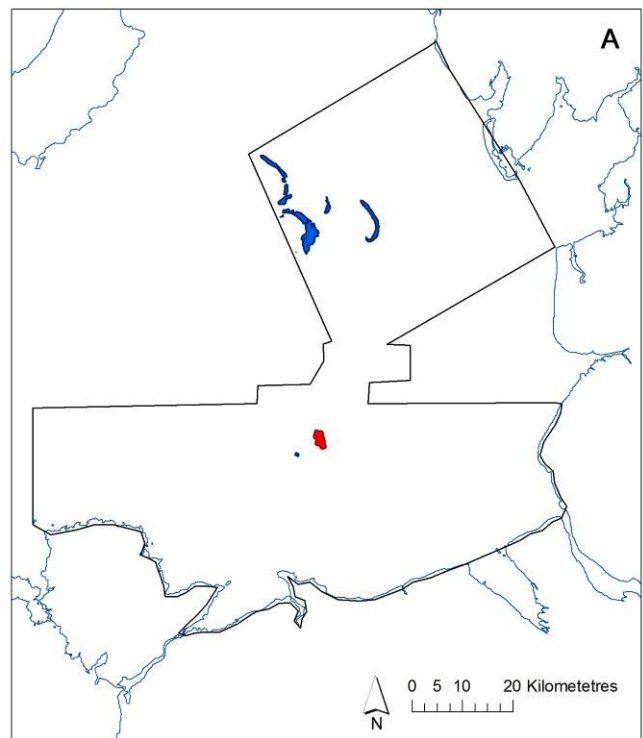
7.1 Examples of 3D features identified

High ground (Figure 14a-c)

7.1.1 Areas of high ground were identified during both the pilot study and the main project. These features were characterised as upstanding areas visible within the seismic data. Generally these features correspond with outcrops of solid geology, which are surrounded by quaternary sediments. Most of the high ground identified during the overall project was to the north and within the pilot study. Two areas of higher ground were identified during the main project in the central area of the main study area.

Figure 14:

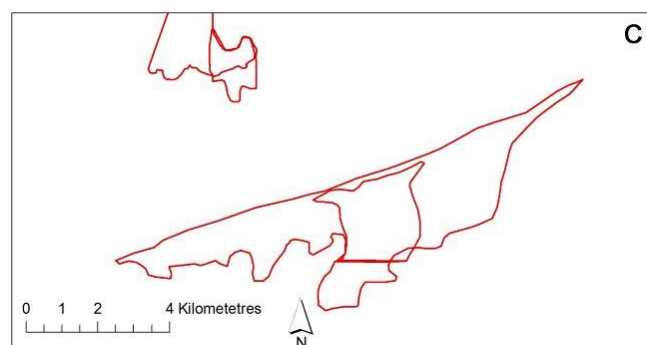
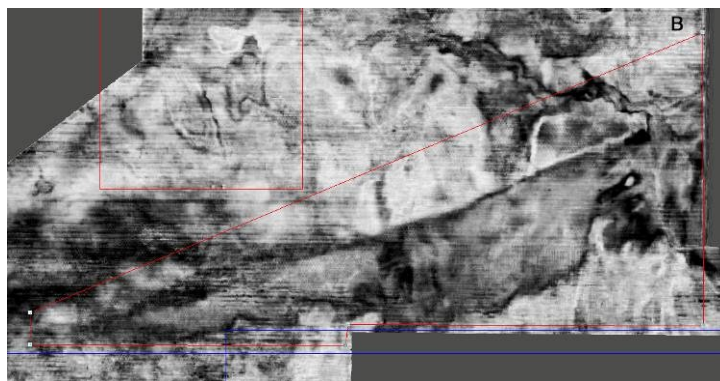
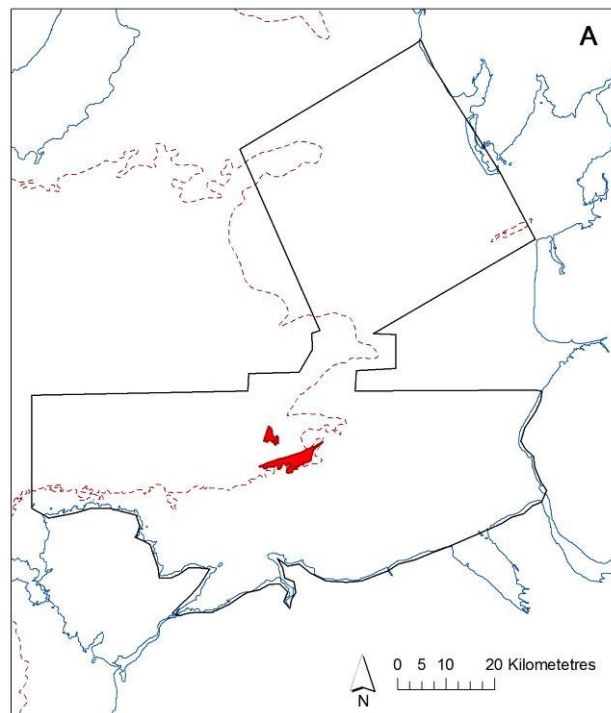
- A) High ground locations (feature shown in red is depicted on B and C)
- B) 3D seismic data timeslice AMPLITUDES 0.056 showing example feature
- C) Example feature outline



Holocene estuaries and coastlines
(Figure 15 a-c)

7.1.2 Evidence for a Holocene coastline and associate estuaries was identified within the central section of the study area. This was identified by a change in the acoustic amplitude which occurred abruptly. Upon examination in vertical section, this was seen to be represented by an erosional contact with the Late Pleistocene layers with subsequent deposition overlying this. In addition the interpreted coastline was seen to be on a broadly similar alignment to the -40m bathymetric contour. This suggests that this feature may have some topographic expression on the current seabed.

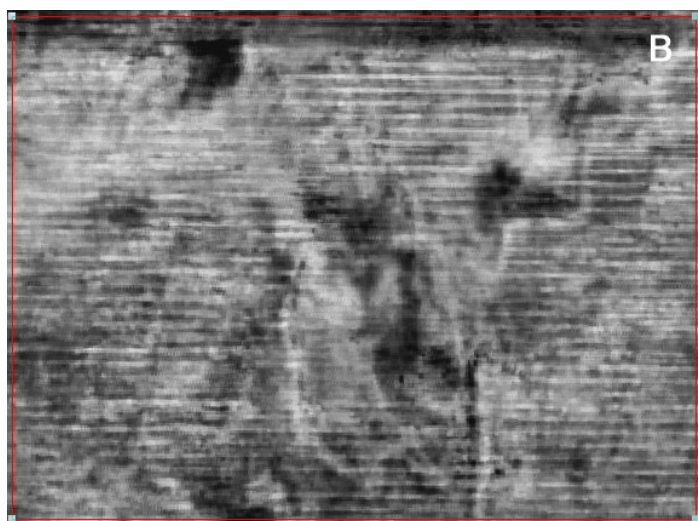
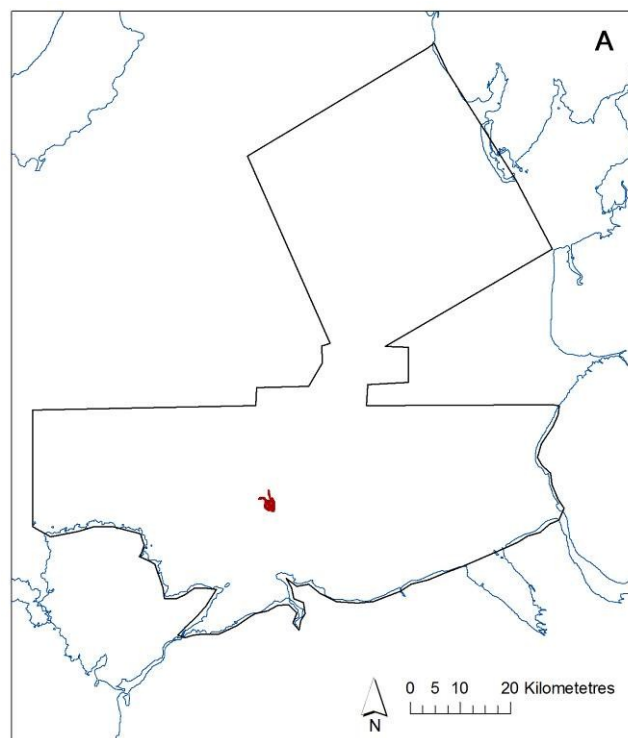
Figure 15:
A) Holocene estuaries and coastlines,
B) 3D seismic data timeslice
AMPLITUDES 0.056 showing features
C) Feature outlines



Small Holocene deltaic system
(Figure 16 a-c)

7.1.3 A small feature interpreted to be a small Holocene deltaic system was identified to the south-west of the estuaries. As the feature is located at a similar level it is suggested that this feature may be contemporaneous with the coastlines described previously. The feature was ephemeral and difficult to digitise, which suggests that the structure might have been short lived. In addition there are several overlapping channels, which illustrate lateral movement occurring within the system, - possibly due to sea-level rise.

Figure 16:
A) Small Holocene deltaic system
B) 3D seismic data timeslice
RUNSUM 0.064 showing feature
C) Feature outline



End glacial channels in large floodplains (Figure 17 a-c)

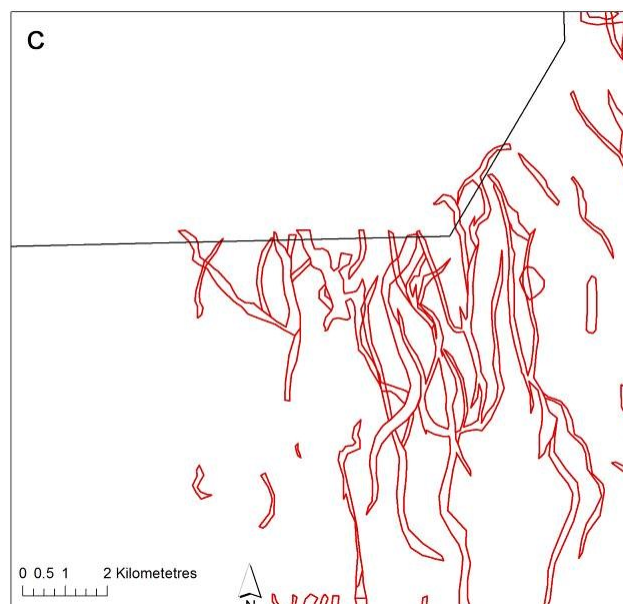
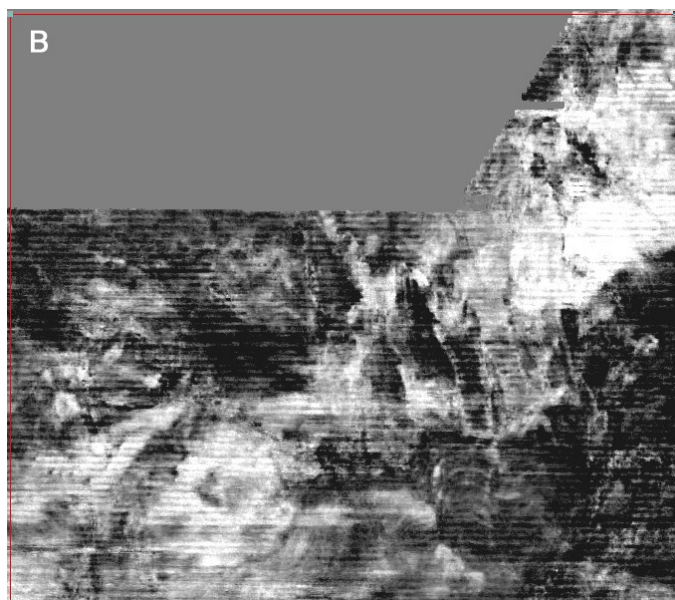
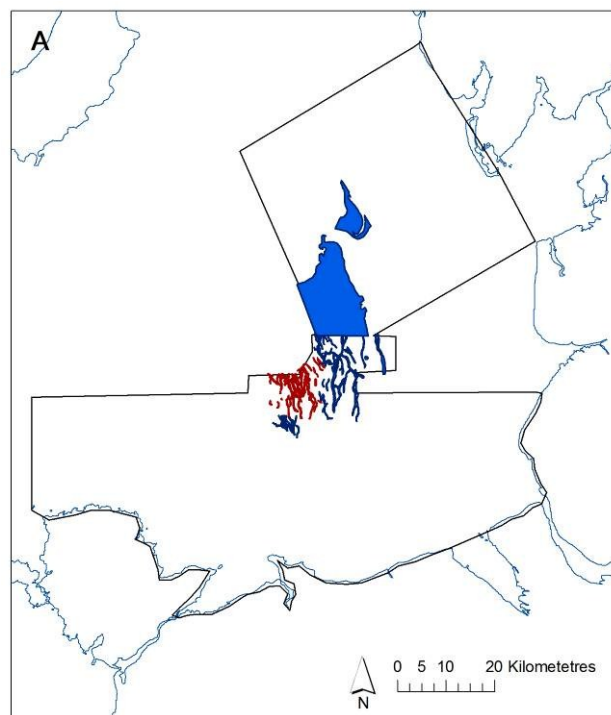
7.1.4 The central section of the study area was characterised by a broad area containing thin, ephemeral channel features situated within a large floodplain. The features are thought to represent the channel systems draining glacial melt water. This floodplain extended to the north within the boundaries of the pilot study, although this was not recorded in detail during this phase of research due to its age and depth. The features at the western extent of this area were roughly aligned southeast – northwest, with the channels further to the east having a more north-south alignment.

Figure 17:

A) End glacial channels in large floodplains (features shown in red are depicted in B and C)

B) 3D seismic data timeslice HILBERT 0.064 showing example features

C) Example feature outlines



Glacial tunnel valleys (Figure 18 a-c)

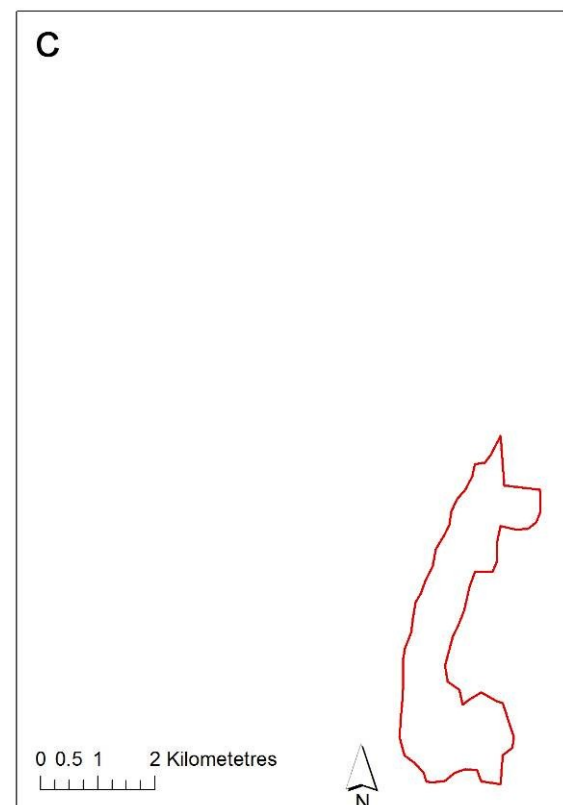
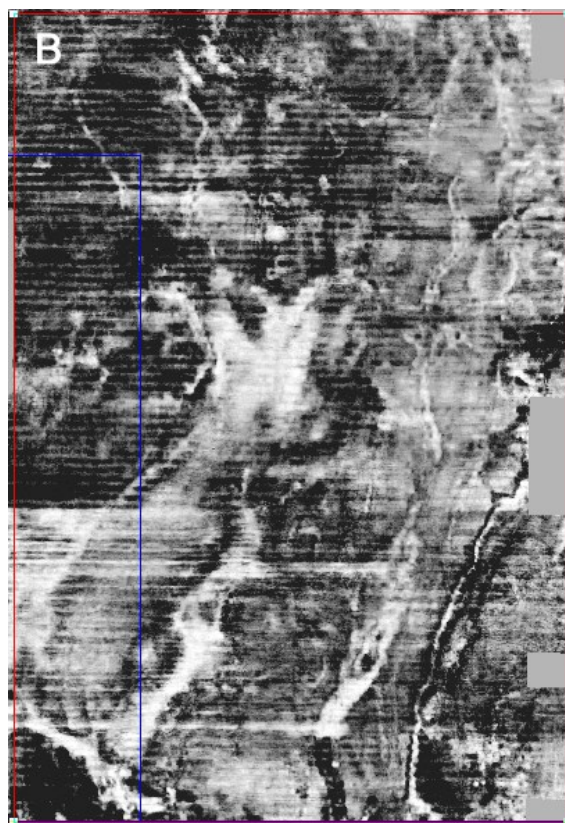
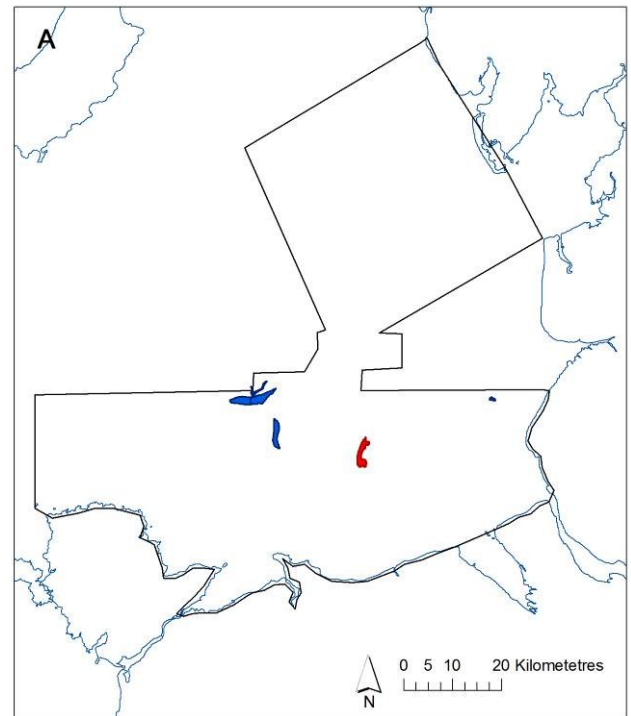
7.1.5 A number of glacial tunnel valleys were identified within the study area. The mode of formation of tunnel valleys is a matter of some debate; one proposal is that these were formed from subglacial melt water under hydrostatic pressure at the bottom of an ice sheet. However, there are some proposals that these form from catastrophic floods of melt water produced by a breakthrough of water at the glacial margin. The morphology of these features however is relatively gentle and their scoop-shaped form indicates that a subglacial origin is most likely.

Figure 18:

A) Glacial tunnel valleys (Feature shown in red is depicted in B and C)

B) 3D seismic data timeslice HILBERT 0.064 showing example feature

C) Example feature outline



Holocene channels and Holocene fluvial floodplains (Figure 19 a-c)

7.1.6 A number of Holocene channels and fluvial floodplain deposits were identified in both the pilot project and the main project and are located relatively close to the seabed reflector in the seismic data. The channels identified in the pilot project were mostly on a northeast – southwest alignment, in places dissecting the areas of high ground also identified in this area. Within the new areas assessed, the main Holocene channel was clearly identified aligned roughly southeast – northwest, and again between two newly identified areas of higher ground. This area also has a coastline with deltaic system to the south and evidence of Holocene estuaries. This would have been a dynamic landscape during the Mesolithic period. It would have been very attractive to humans, given the multiple resources of the area, but would also have been inundated quickly.

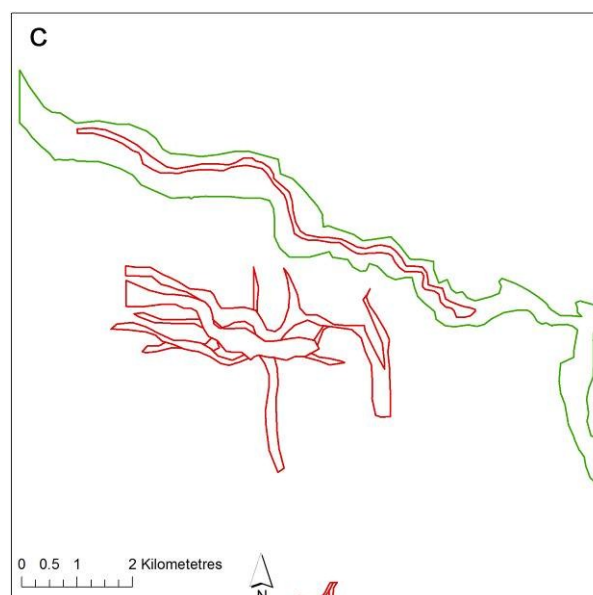
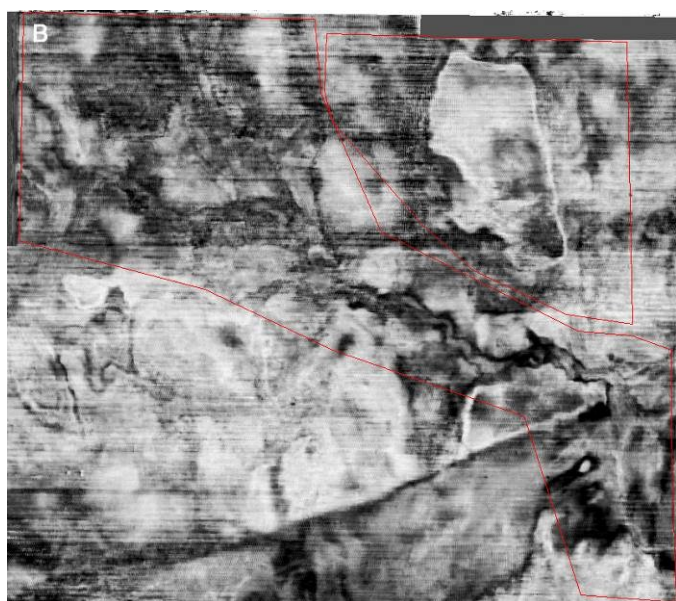
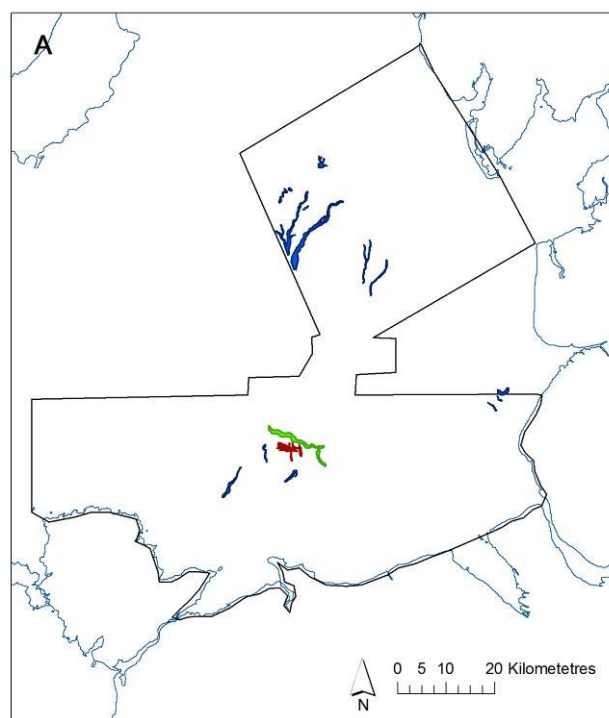
Figure 19:

A) Holocene channels (examples depicted in B and C in red, other features in blue) and Holocene fluvial floodplains (example depicted in B and C in green, other features in blue)

B) 3D seismic data timeslice

AMPLITUDES 0.056 showing example features

C) Example feature outlines



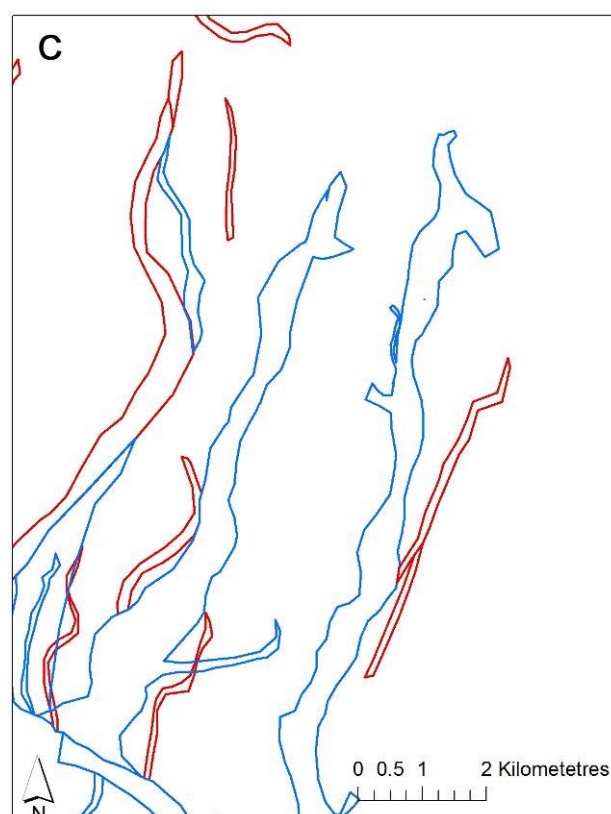
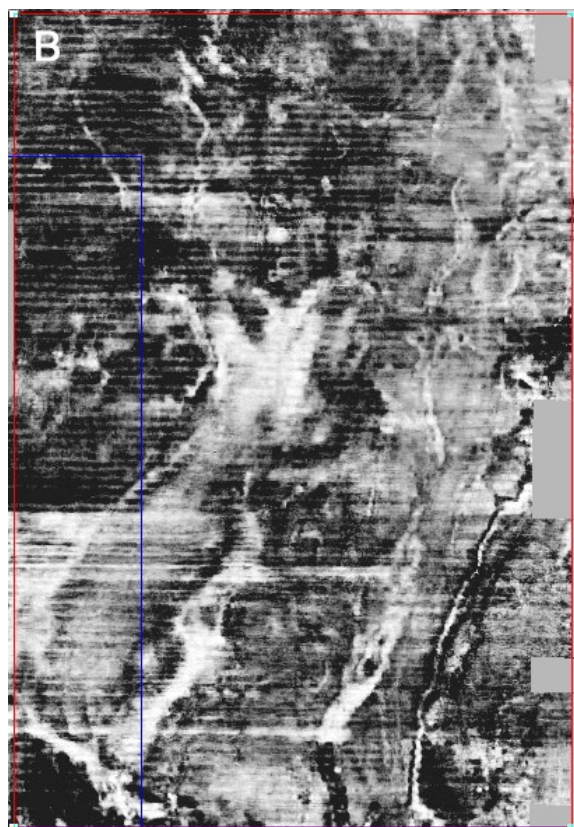
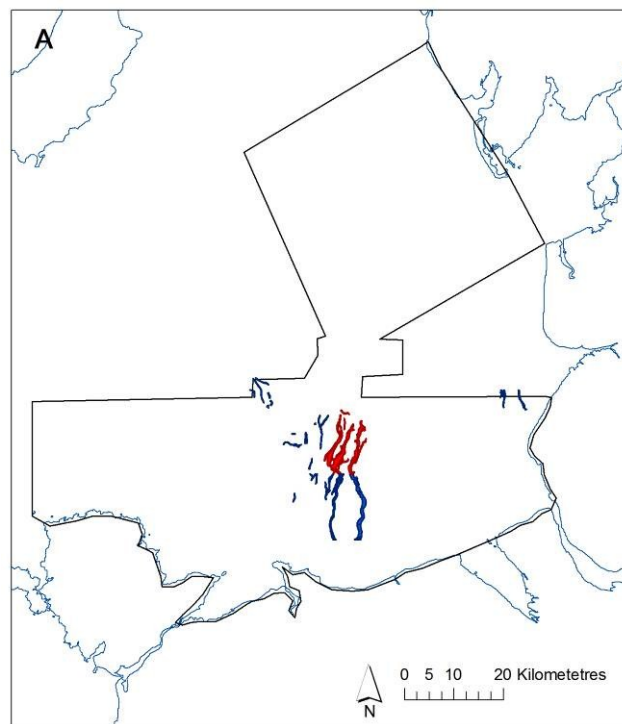
Late glacial features (including those reused in Holocene) (Figure 20 a-c)

7.1.7 It was apparent that there were a number of late glacial features in the study area that had evidence of re-use during the Holocene. The majority of these were located in the central southern part of the study area, and were aligned north – south. Some had very strong signals within the 3D dataset, indicating that the original late glacial channel had formed a well developed valley. Given the presence of these depressions in the Holocene, it is perhaps not surprising that they are re-used by later river channels. Other smaller late glacial features were also identified during the project.

Figure 20:

A) Late glacial features (features depicted in B and C shown in red)
 B) 3D seismic data timeslice HILBERT 0.064 showing example features
 C) Feature outlines - Late glacial features reused in Holocene shown in blue, other late glacial features shown in red

C) Feature outlines - Late glacial features reused in Holocene shown in blue, other late glacial features shown in red

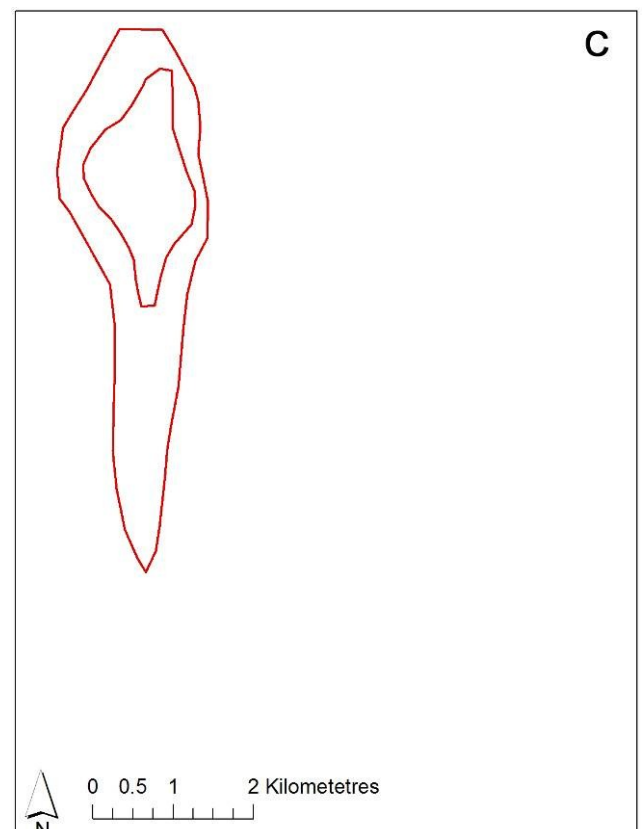
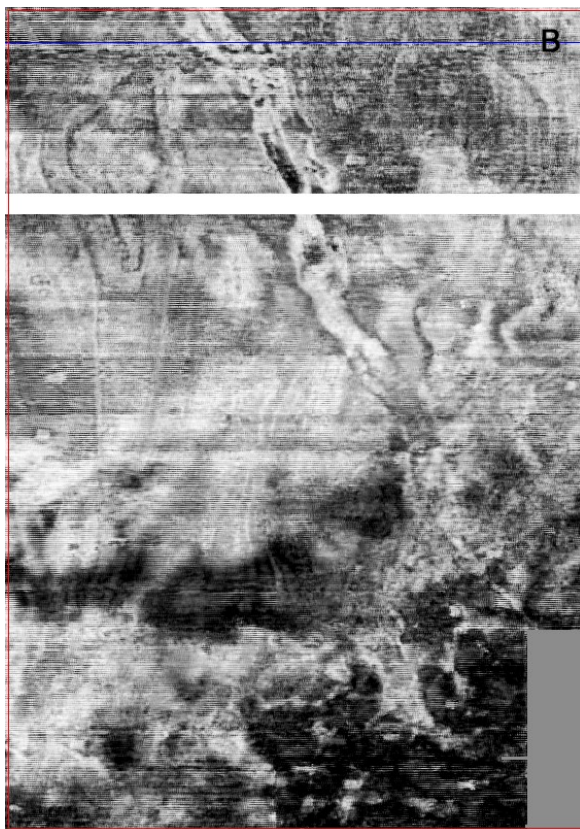
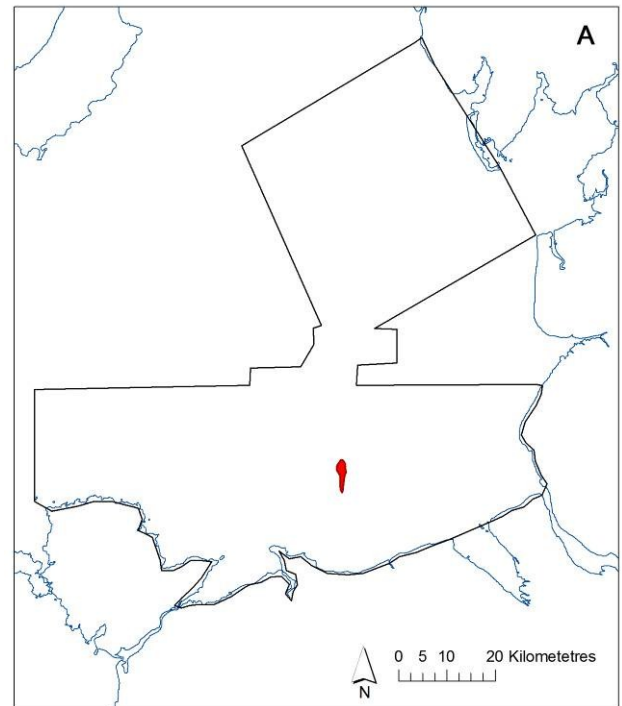


Basin structures (Figure 21 a-c)

7.1.8 A basin structure was identified in the southern part of the study area, located between two large end glacial features that were reused in the Holocene. The origin of the feature cannot be fully determined, but may represent a glacial lake. It is likely that this structure was present during both the Upper Palaeolithic and Mesolithic periods, and may have represented a body of fresh water available to hunter gatherers.

Figure 21:

- A) Basin structures (shown in red)
- B) 3D seismic data timeslice
- AMPLITUDES 0.052 showing feature outline
- C) Feature outline



7.2 Examples of 2D features identified

Wide channels (Figure 22)

7.2.1 A wide channel aligned east – west and located at a depth within the dataset which suggested it was likely to date to the Pleistocene. This feature was identified in 4 lines, and was seen to branch towards the south. Due to the feature being earlier in age than the period considered by this study, no additional work was performed on this system. The feature may be relevant to earlier archaeological periods, including the Middle Palaeolithic.

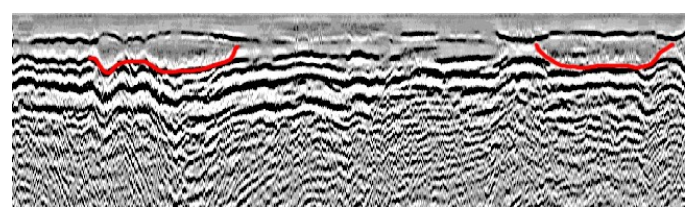
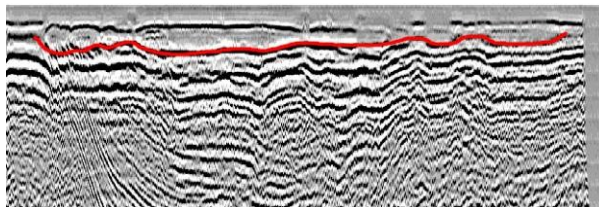
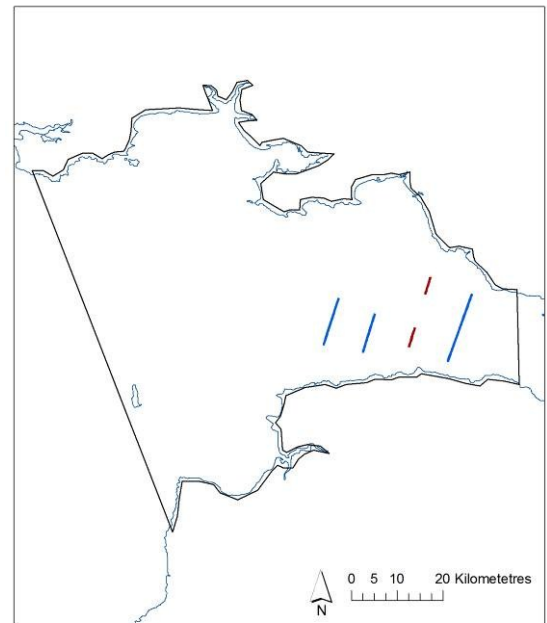
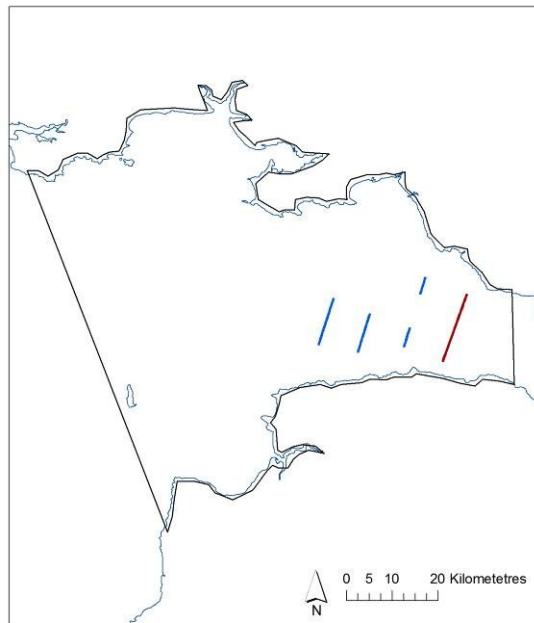


Figure 22: Wide channels (examples shown in red)

Sediment filled basin (Figure 23)

7.2.2 Two areas containing sediment filled basins were identified within the study area. The smaller was located outside the boundaries of the study area on a long seismic line which covered the study area. However, a larger basin was also observed in the southwest part of the study area. This feature was identified as a series of laminated layers infilling a depression cut into bedrock. Whilst the feature has no current topographic expression, it is apparent that it would have certainly represented a basin in the Palaeolithic and possibly even the Mesolithic. Nearby channels may have run into this basin, resulting in a lake during these periods. Identification of continuous overlying sediments within the basin suggests that the lake was probably completely infilled with sediment prior to inundation.

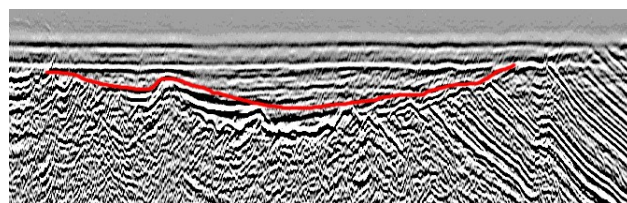
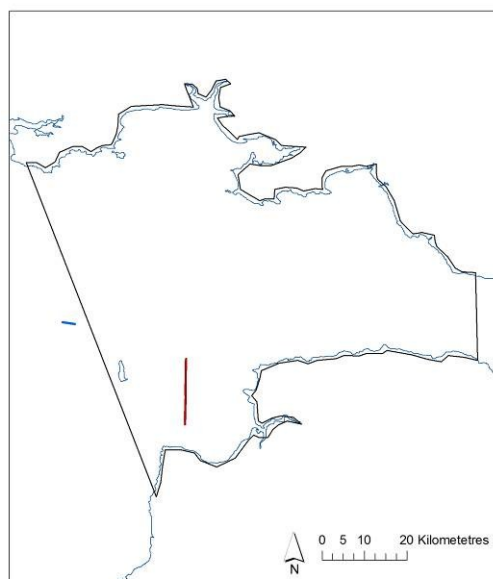


Figure 23: Sediment filled basins (example shown in red)

Holocene channels with infills (Figure 24)

7.2.3 Holocene channels were identified in the northwest corner of the study area. The northernmost channel corresponded with the interpolated channel in this area, running sinuously from east to west. The southernmost channel was not interpolated, but is representative of other likely channels in this area. Both channels are located near to the seabed surface and can be clearly be seen to cut into the earlier landscape.

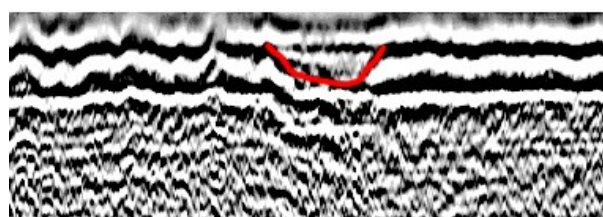
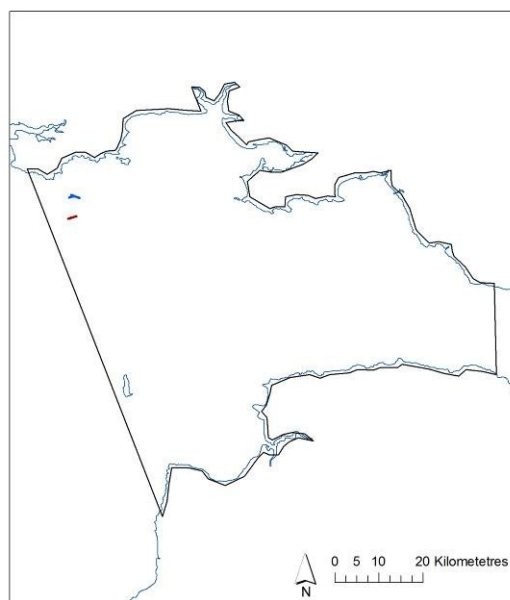
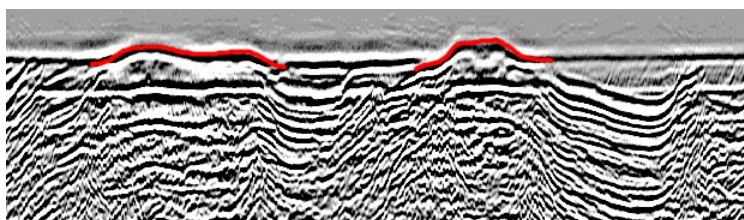
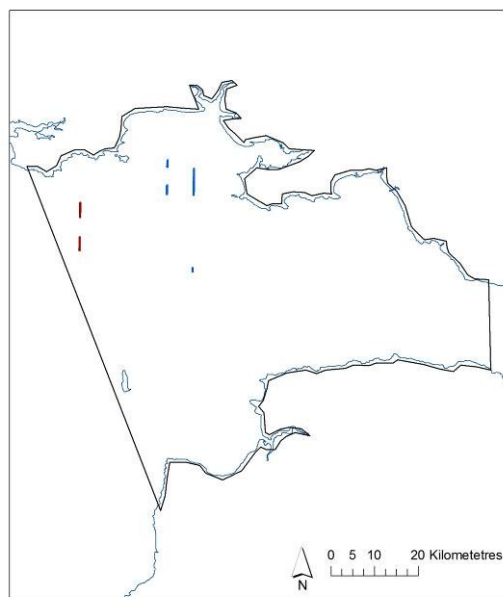


Figure 24: Holocene channels (example shown in red)

Positive topography (yellow) (Figure 25)

7.2.4 Several areas of positive topography were identified in the north of the study area, and are thought to represent outcrops of limestone. This is important as this highlights the possibility of caves being present within the study area. If such caves existed then they might provide an opportunity to prospect for occupation deposits dated to the Palaeolithic and Mesolithic.

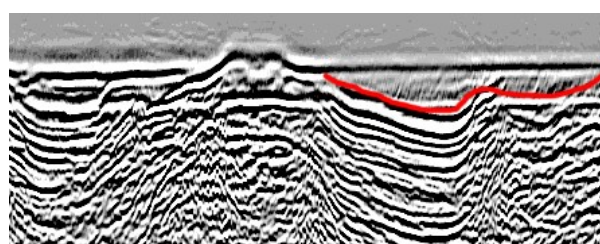
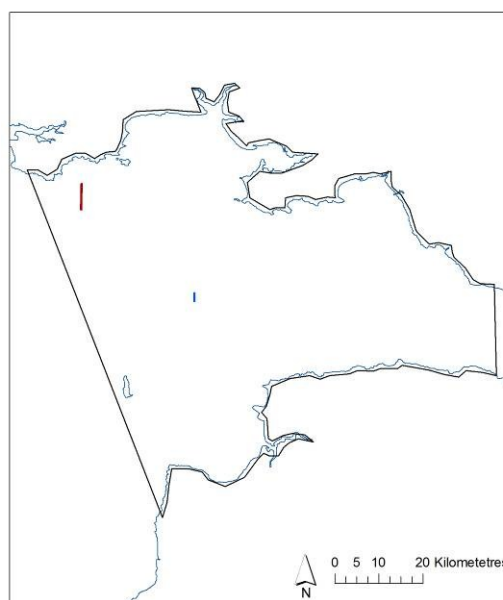
Figure 25: Positive topography (example shown in red)



Glacial lake deposits (Figure 26)

7.2.5 A depression was identified within the seismic data immediately adjacent to an area of positive topography in the northwest of the study area. Given the nature of this feature, and its incision within bedrock it is probable that this feature was generated by earlier erosion and the depression subsequently formed a lake during the Late Glacial. This feature was progressively infilled throughout the Holocene. The lake basin's infilling has been completed by more modern sediments. Its full extent is unknown.

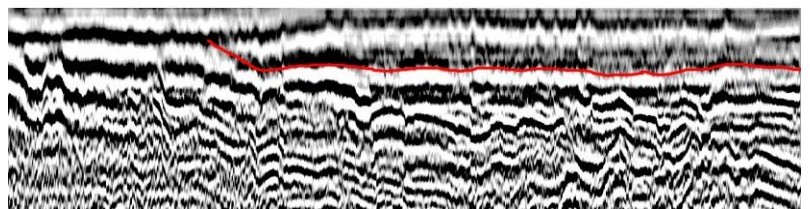
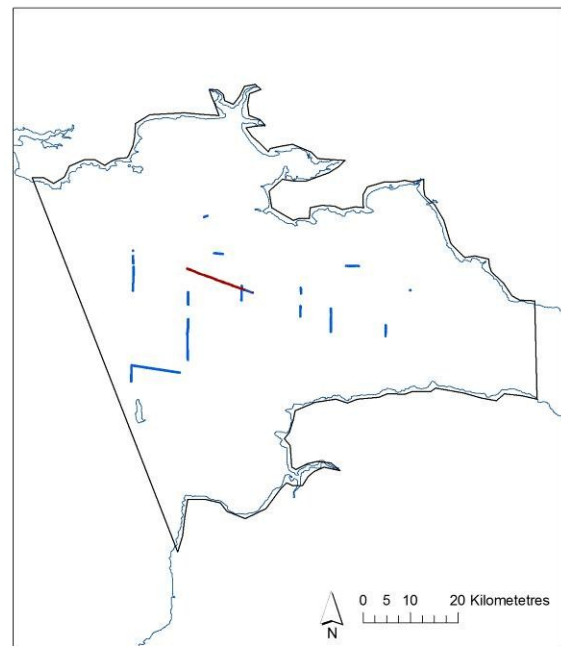
Figure 26: Glacial Lake deposits (example shown in red)



Peat/organic floodplain deposits
(Figure 27)

7.2.6 The potential presence of organic material within several areas suggested the possible presence of floodplain deposits. This type of feature was observed in several of the lines and formed a broad band within the centre of the study area,. The seismic data shows these deposits to have characteristics that are often associated with such deposits (Plets *et al* 2007). However the 2D seismic data has insufficient density to produce a specific determination of this material.

Figure 27: Peat/organic floodplain deposits (example shown in red)



7.3 The integration, analysis, and interpretation of 2D and 3D seismic survey data within GIS.

7.3.1 Where possible, the 2D data was imported into SMT Kingdom. Features identified within it were digitised, and grouped together by type. In the Bristol Channel study area, 11 feature types were identified in the dataset. In the Liverpool Bay study area, 16 feature types were identified (see Tables 3 and 4). These features were exported as a point shapefile along the line. Where a particular feature had multiple potential interpretations, the shapefile was exported twice (see peat/organic layers, and thin lateral floodplains etc).

7.3.2 Additionally, the scanned paper 2D lines were also analysed. A number of feature types were identified from this dataset in the Liverpool Bay study area, although these were less detailed than the features identified within the digital datasets (see Table 4).

7.3.3 The feature dataset from Kingdom also possessed a Z attribute (time/depth) and so was also interpolated within Kingdom to create a grid or surface that extrapolated the high ground and the low ground between the known, identified features within the 2D dataset. The grid of points was imported into ArcGIS, and interpolated into a raster. The accuracy of this grid, and all other interpolations derived from the original data) decreases with distance from the survey lines (Figures 28 and 29).

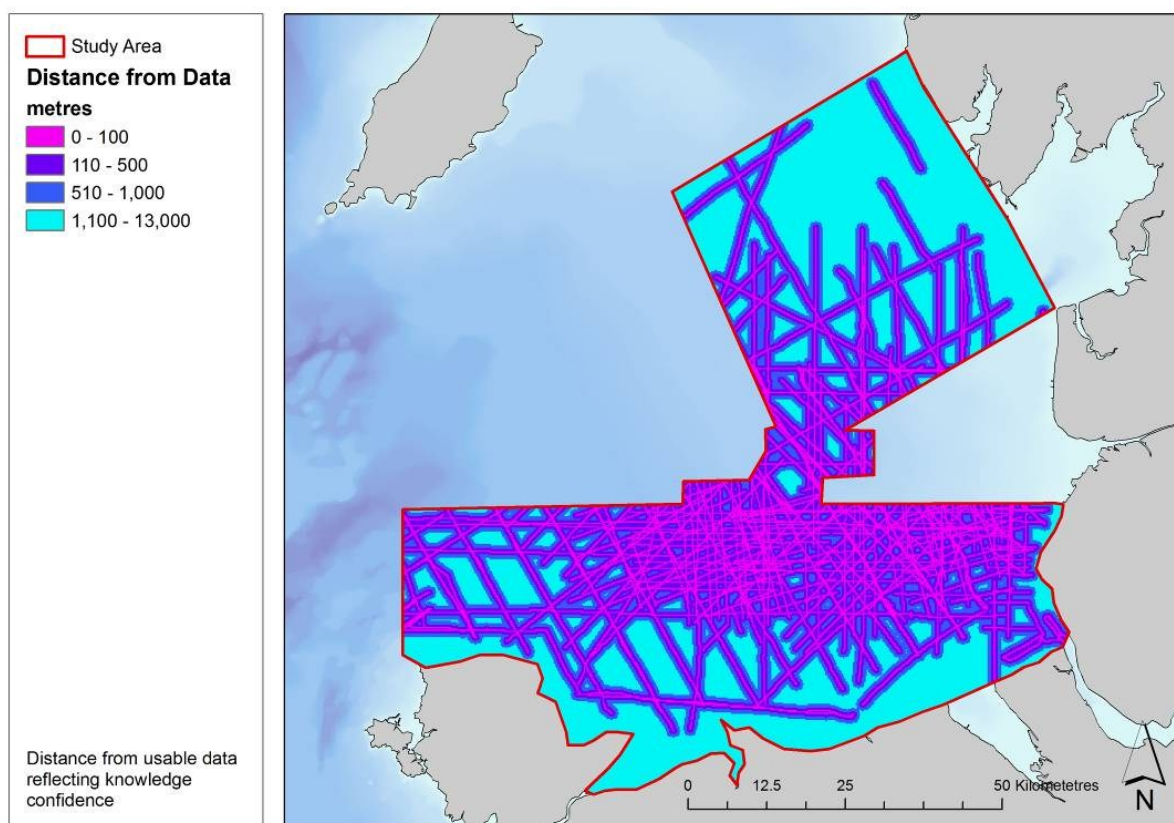


Figure 28: Confidence map showing distance from lines in the Liverpool Bay study area

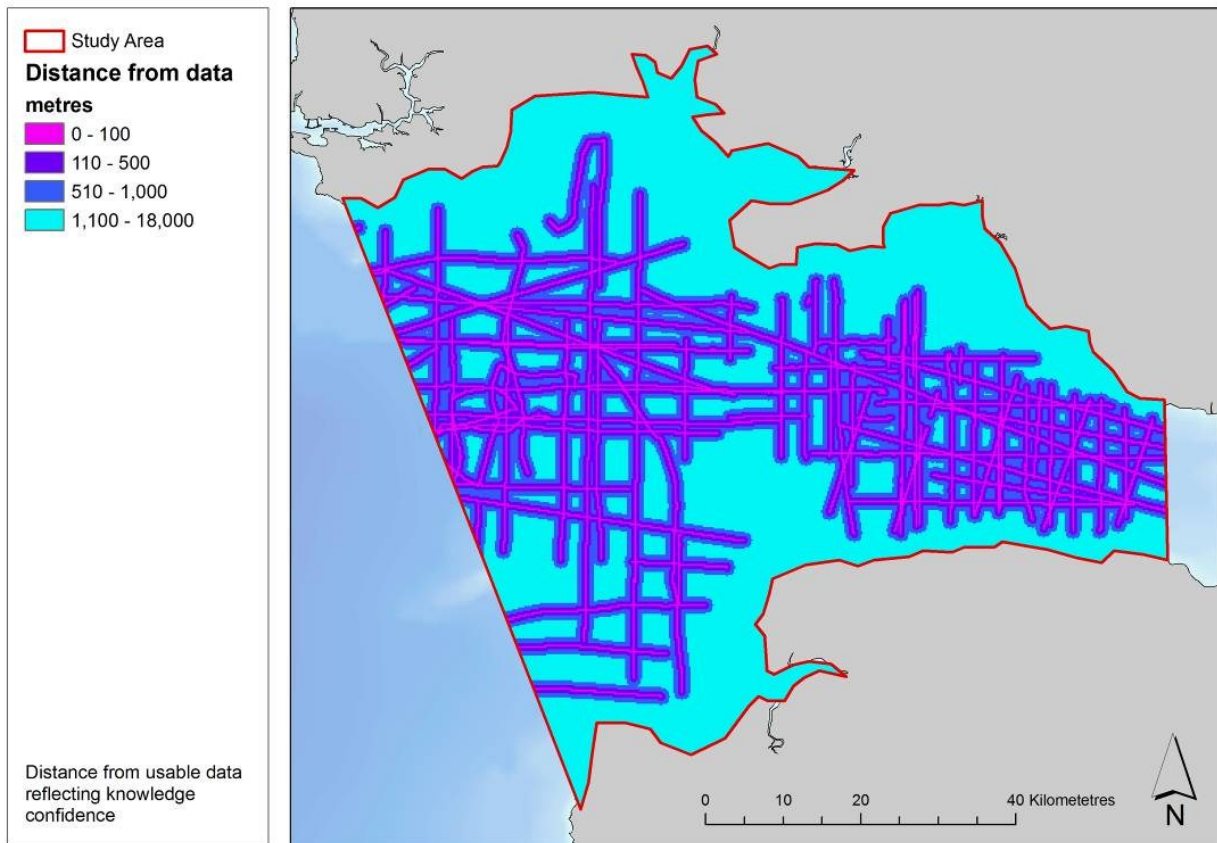


Figure 29: Confidence map showing distance from lines in the Bristol Channel study area

7.3.4 The 3D seismic data was also imported into Kingdom and processed. Where features were present within any of the timeslices, they were digitised as lines or polygons, and this dataset was exported from Kingdom as a DXF, then imported into ArcGIS (Figure 13).

Bristol Channel

7.3.5 The 2D survey lines were imported into Kingdom, and assessed for the presence of archaeological features. Where features were present, these were highlighted in Kingdom, and the corresponding shotpoints were exported as a CSV file, to be imported into ArcGIS. For ease of use, the individual point features were then converted into lines, which were then buffered to a distance of 100m (Table 3, Figure 30).

A certainty value was given to all features (2D and 3D) that aimed to give an indication of confidence of presence for each feature. The features identified within the 2D dataset were given a confidence value of 1, as each feature was visible within one survey line. Interpolated features were given a certainty value of 0, as they were created as potential features within the landscape, rather than indicating the presence of an actual feature. The 3D data was treated as multiple datasets, and features identified within this dataset were given certainty values of 1-24 (see 7.3.14 below).

Bristol Channel 2D features	
Description	Total of features
Glacial lake deposit.	2
Holocene channel with layered infill.	2
Holocene channel, with transparent homogenous infi	2
Holocene channel.	3
Peat/organic etc.	22
Pleistocene channel, some infill.	3
Pleistocene.	1
Positive topography.	11
Sediment filled basin.	2
Thin lateral floodplain or organic layer deposit.	20
Wide channel, surface sands infilled - at the star	6

Table 3: Features identified within the Bristol Channel study area

7.3.6 The Z values of the points of features imported from Kingdom were also used to interpolate rasters projecting the topography of each of the study areas between identified features (Figure 31).

7.3.7 The next stage of data interpretation within the Bristol Channel study area involved the creation of a series of "Broad Area Features". These were created by digitising zones around features and bathymetry of similar types, and represent a first pass at interpreting the information. Using the known 2D features and the raster interpolation, a total of 19 broad area zones or features were digitised within the Bristol Channel study area (Figure 32). Of these, 1 was interpreted as a 'wide old channel', with 3 areas of positive topography, 5 areas of possible Pleistocene deposits, with the rest being indicative of flood plains. The spatial extent of these areas is not considered accurate; they were used as guidelines for more detailed interpretation of the data.

7.3.8 Within the Bristol Channel study area, the only data available was the 2D lines features. These were used in conjunction with the bathymetric data and the data interpolated to generate a series of shapefiles predicting the presence of landscape features such as lakes and rivers. These, in turn, were extrapolated from selected known targets in the 2D data (Figure 33). Because of the lack of absolute data, these features are considered to have a certainty of 0. They are 'guestimates' and as such, are likely to be refined when more detailed data becomes available. They are also simple features, as it was not possible to extrapolate detailed information from the data. They were created to give an idea of the likely presence, type and location of features. As a consequence there is a deliberate discrepancy between the 'known features' and representative features identified in this dataset.

7.3.9 The data was then used in conjunction with the bathymetric data to create a map of 'relative topography' (Figure 34).

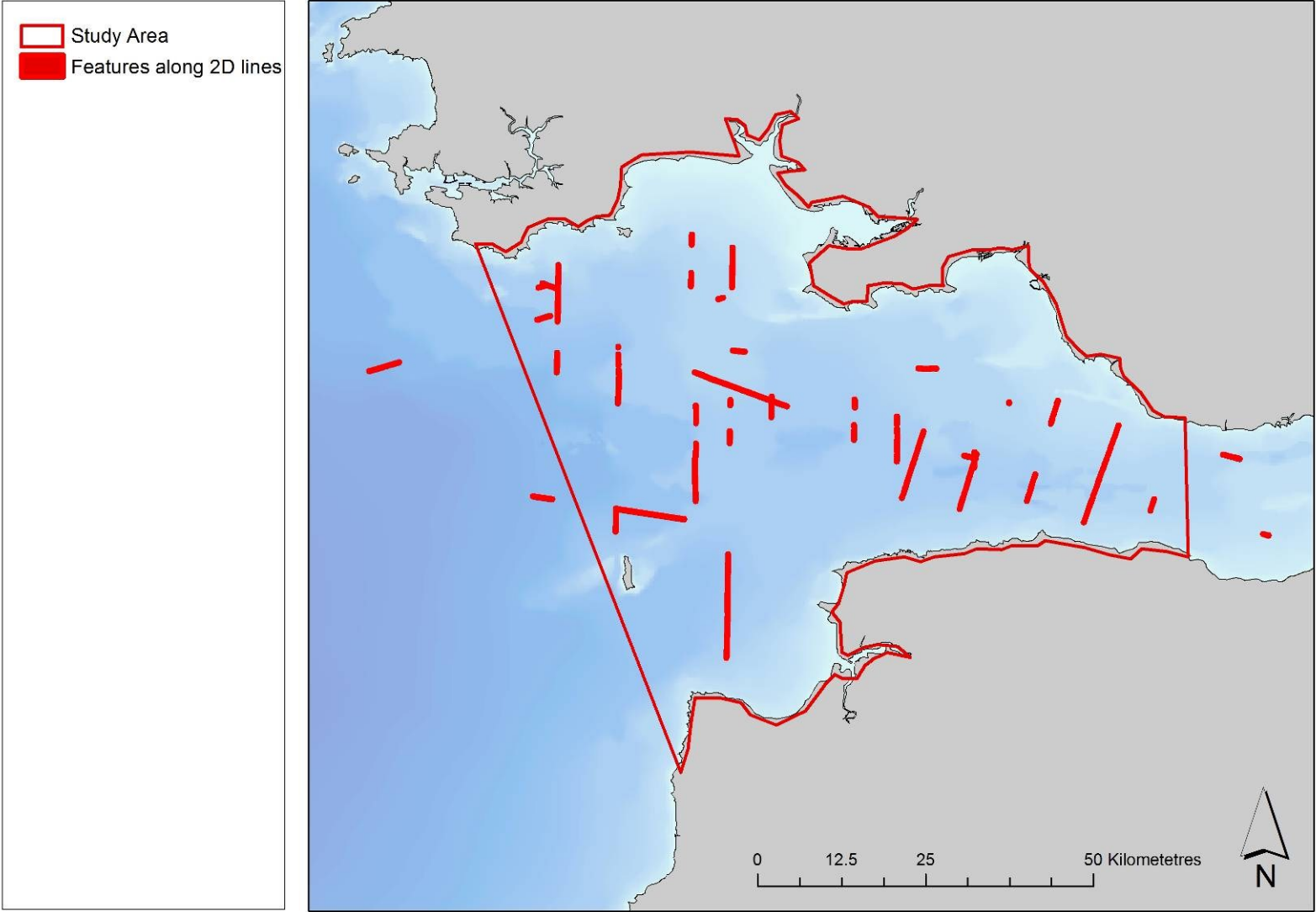


Figure 30: 2D features within the Bristol Channel study area

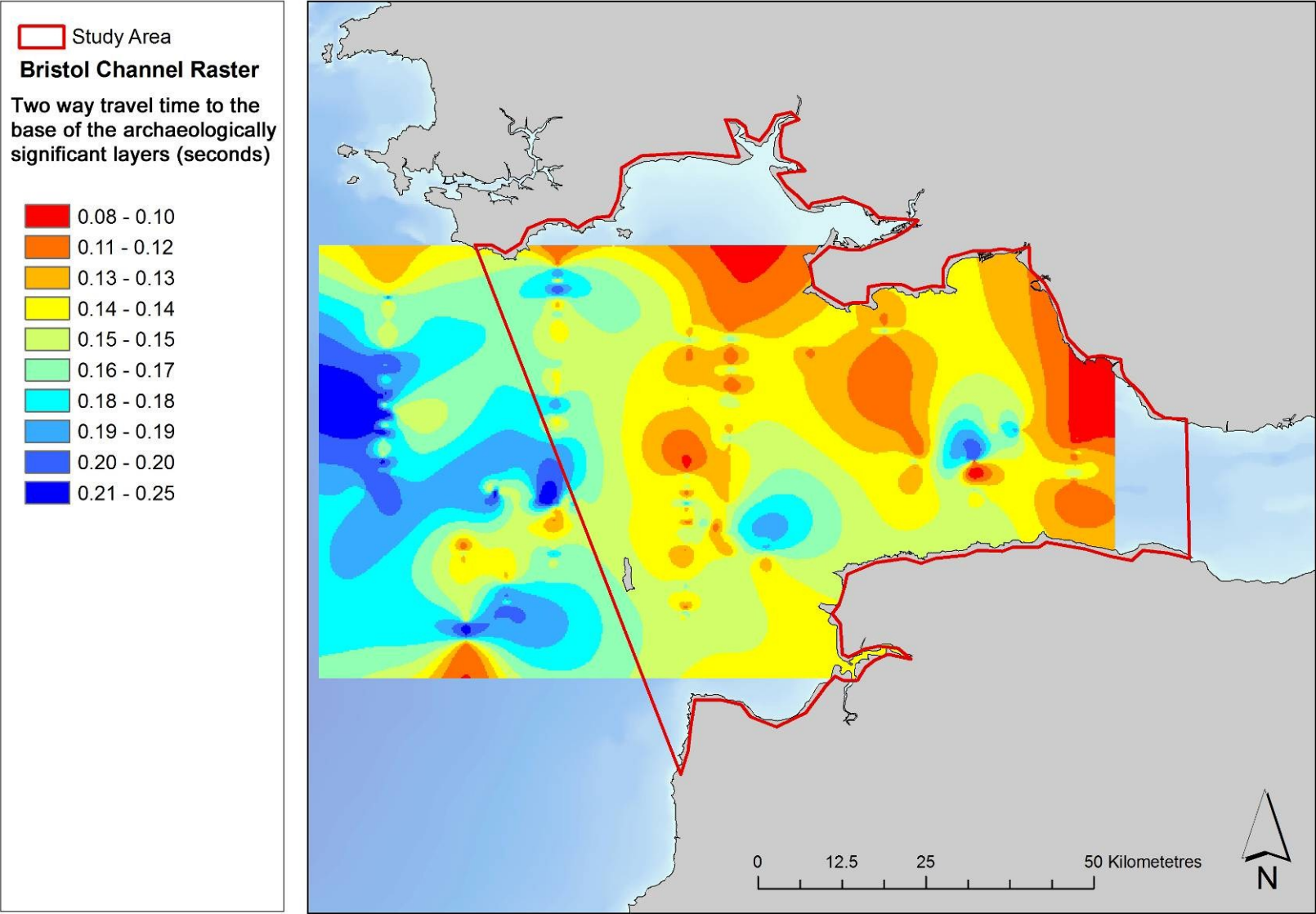


Figure 31: Interpolated raster depicting the time/depth values of the 2D features of archaeological significance

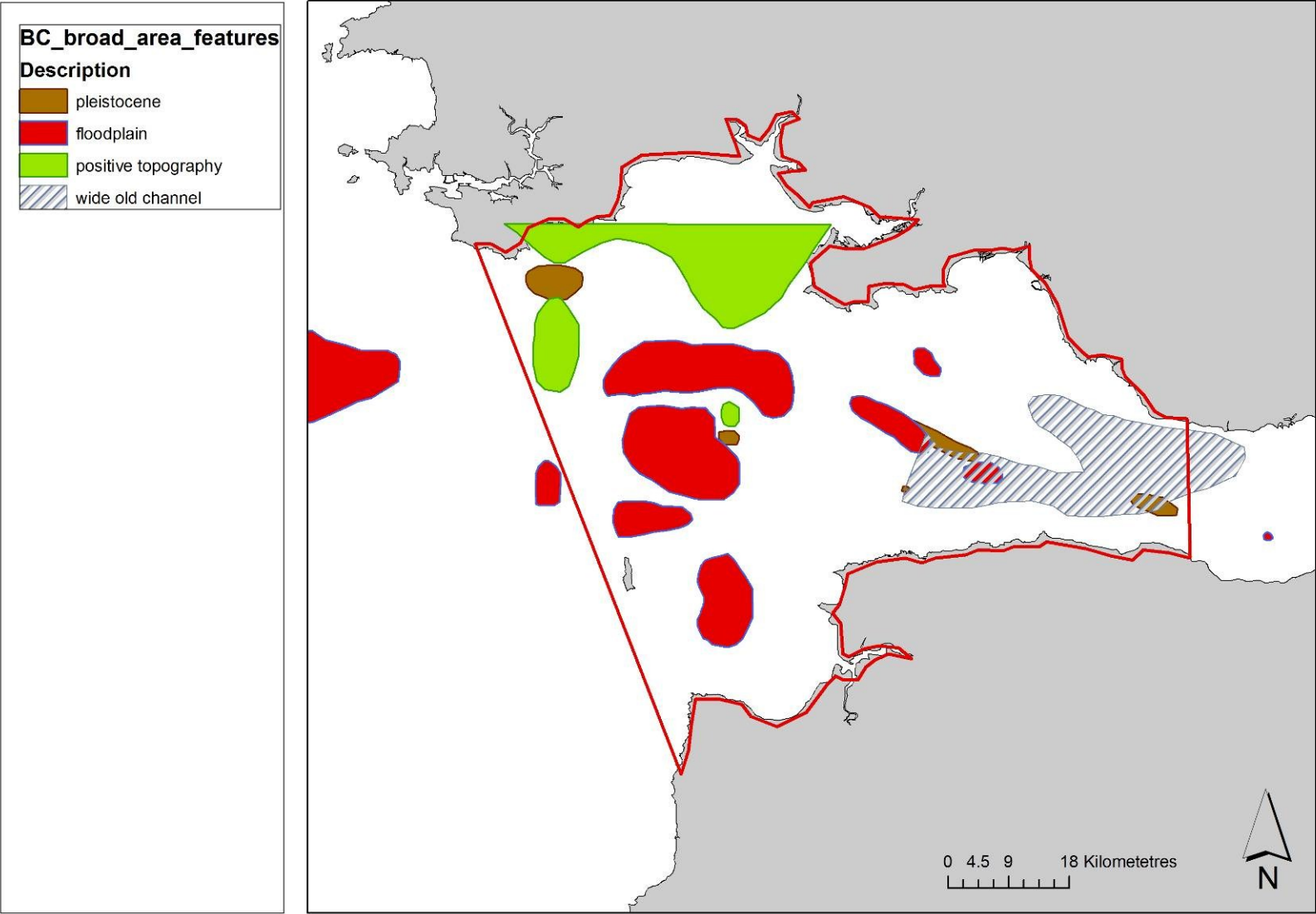


Figure 32: Broad area features identified within the Bristol Channel study area

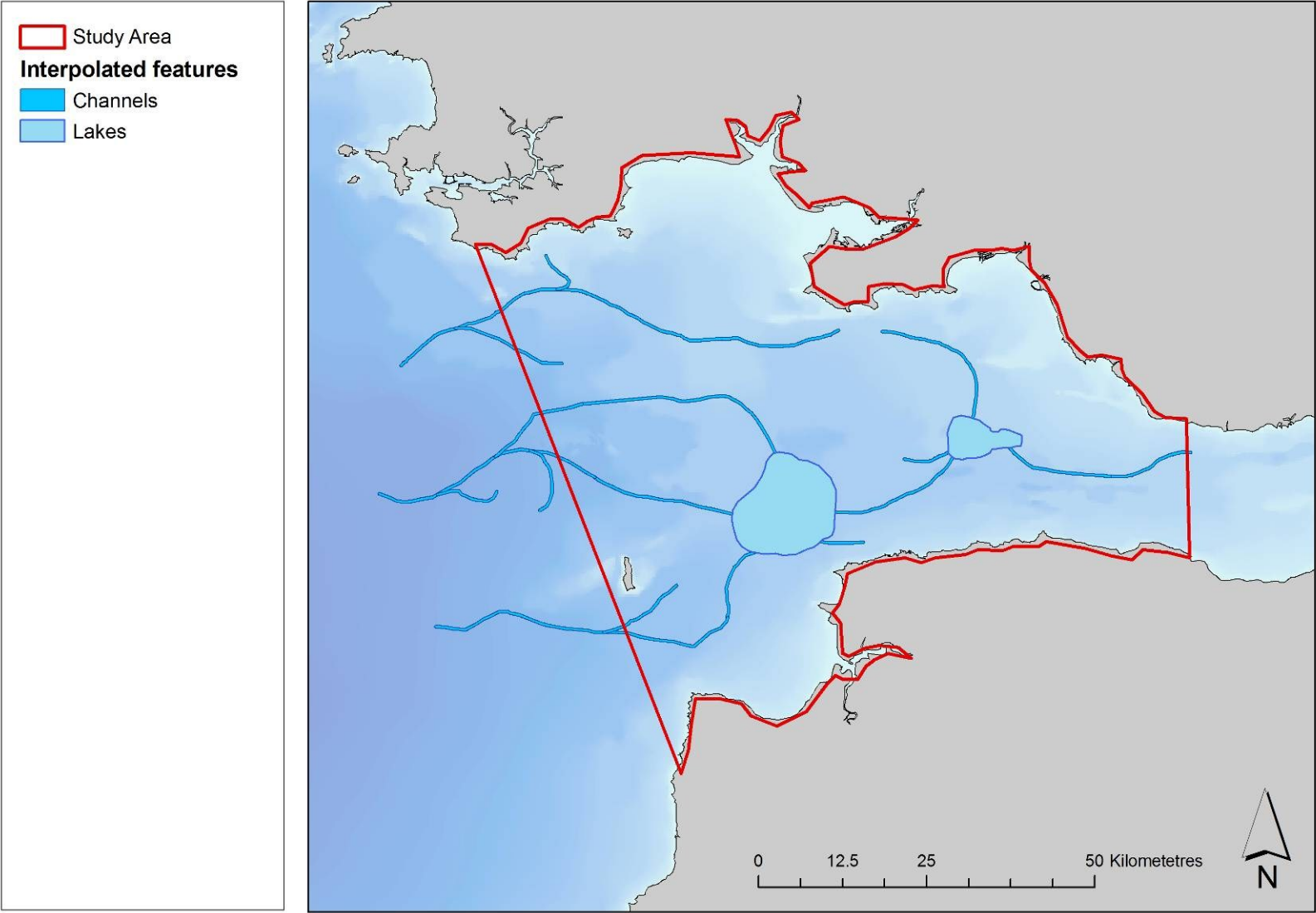


Figure 33: Interpolated features generated within the Bristol Channel study area

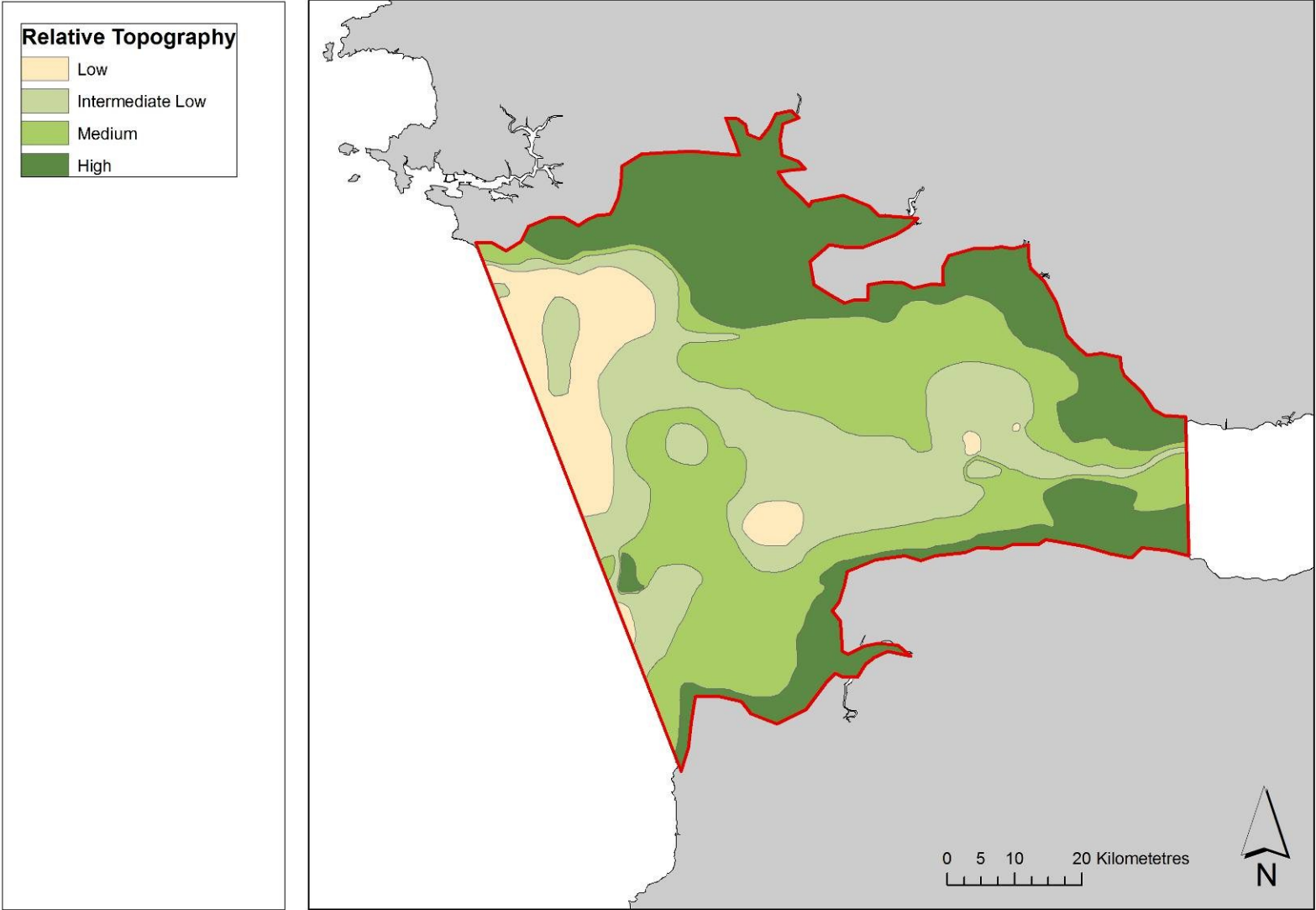


Figure 34: Relative topography within the Bristol Channel study area

Liverpool Bay

7.3.10 Both digital and paper 2D datasets were used within the Liverpool Bay study area. The digital data was processed in the same way as the Bristol Channel datasets. The paper lines were scanned and viewed, and the presence of features and the corresponding shot points were recorded in an excel table. This table was imported into ArcGIS, where the features (points) were converted into lines and polygons in the same way.

7.3.11 Within the 2D paper dataset, several channels were identified, as well as areas of erosion. Indentations, depressions, and features with uncertain interpretational confidence were also recorded.

7.3.12 In total, 328 features were identified within the combined 2D lines (Figure 35, Table 4).

LivBay2D		
source	description	Total Of OBJECTID
2D lines	Deep and wide organic Holocene deposit.	1
2D lines	Glacial tunnel valley and outwash plain.	1
2D lines	Holocene (possibly Pleistocene) wide, low relief	1
2D lines	Holocene channel	14
2D lines	Holocene channel, with transparent homogenous fill	8
2D lines	Holocene infill in low relief trough like feature.	1
2D lines	Large Holocene channel with amorphous homogeneous	5
2D lines	Large Pleistocene glacial channel	1
2D lines	Peat/organic etc	137
2D lines	Pleistocene	13
2D lines	Pleistocene channel with Holocene infill.	1
2D lines	Pleistocene channel with transparent homogeneous i	1
2D lines	Pleistocene channel, some infill.	7
2D lines	River	1
2D lines	Shallow banked, wide double channel with infill	1
2D lines	Thin lateral floodplain or organic layer deposit	116
paper 2D	2 indentations (pin)	1
paper 2D	2 indents	1
paper 2D	Channel	3
paper 2D	channel (pin)	2
paper 2D	channel?	2
paper 2D	erosion surface	1
paper 2D	Large channel	1
paper 2D	shaded area	2
paper 2D	shaded area (pinger) feature?	1
paper 2D	shaded area feature?	1
paper 2D	shaded area indent (pinger)	1
paper 2D	topology on whole line	1
paper 2D	Two depressions (pinger)	1
paper 2D	Two indents with shading	1

Table 4: Features identified in the 2D seismic datasets within the Liverpool Bay study area

7.3.13 As each of the features identified along the 2D lines were only seen once in each dataset, a certainty value of 1 was assigned. The Z values of the 2D features identified from the digital datasets were interpolated into a raster (Figure 36).

7.3.14 3D data was also available within the Liverpool Bay study area,. A total of 181 features (or feature parts) were identified from the analysed 3D datasets. These had a range of certainty values 1 to 24, depending on how many timeslices assessed the feature was visible in (Figure 37). Small features and ephemeral features were only visible in a few slices, therefore they have a low confidence, but this may be a product of their morphology, and therefore there is bias towards larger features, which have a strong signal visible in several slices through the data.

7.3.15 The features themselves were generated from the exported dxf and assessed visually in ArcGIS, and the timeslice chosen which best represented the feature as a whole. Complex feature sets were simplified where appropriate (Figure 13).

7.3.16 The features were then interpreted based on their form and morphology, and a description attribute was added to each feature. The description aimed to inform the date and type of each feature where it was ascertainable (Table 5, Figure 38).

Liverpool Bay 3D features		
source	description	Total Of Features
3D (pilot project)	Geological feature forming regional high	12
3D (pilot project)	Holocene fluvial channels and related features	9
3D (pilot project)	Late Upper Palaeolithic fluvio-glacial floodplain	2
3D survey	Basin structure	2
3D survey	End glacial channel in large floodplain	82
3D survey	End glacial channel in local floodplain	1
3D survey	End glacial floodplain	1
3D survey	End glacial local floodplain	1
3D survey	Glacial tunnel valley	6
3D survey	High ground	2
3D survey	Holocene channel	18
3D survey	Holocene channel with floodplain	1
3D survey	Holocene coastline	1
3D survey	Holocene estuary	4
3D survey	Holocene fluvial floodplain	3
3D survey	Late glacial channel	29
3D survey	Late glacial channel reused in Holocene	9
3D survey	Late glacial feature reused in Holocene	6
3D survey	Possible late glacial channel	1
3D survey	Small Holocene channel	4
3D survey	Small Holocene deltaic system	10
interpolation	channel	1
Interpolation from 2D lines	channel	6
Interpolation from 2D lines	End glacial channel in large floodplain	1
Interpolation from 3D survey	End glacial channel in large floodplain	1
Interpolation from 3D survey	Glacial tunnel valley	1
Interpolation from 3D survey	Holocene estuary	1
Interpolation from 3D survey	Holocene fluvial floodplain	1
Interpolation from 3D survey	Late glacial channel	3
Interpolation from 3D survey	Late glacial channel reused in Holocene	4
Interpolation from 3D survey	Late glacial feature reused in Holocene	1
Interpolation from 3D survey and 2D lines	End glacial channel in large floodplain	1
Interpolation from 3D survey and 2D lines	Glacial tunnel valley	1
Interpolation from 3D survey and 2D lines	Late glacial channel	1

Table 5: Features identified within the 3D seismic datasets

7.3.17 Twenty three features were identified during the pilot study, with 3 different feature types

- Geological feature forming regional high
- Holocene fluvial channels and related features
- Late Upper Palaeolithic fluvio-glacial floodplain

7.3.18 Although these were derived from the 3D dataset, a certainty value of 1 was given to all, as the number of times a feature was identified was not recorded. The methodology was not necessarily exactly the same within the pilot as the main project (Figure 39).

7.3.19 An additional 23 features were digitised using the 2D and 3D data, as well as the underlying bathymetric data to interpolate between the known datasets (Figure 39). This allowed the filling in of areas where features were likely to join, and to expand the 3D feature dataset beyond the areas covered by the 3D surveys using the 2D features identified. Each of these features was given a certainty value of 0.

7.3.20 Additional period fields were then added, Holocene and EndGLACIAL, in order to be able to filter the features for each of these time periods.

7.3.21 Within the Liverpool Bay study area, 10 zones that might represent organic layers and/ or evidence for floodplains were digitised following interpolation from the 2D lines. They were given a certainty value of 0. Unlike within the Bristol Channel study area, no other types of broad area were digitised, despite the greater density of data. Again, this dataset was utilised as a preliminary 'first pass' (Figure 40).

7.3.22 Using the raster interpolation along with the bathymetry dataset, the whole area was divided into 16 areas with 6 relative topography categories (Figure 41) –

- Very Low
- Low
- Intermediate Low
- Intermediate
- High Intermediate
- High

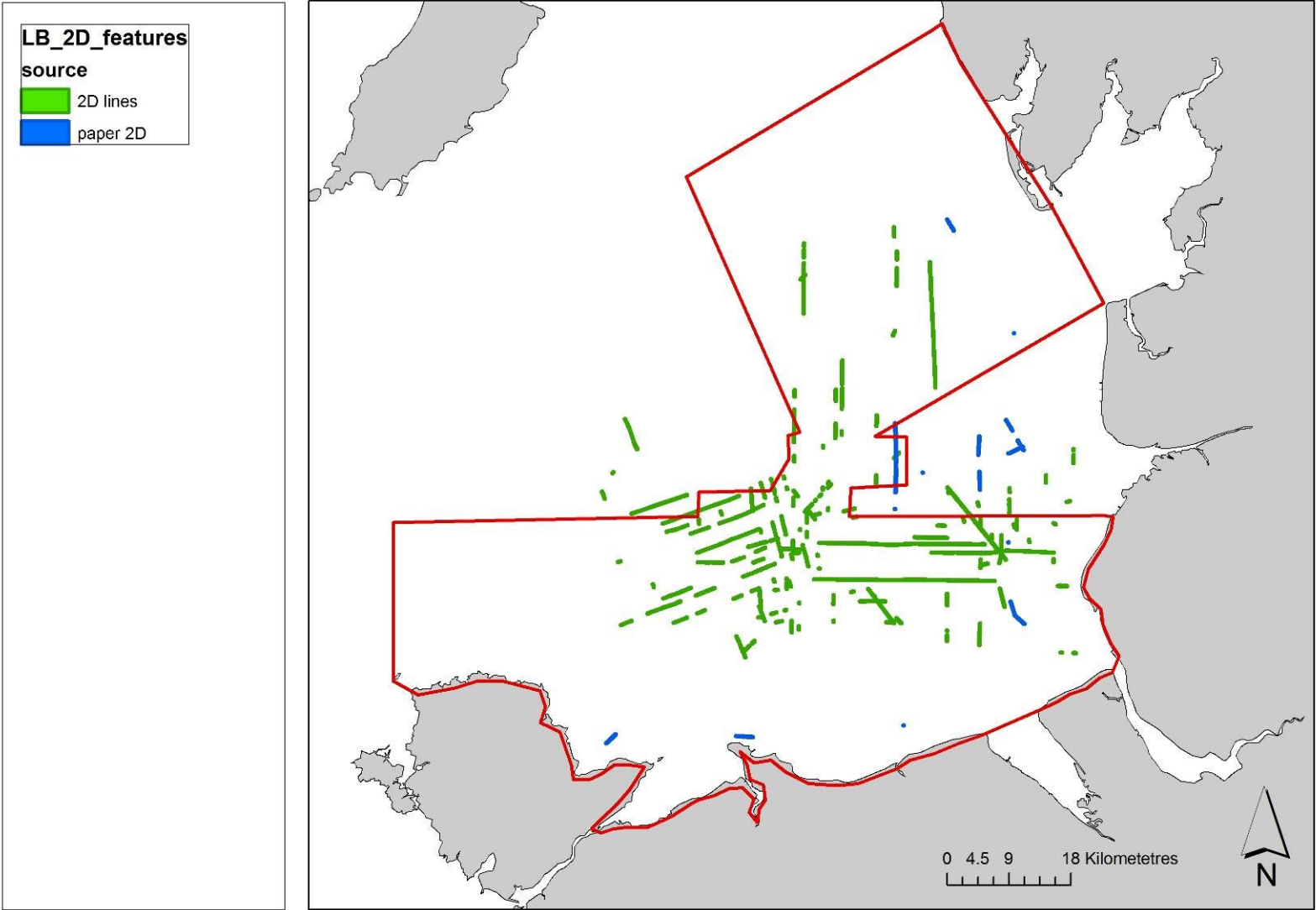


Figure 35: 2D features identified within the Liverpool Bay study area

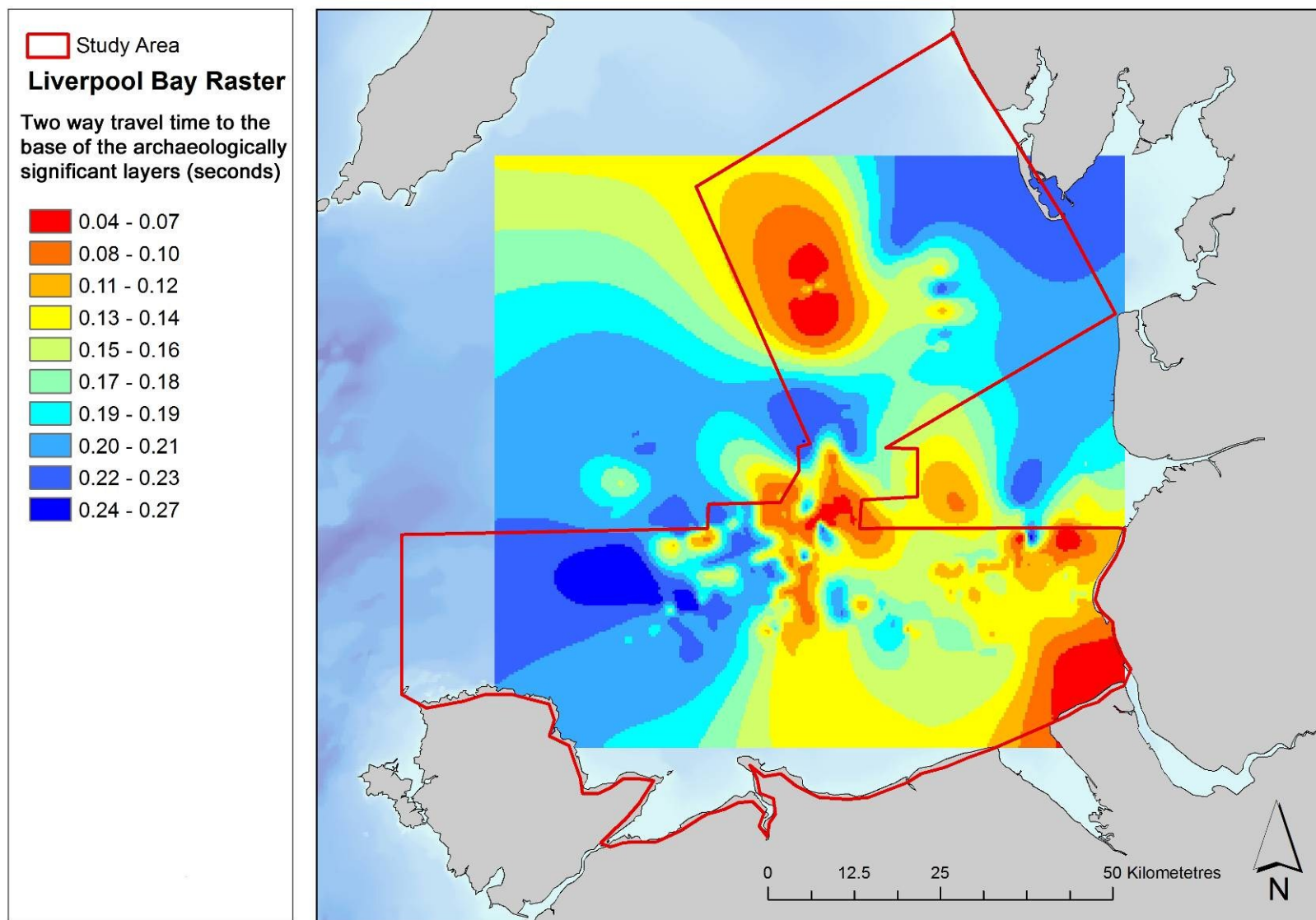


Figure 36: Raster interpolation derived from the Z values of the 2D features identified within the Liverpool Bay study area

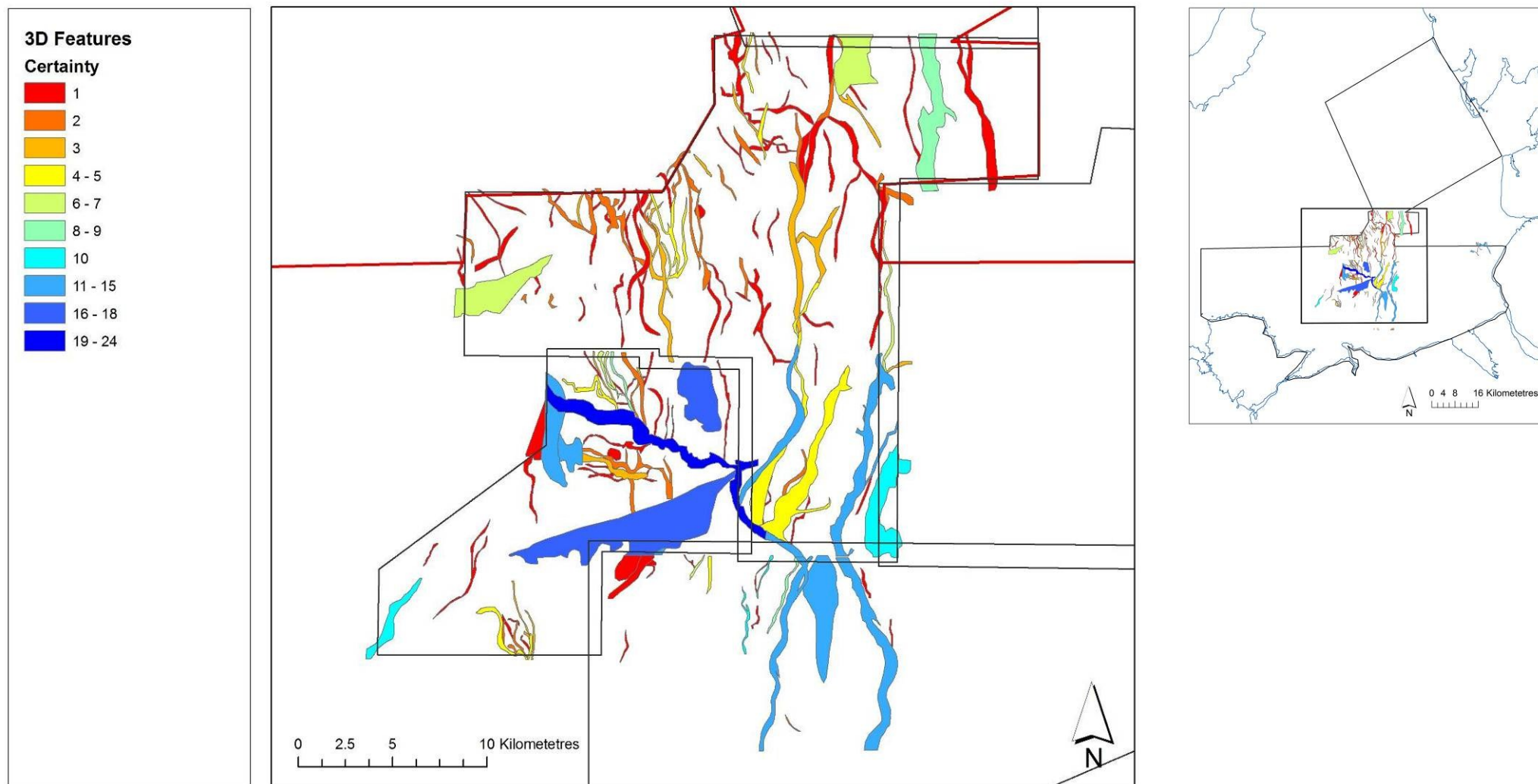


Figure 37: Features identified from the 3D dataset in the Liverpool Bay study area showing number of timeslices each feature was identified in (relating to certainty of feature presence)

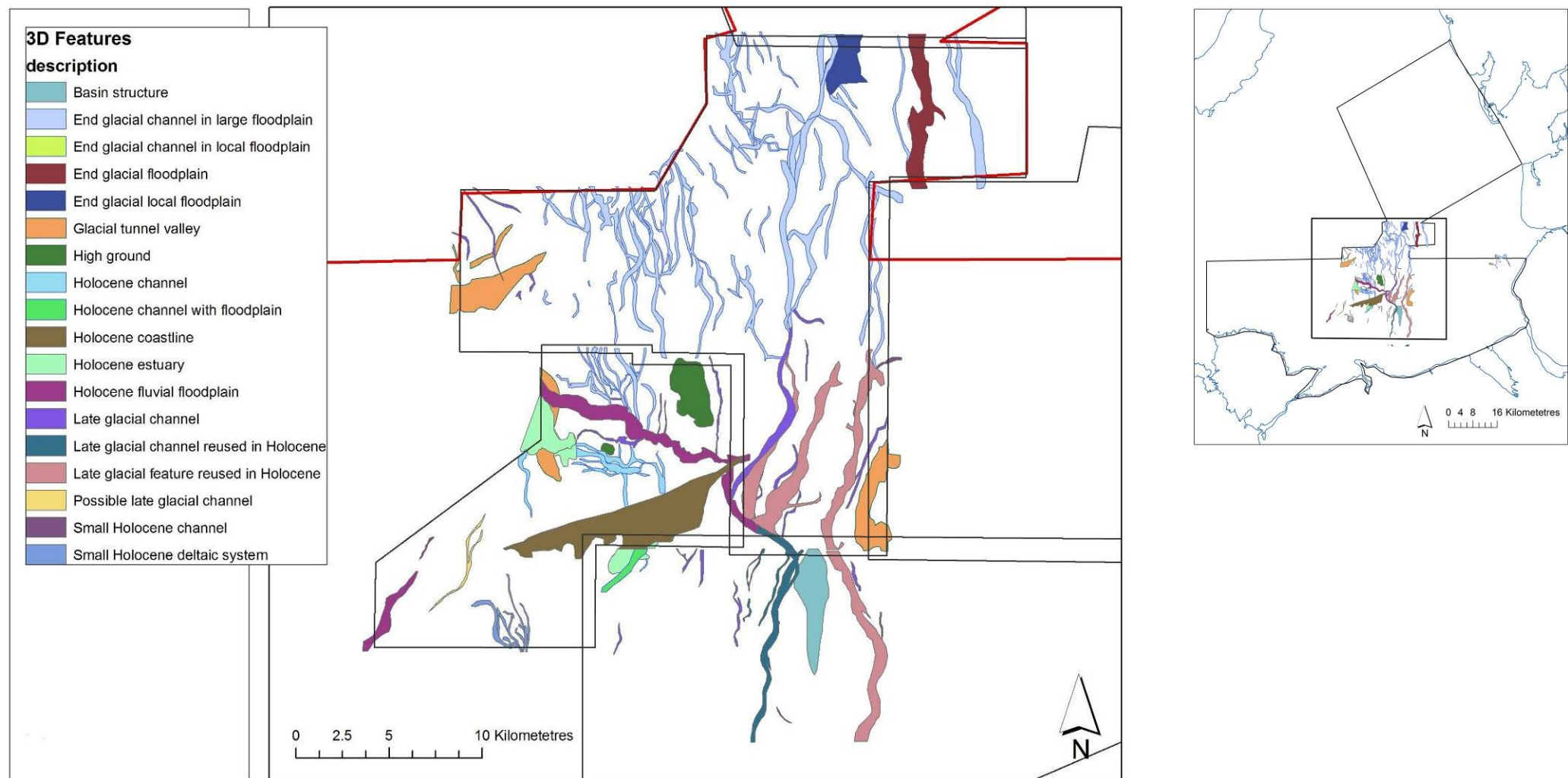


Figure 38: Interpretation of features identified within the 3D dataset

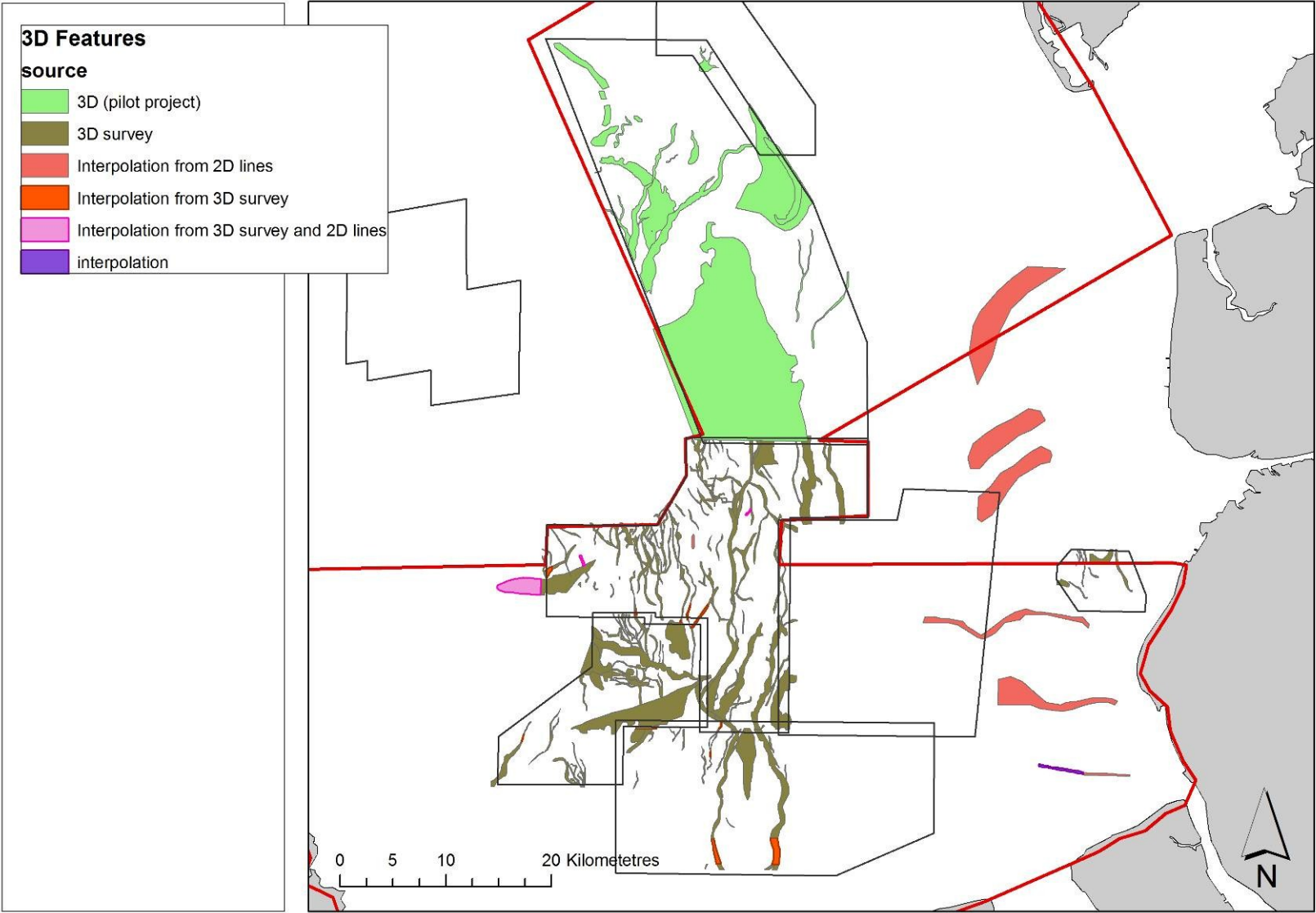


Figure 39: Additional 3D features identified within the Liverpool Bay study area

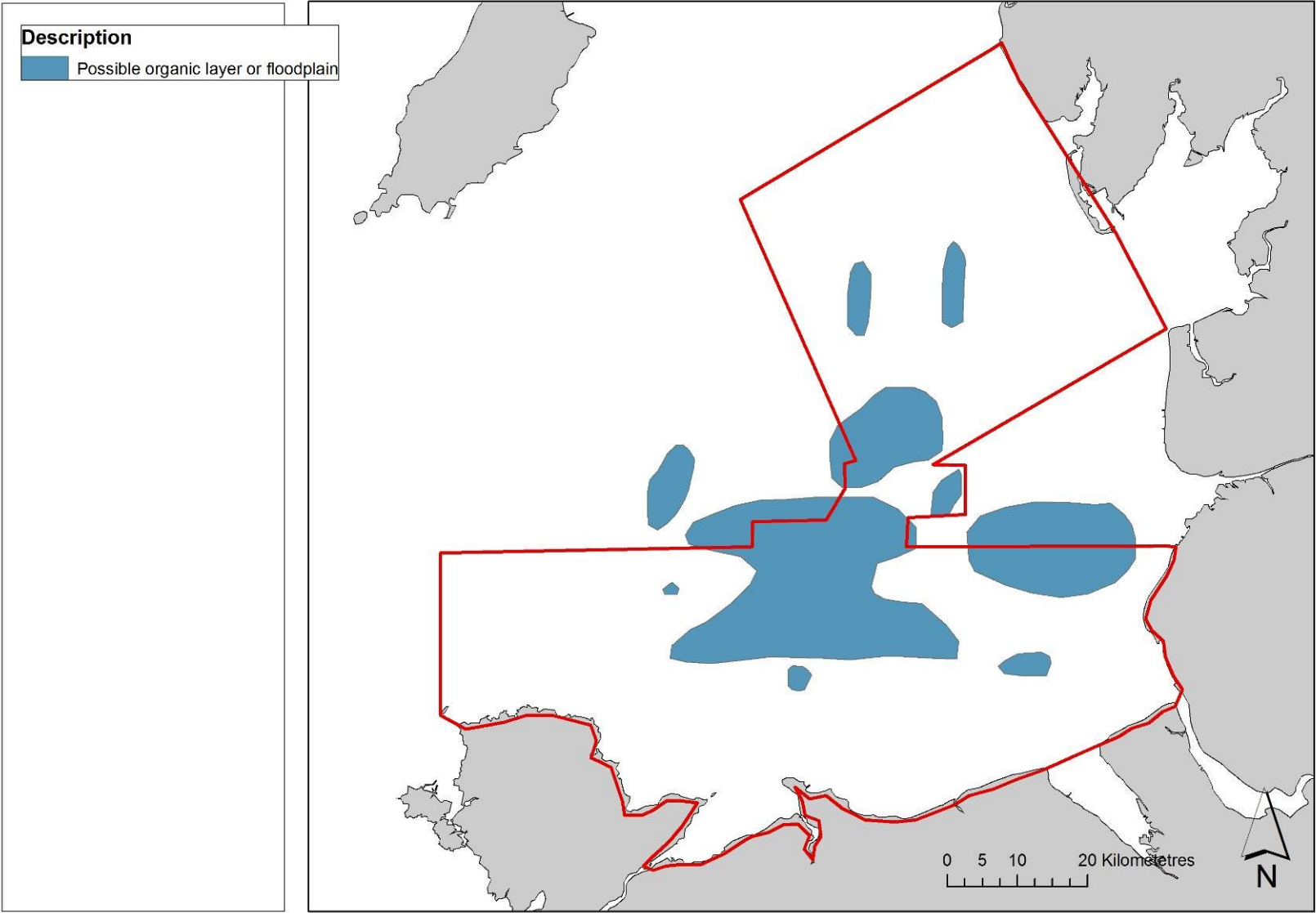


Figure 40: Broad area features identified within the Liverpool Bay study area

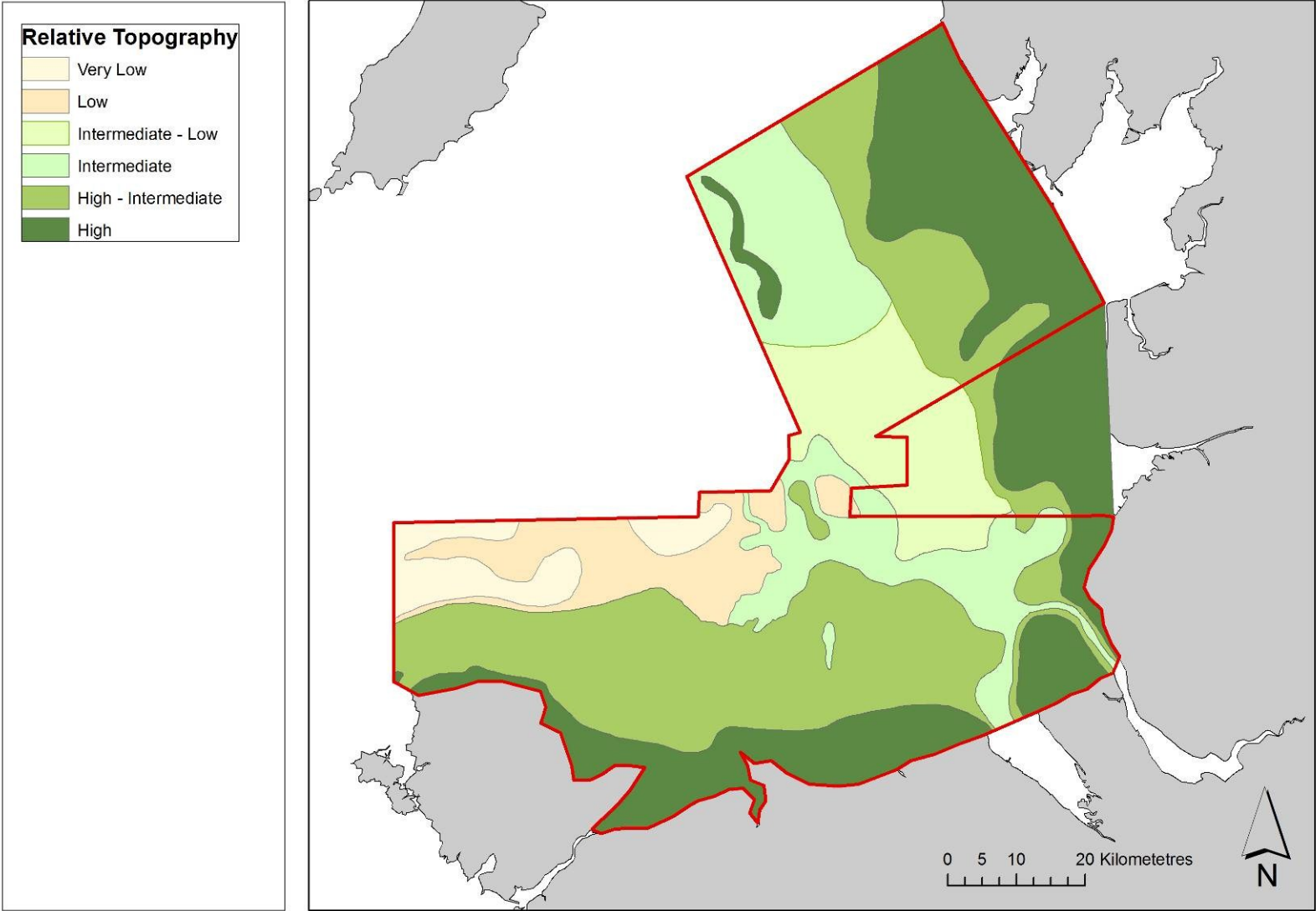


Figure 41: Relative topography within the Liverpool Bay study area

7.4 Prehistoric Landscape Characterisation

7.4.1 All the data was used to create prehistoric Landscape Characterisation Zones. These zones represent the general character of the area based on relative topography and associated features, the nature of settlement or archaeology activity that the zone is likely to support, and date. The zones do not make any judgements on the potential presence of any archaeology, or importance. The divisions between the zones are unambiguous, and requires an individual assessment of confidence at the edge of each zone.

7.4.2 Where no features were identified or postulated within the study area the character zones used the underlying bathymetry as a proxy. Whilst the bathymetry represents the current seabed in this area, it can also in areas of non-deposition, as a minima for the prehistoric landscape, and thus allows a consideration of these areas within the landscape characterisation as a whole.

7.4.3 These zones represent therefore the general character of each area and the archaeological activity conducted within them. This characterisation was not used to make a determination of the potential presence or importance of any archaeological material located within these areas. However, the presence of landscape features which would have had an effect on prehistoric activity and settlement (eg coastlines, rivers) are observed within the characterisation.

7.4.4 Sea-level data derived from the sea-level curve provided for the Bristol Channel by Shennan and Horton (2002) was applied to the landscape data to provide a sense of temporality within the characterisation. The areas which were determined to be solely Holocene or Mesolithic in date were derived from features which were not submerged prior to 10,000 BP. Features which were emergent before this date were considered to be present within the latest Palaeolithic landscape. The divisions between the zones are not unequivocal, and individual assessment of the confidence at the edge of each zone must be considered.

7.4.5 Within the Bristol Channel study area, 14 landscape characterisation zones were digitised, representing a total of 6 different character types (Figure 42). The total areas are shown in Table 6.

Bristol Channel Landscape Characterisation	
DESCRIPTION	Total Of AREA km2
Area of earlier channels	459.30
Area of floodplain deposits and Pleistocene channel	469.33
Early Holocene floodplains	857.74
Latest Palaeolithic to Earliest Mesolithic plains	520.34
Relative upland areas	2255.25
Holocene wetlands	662.86

Table 6: Landscape characterisation of the Bristol Channel study area

7.4.6 A similar process to that performed in the Bristol Channel was undertaken for the Liverpool Bay area. However, the presence of 3D seismic data allowed for a greater consideration of potential sediments which were likely to have an archaeo-environmental importance. As such, one character zone was created to reflect the potential presence of organic sediments.

7.4.7 Again, sea-level data derived from the sea-level curve provided for the Liverpool Bay area by Shennan and Horton (2002) was applied to the landscape data to provide a sense of temporality within the characterisation. This highlighted the rapid flooding of the central area, and as a consequence the area determined to solely have relevance to the late Palaeolithic landscape is greater. Additionally, as this area has much greater presence of late glacial features due to its proximity to the icesheets as compared to the Bristol Channel, the landscape areas therefore reflect this.

7.4.8 Within the Liverpool Bay study area, 14 landscape characterisation zones were digitised, representing a total of 11 different character types (Figure 43). The total areas of each landscape type are shown in Table 7.

Liverpool Bay Landscape Characterisation	
DESCRIPTION	Total Of AREA km2
Area dominated by tunnel valley	116.23
Area of deeper waters, low probability of early Holocene terrestrial deposits	590.23
Area of erosion with sparse large channels	1816.39
Area of probable organic sediments	346.43
Early Holocene channels	98.00
Early Holocene coastlines and estuaries	99.90
End glacial valleys, reused in early Holocene	198.32
End glacial, fluvio-glacial plain	856.31
Higher ground area, limited evidence	982.73
Holocene fluvial plain, with higher ground areas	422.18
Shallow water area, some small channels	756.13

Table 7: Landscape characterisation of the Liverpool Bay study area

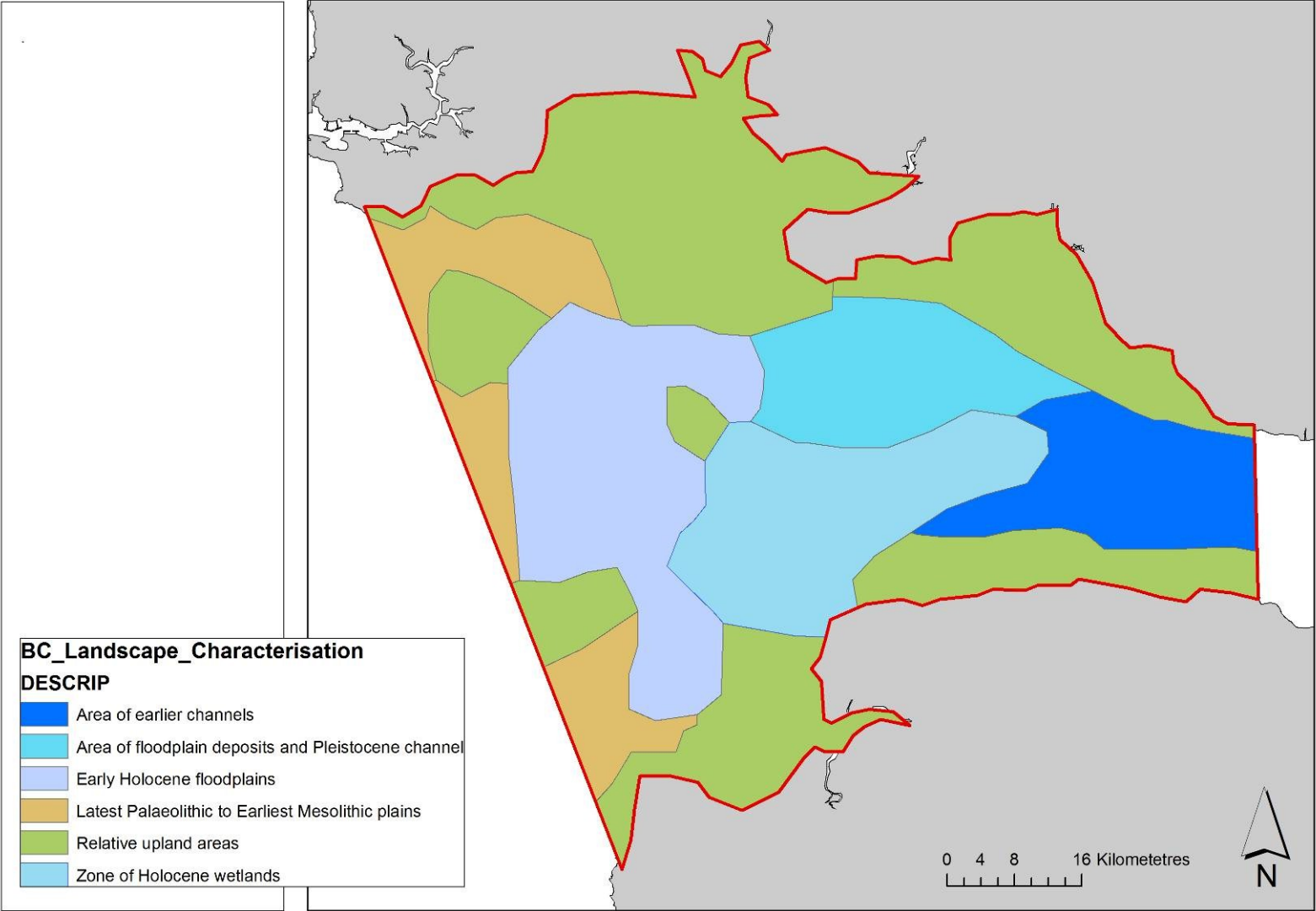


Figure 42: Prehistoric landscape characterisation of the Bristol Channel study area

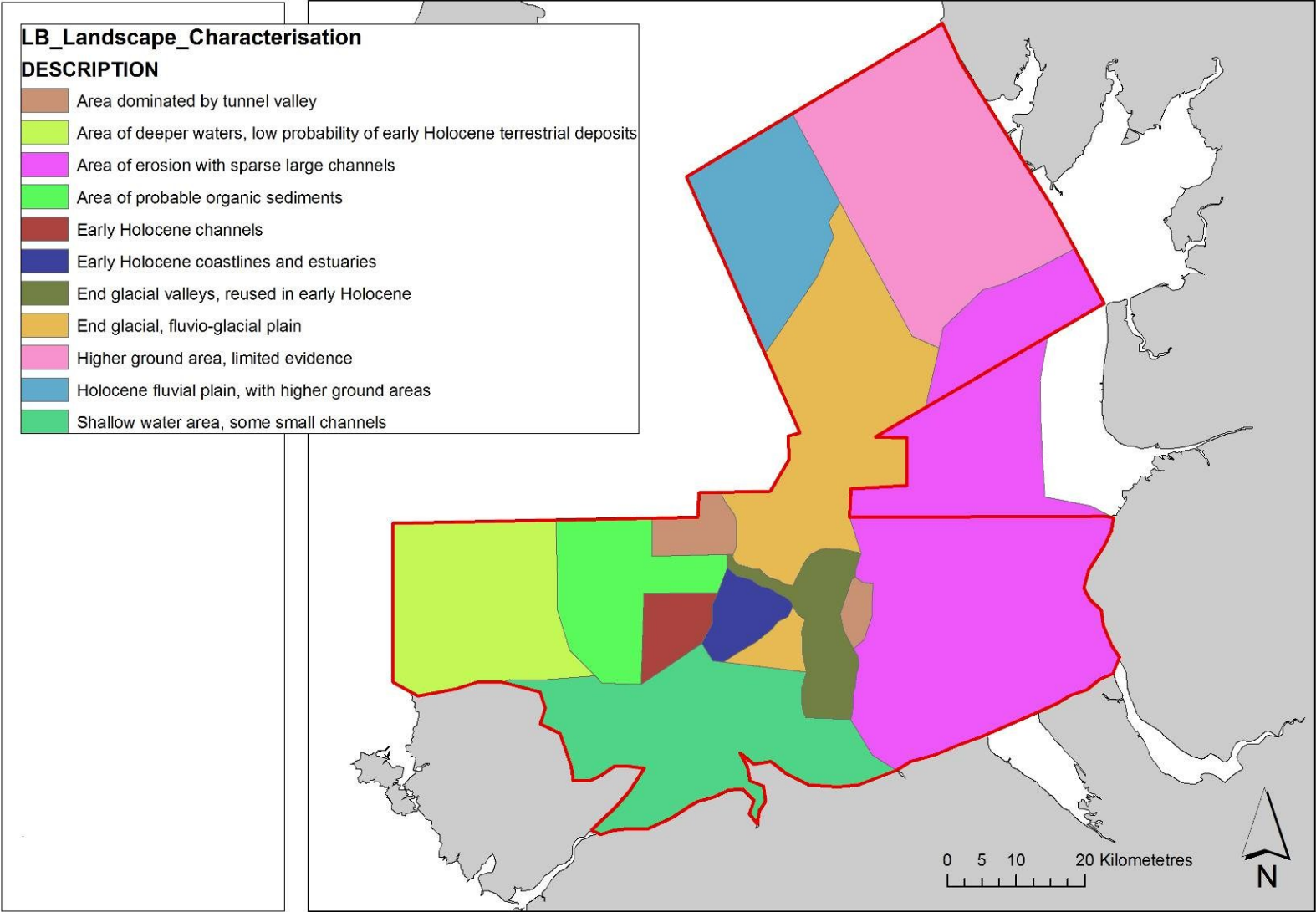


Figure 43: Landscape characterisation of the Liverpool Bay study area

7.5 Potential Mapping

7.5.1 The collected data from the project was used in combination to create a series of raster maps to fulfil Aim 3, and provide a map of survival potential for archaeological deposits within the study areas. This was to aid heritage management of the two study areas by identifying areas of known archaeology and assessing the potential survival of other features and deposits of archaeological significance. In generating this data, it should be stressed that the output maps do not identify actual presence or absence of archaeological deposits across the study area - except in those circumstances where such deposits have been identified directly within the original data. These images highlight conditions in which preservation or destruction of deposits may occur. Separate investigations would be required to ascertain the actual conditions at any specific point of interest. Consequently, the data is generalised and all raster maps were generated at a cell size of 200m.

7.5.2 The input datasets included in the processes include –

- Features identified and digitised from the 3d surveys and 2d lines
- Water depth generated from the 250k bathymetric survey
- Areas of potential erosion and/or preservation identified

7.5.3 For each study area, the rasters generated were clipped to the extents of the study areas and reclassified 0 to 255.

7.5.4 For each of the study areas, the buffer polygons created for the 2D features along the survey lines was added to the 3D feature polygons. In the Bristol Channel study area the 3D features comprised the interpolated rivers and lakes; in the Liverpool Bay study area only the 3D features derived directly from the 3D seismic surveys were used, to enhance the accuracy of this layer. A distance raster from these polygons was then calculated, (Figures 44 and 45). This gradient is useful in indicating the uncertainty of the absence of features. The indeterminate nature of response (whether due to absence of data or actual lack of response to exploratory technologies) suggests that the further one goes from a known feature the greater is the uncertainty of encountering undetected or undiscovered deposits/. The images do not indicate that there is certainty that such features exist. .

7.5.5 The second dataset used to generate maps was the bathymetric water depth. In this case, it was concluded that the deeper the water and presumably accessibility, the lower the risk to any archaeological features present. This, clearly, has no implications for those areas that retain known deposits. The complexity of taphonomic circumstance is such that it is not possible to predict any outcome with certainty. However, the presumption that less accessible deposits are, under the best of circumstances, be more likely to be protected or preserved seems a reasonable conclusion. This raster was generated from the 250k bathymetric BGS contour data and was clipped to the study area and reclassified 0 to 255, with the high value being the deepest water (Figures 46 and 47).

7.5.6 Areas of potential erosion/preservation were digitised as polygons incorporating BGS geology maps and data on rock outcrops, areas of Holocene absence, areas of sandwaves and megaripples, and tidal stresses on the sea floor.

West Coast Palaeolandscapes Survey 2011

Tidal Stress	-	High	-	Survival potential low	0 (or 85)
Tidal Stress	-	Low	-	Survival potential high	255 (or 170)
Sandwave field		Present		Survival potential high	255
Sandwave field		Absent		Survival potential low	0
Rock outcrops		Present		Survival potential low	0
Rock outcrops		Absent		Survival potential high	255
Quaternary sediment	Present			Survival potential high	255
Quaternary sediment	Absent			Survival potential low	0

7.5.7 Tidal stresses were provisionally zoned within each study area in order to identify areas where tidal stresses were greater and lesser. The zones were ordered, and then reclassified 0-255 (255 representing lower stress and risk to potential archaeological deposits, therefore a higher survival potential). Seven provisional zones were identified in the Bristol Channel area, however, there was less variation in the Liverpool Bay study area, and so for this area, the stress could only be determined to be present or absent. Initially this was reclassified into 0 and 255; however it was decided that this was inappropriate and the zones were altered to represent 85 and 170, rather than the limits of the raster (Figures 48 and 49).

7.5.8 Areas of rock outcrops and areas where Holocene sediment was absent were identified as areas where there was a low potential for features and deposits of archaeological significance to survive due to erosion. Areas where megaripples or sandwaves were present were determined to have a higher potential for survival of features and deposits of archaeological significance, due to the preservation of archaeological deposits beneath the sand. These areas were digitised individually (Figures 50 and 51), and then overall rasters were then produced by combining these datasets together (Figures 52 and 53).

7.5.9 The location of features, the water depth, and additional factors determining potential presence/ absence such as erosion were then added together to provide an overall map depicting the survival potential for features and deposits of archaeological significance, with areas of high potential for archaeological presence and survival (255) and areas of low potential for archaeological presence and survival (0) (Figures 54 and 55).

7.5.10 Again, it should be stressed that the output maps do not identify actual presence or absence of archaeological deposits. Site taphonomy is a highly complex and situational process and the data presented here is, of necessity, variable in quality and coarse in resolution. Having said that the results can be used as a form of red flag mapping and raise awareness of general uncertainty of knowledge rather than, perhaps, specific certainty of risk.

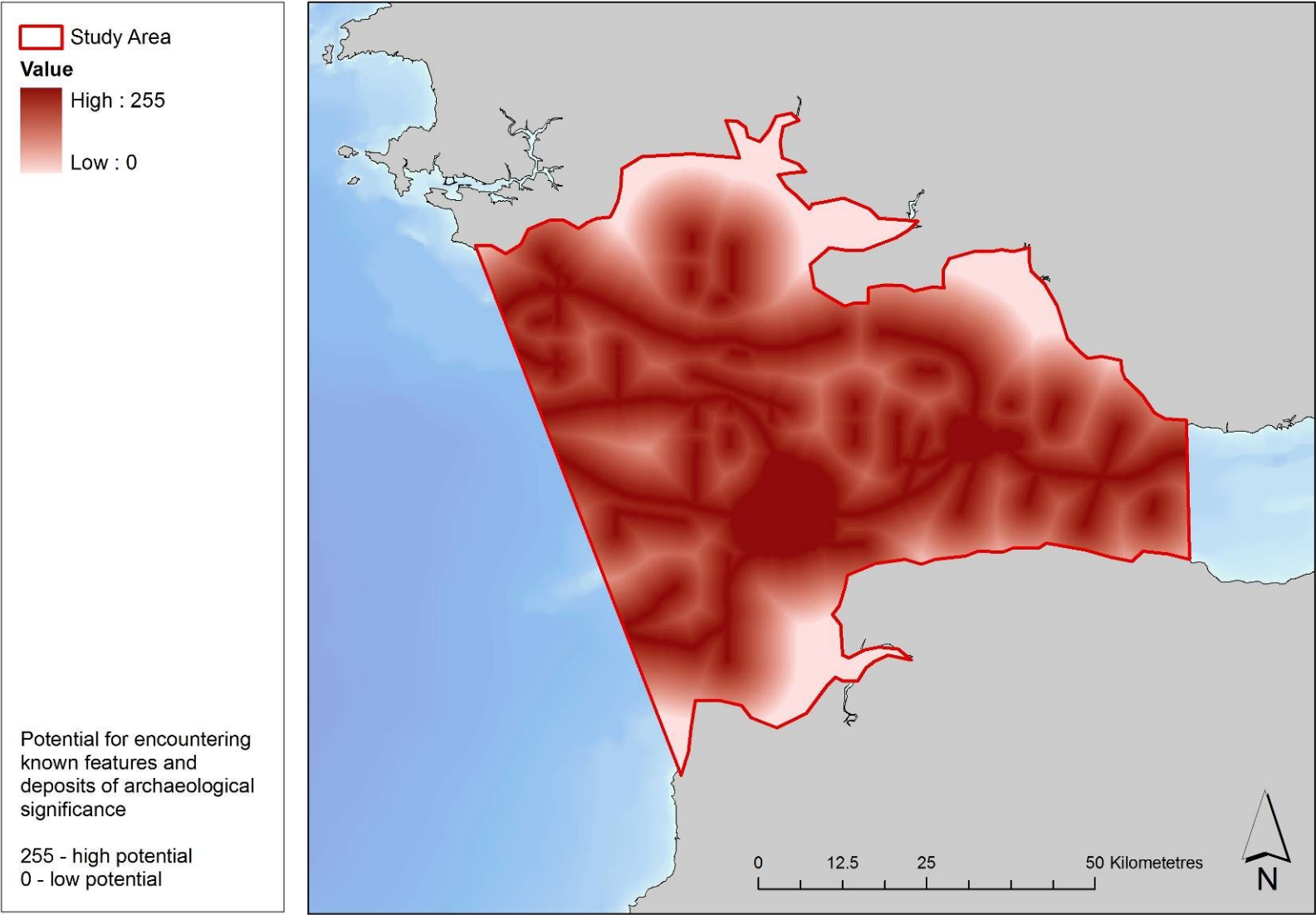


Figure 44: Potential for encountering known features and deposits of archaeological significance determined by distance in the Bristol Channel study area

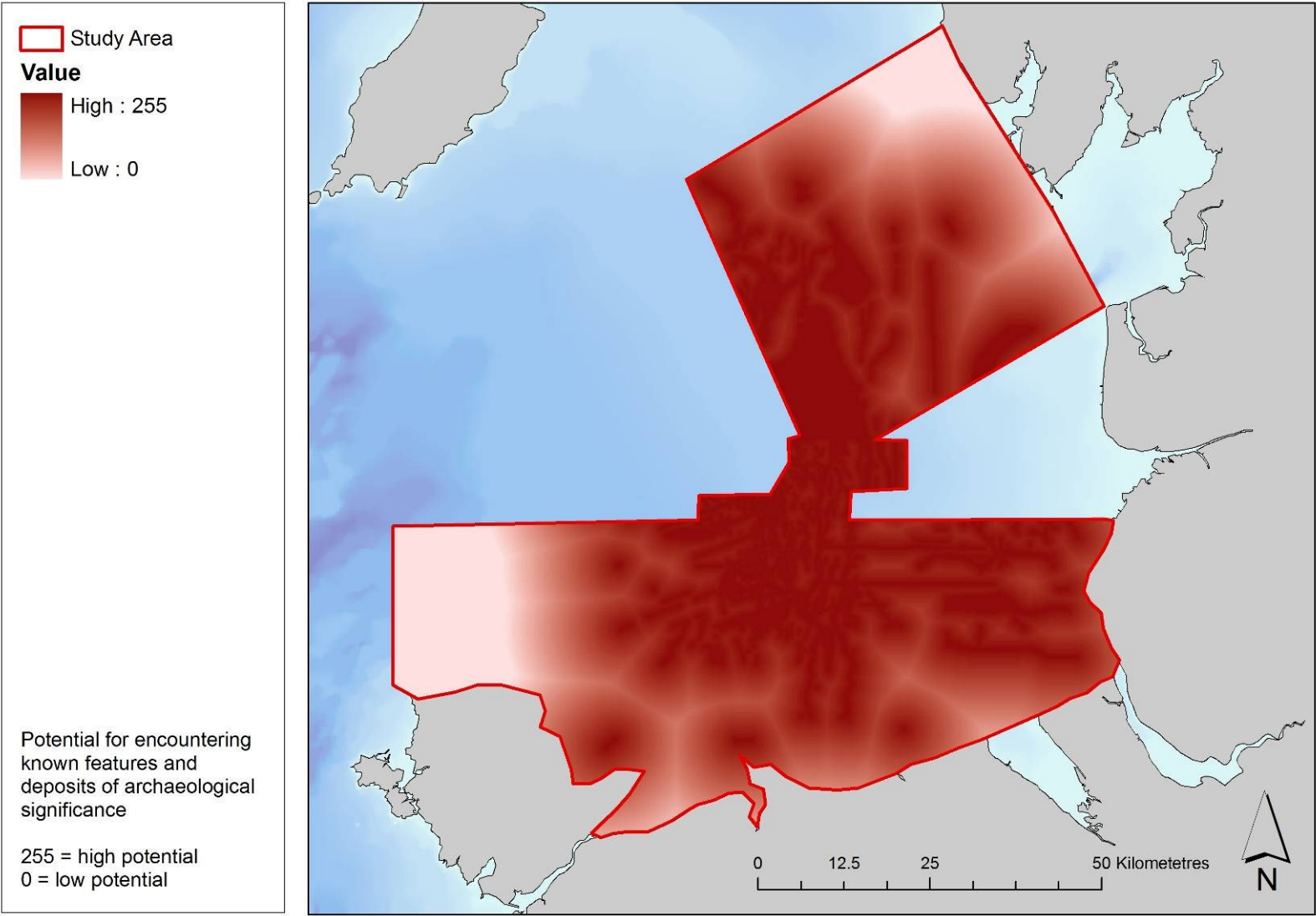


Figure 45: Potential for encountering known features and deposits of archaeological significance determined by distance in the Liverpool Bay study area

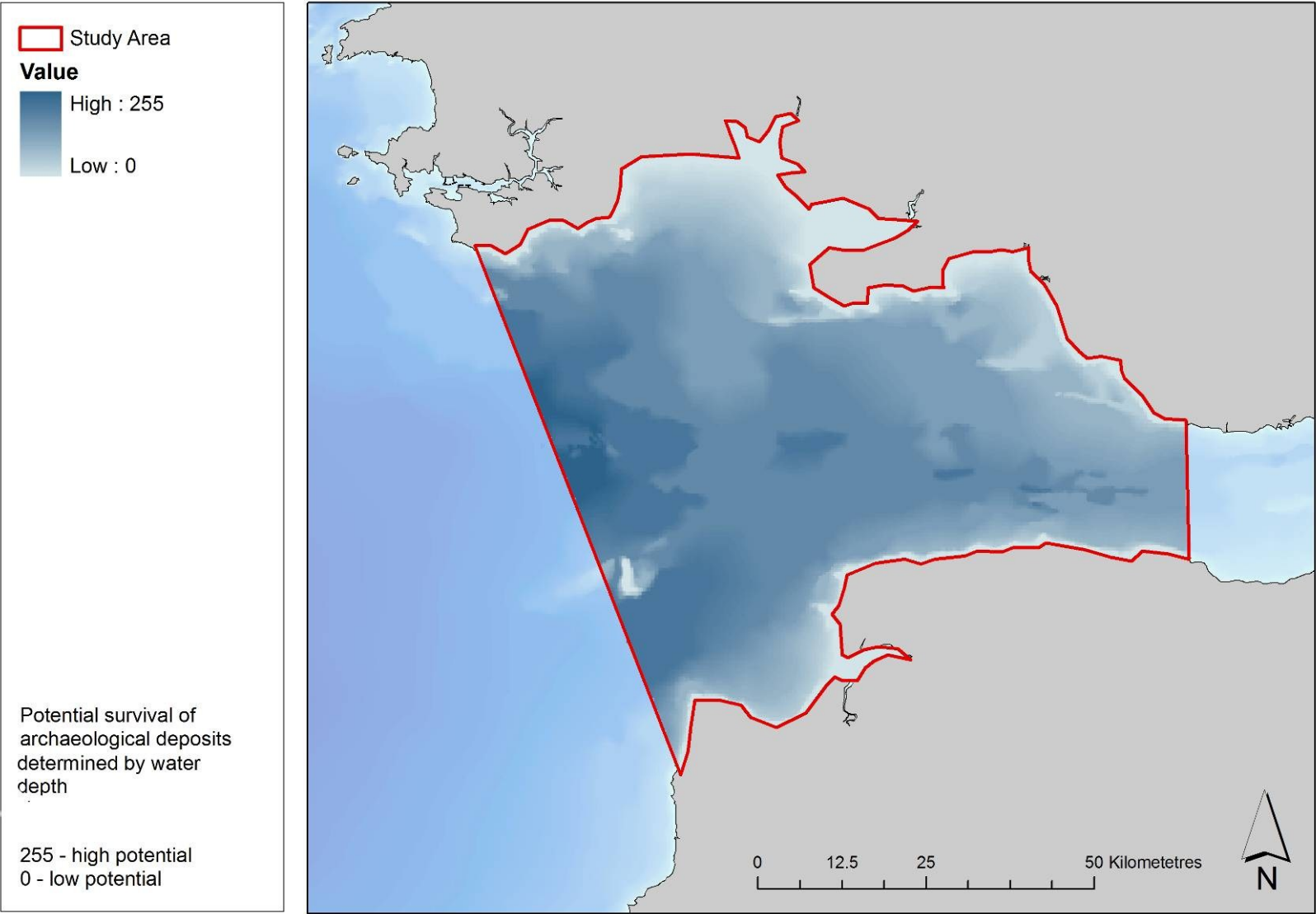


Figure 46: Potential survival of features and deposits of archaeological significance determined by water depth in the Bristol Channel study area

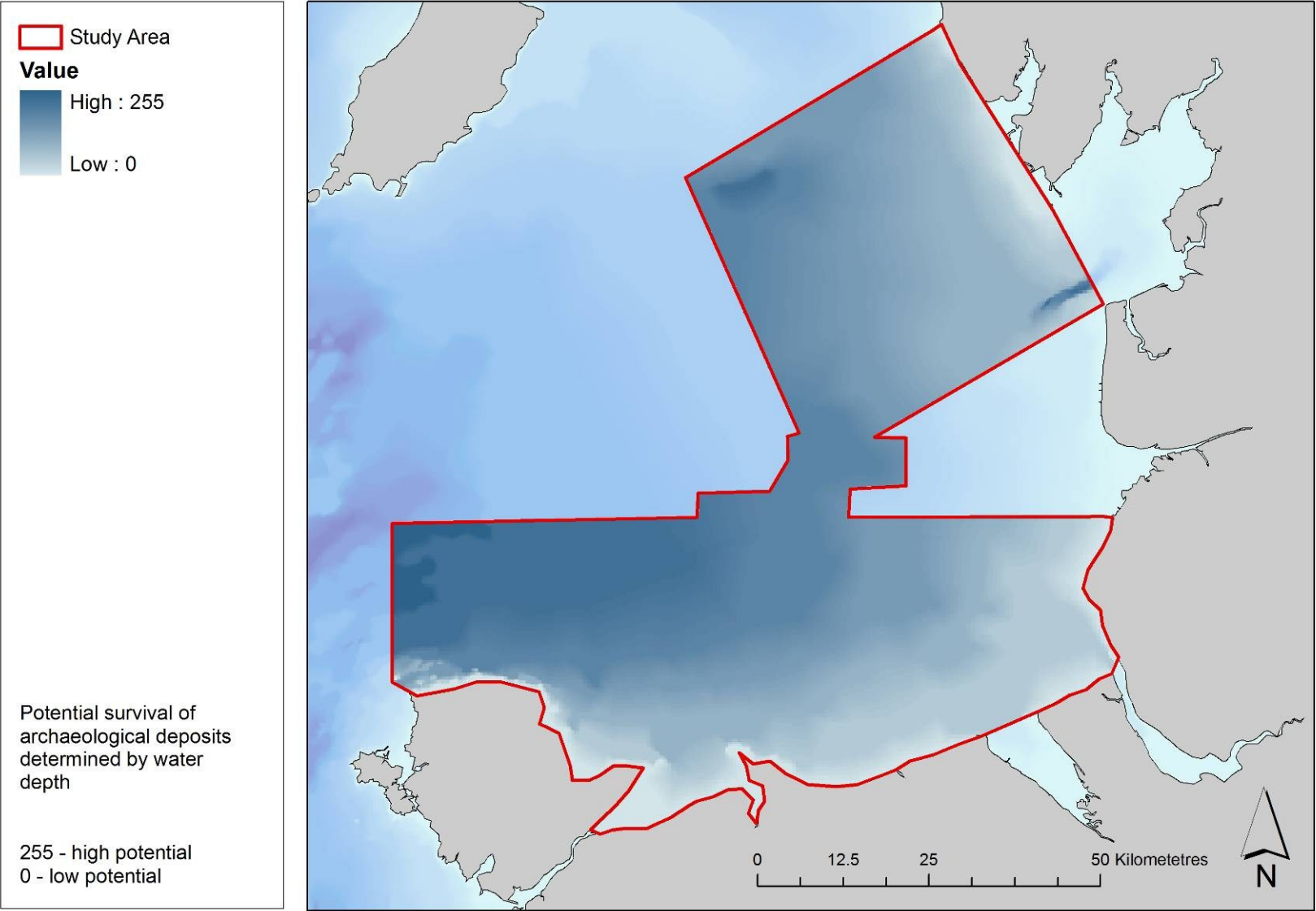


Figure 47: Potential survival of features and deposits of archaeological significance determined by water depth in the Liverpool Bay study area

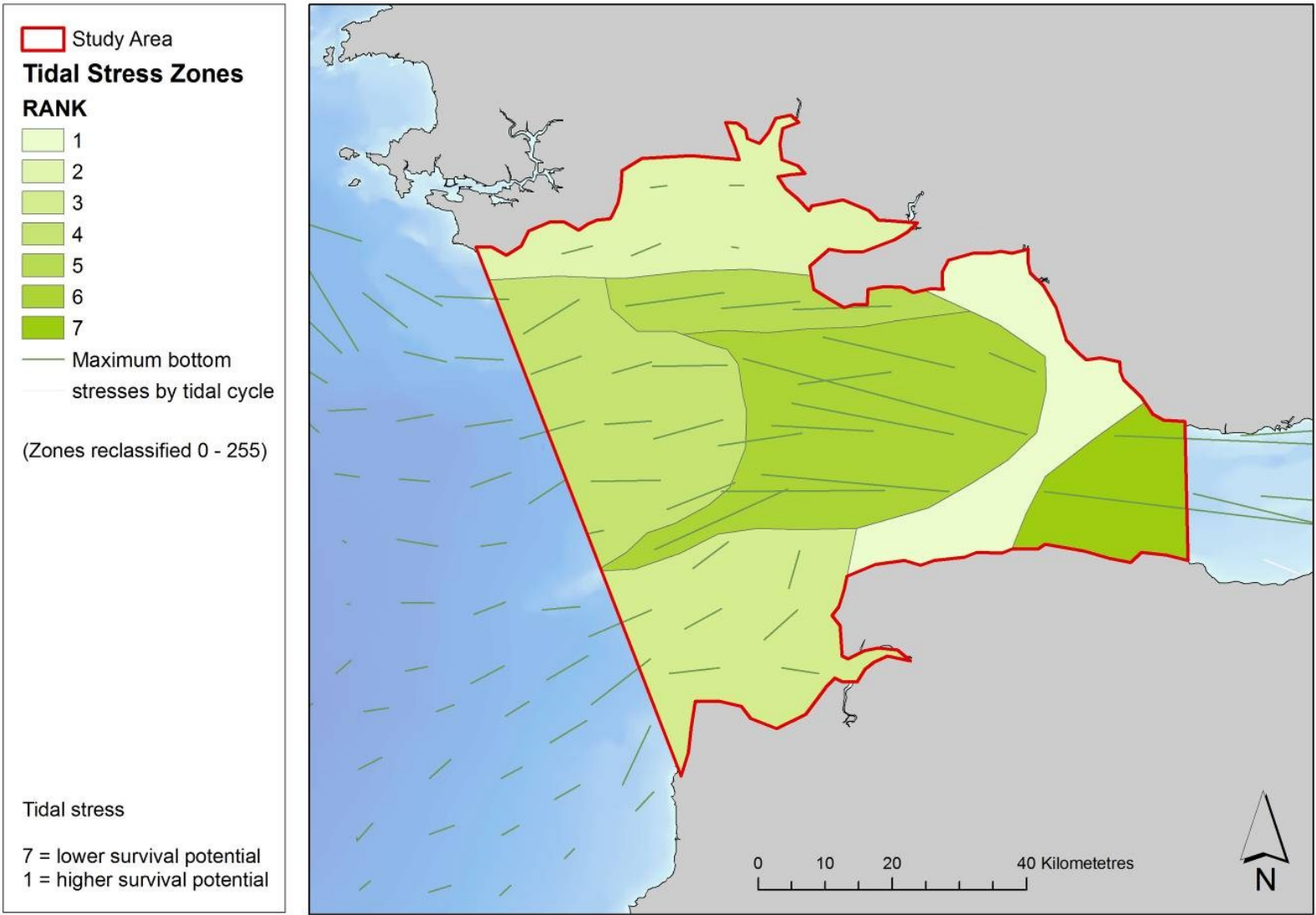


Figure 48: Tidal stress zones within the Bristol Channel study area

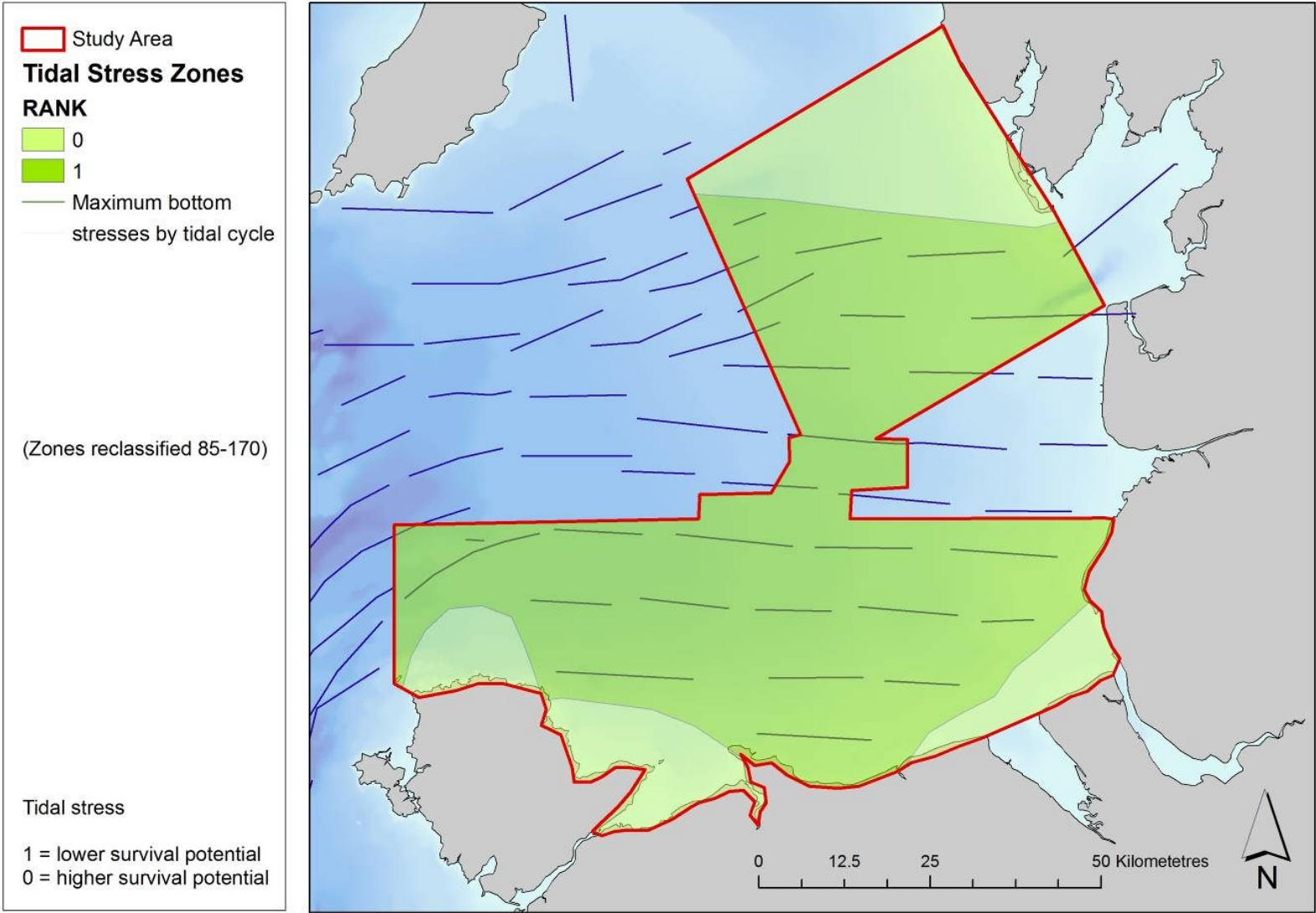


Figure 49: Tidal stress zones within the Liverpool Bay study area

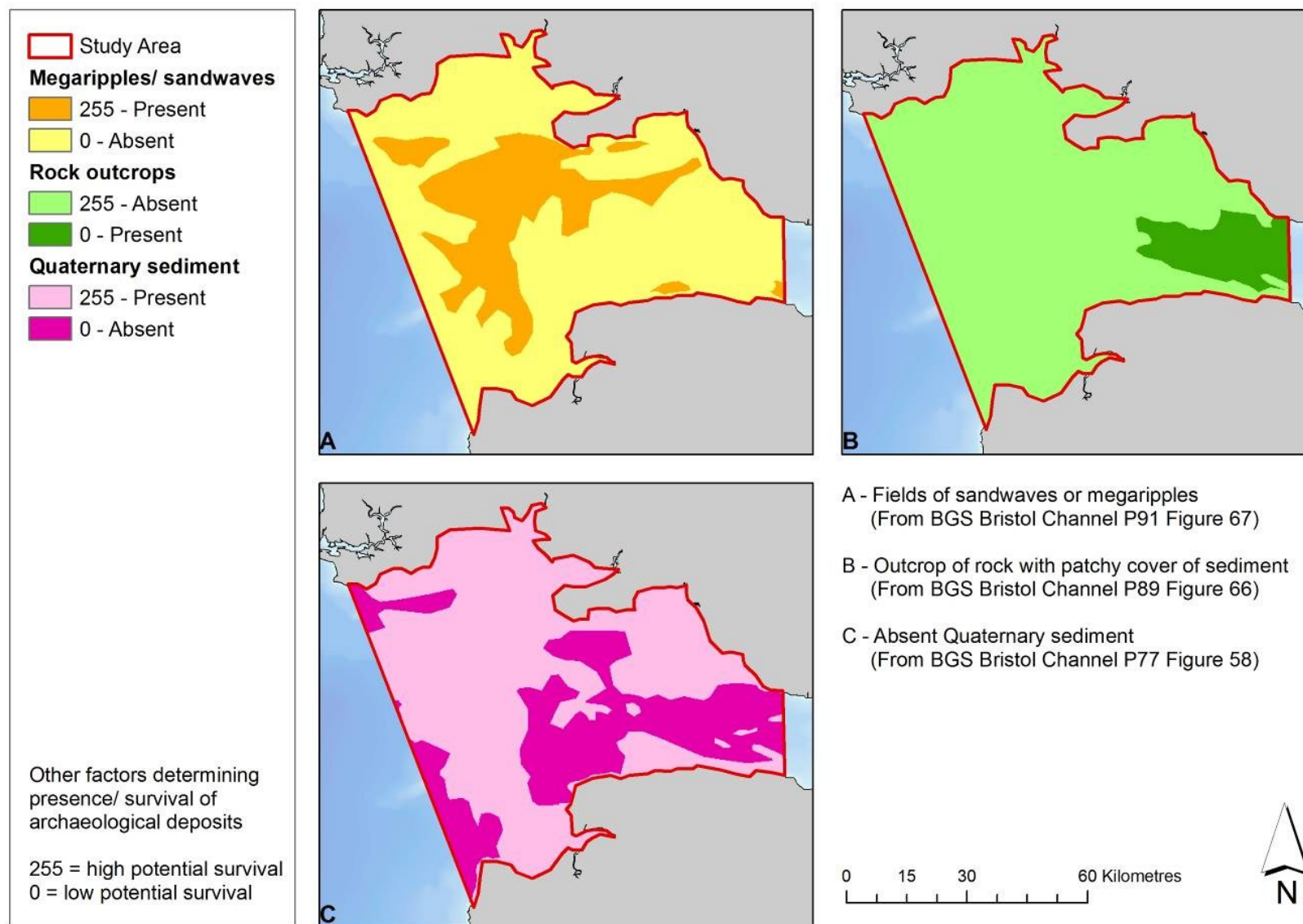
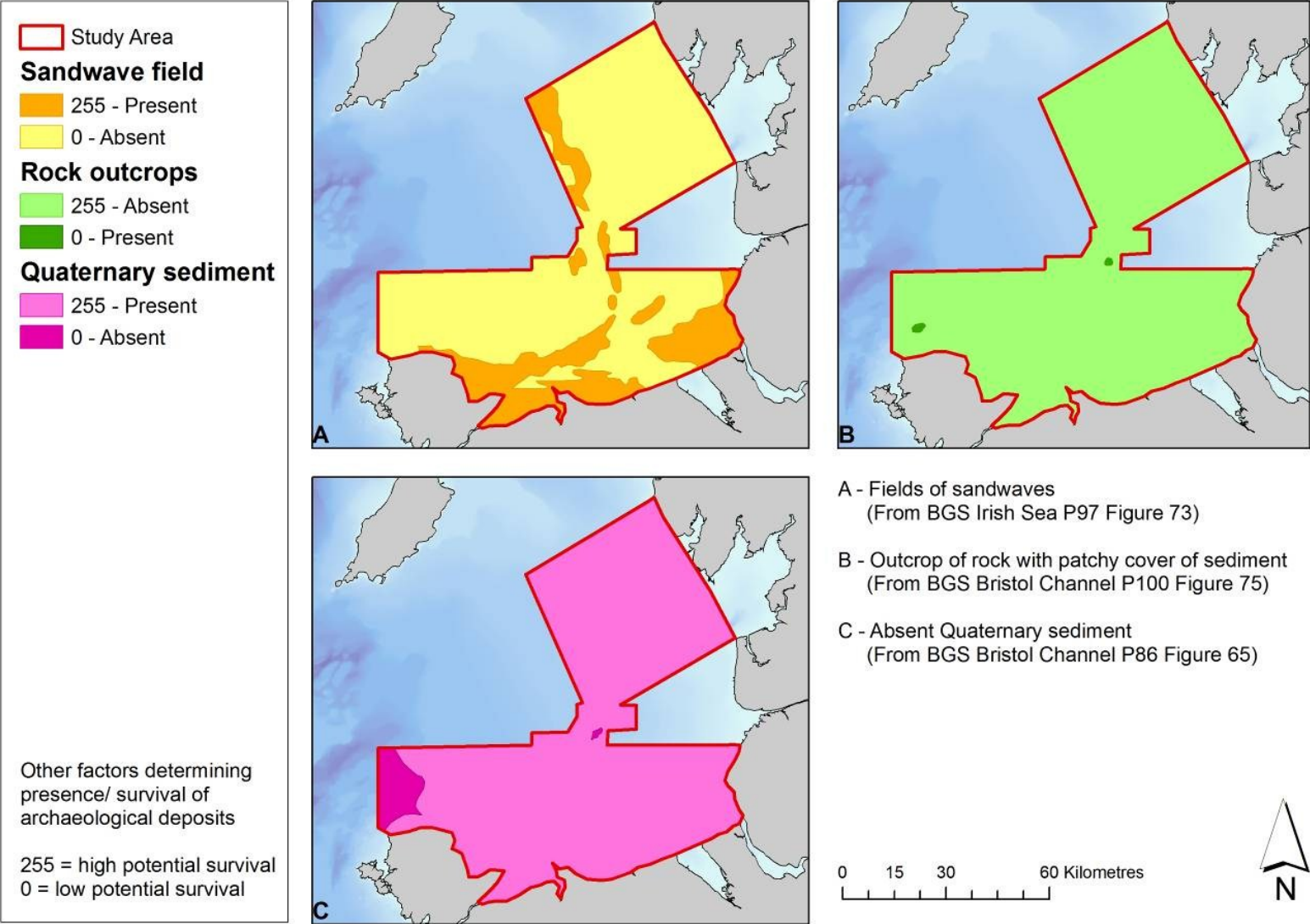


Figure 50: Other factors determining the presence/survival of archaeological deposits within the Bristol Channel study area (After Tappin 1994)



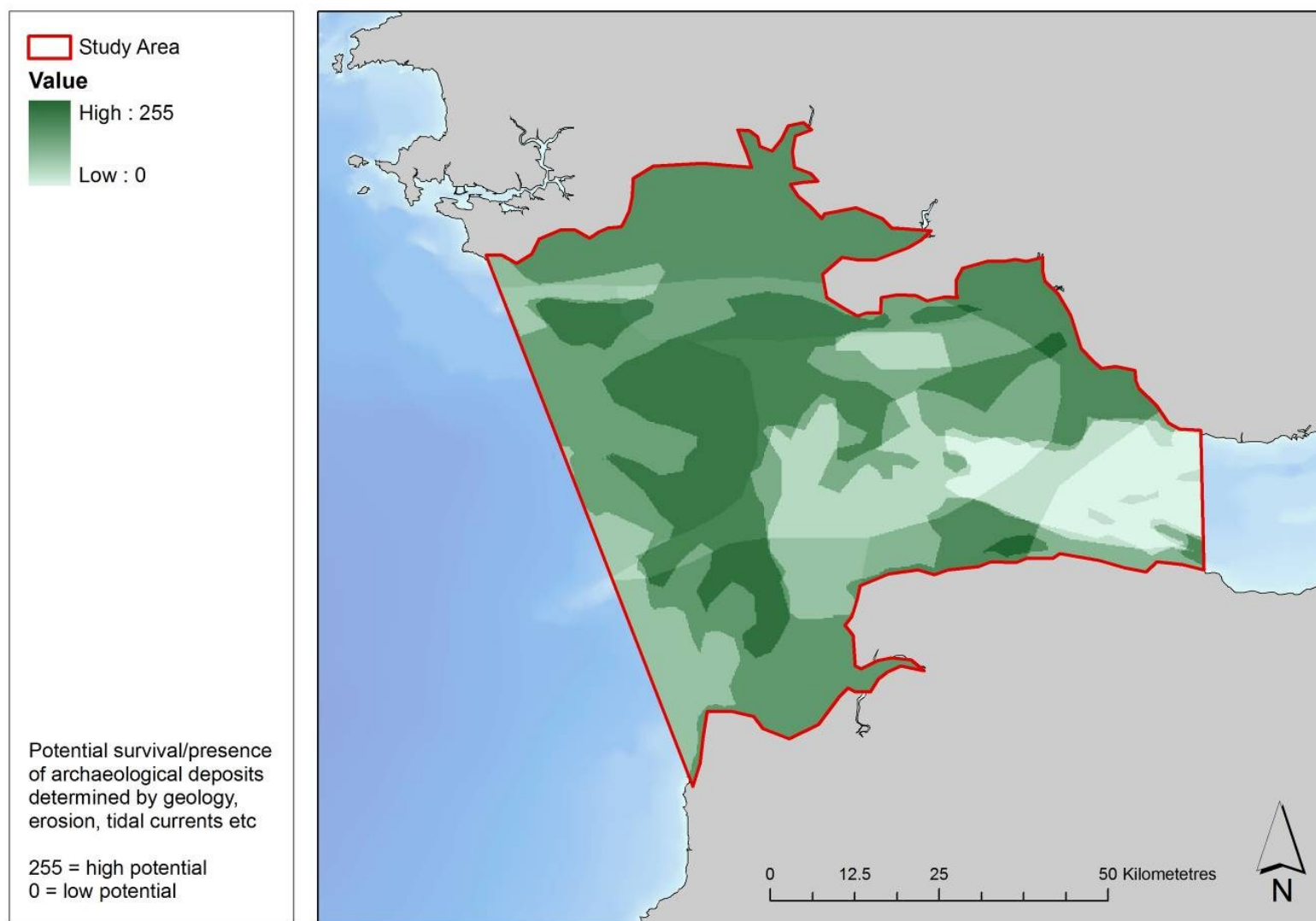


Figure 52: Potential survival of archaeological deposits (combination of tidal stress, erosion, geology etc) within the Bristol Channel study area

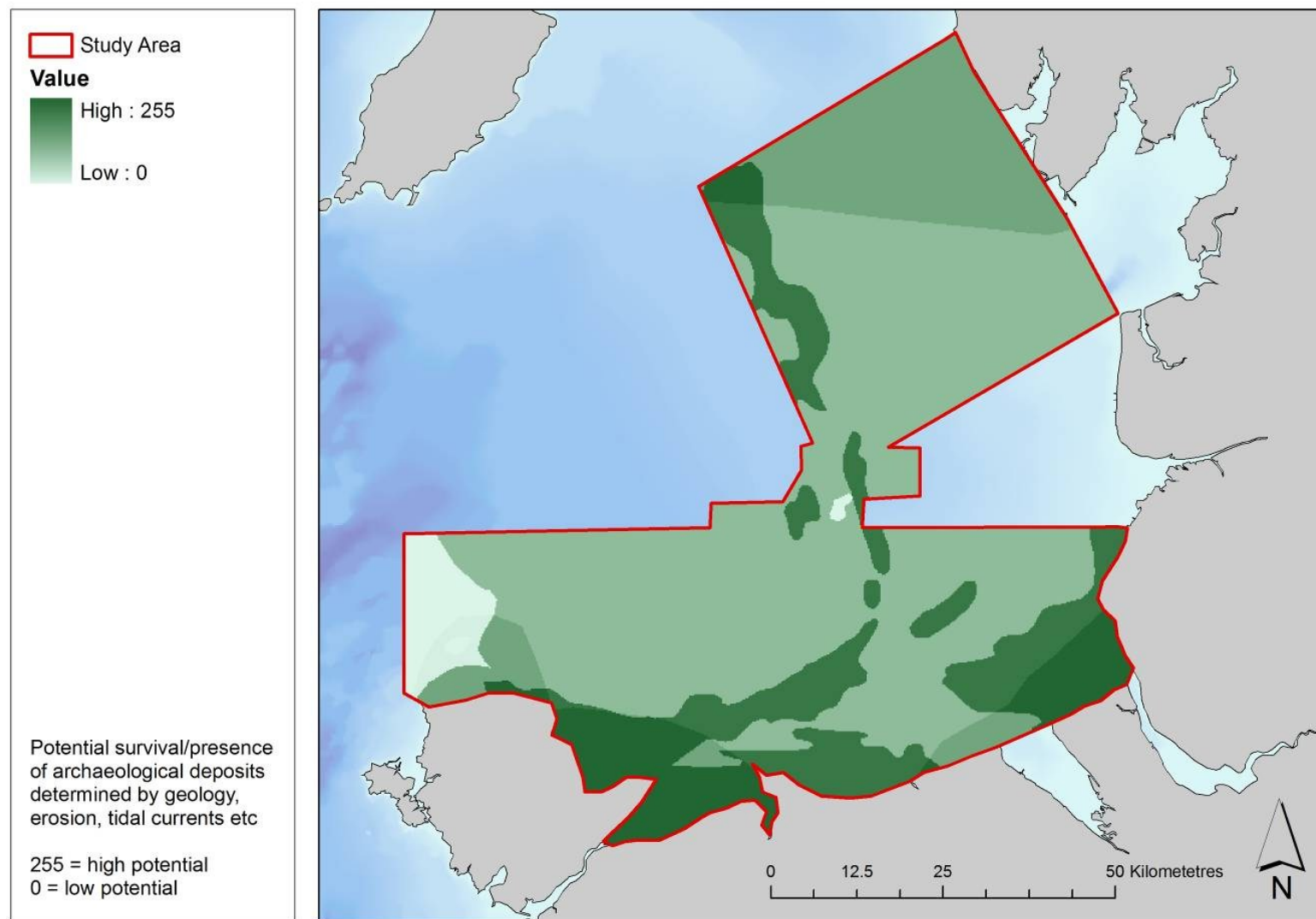


Figure 53: Potential survival of archaeological deposits (combination of tidal stress, erosion, geology etc) within the Liverpool Bay study area

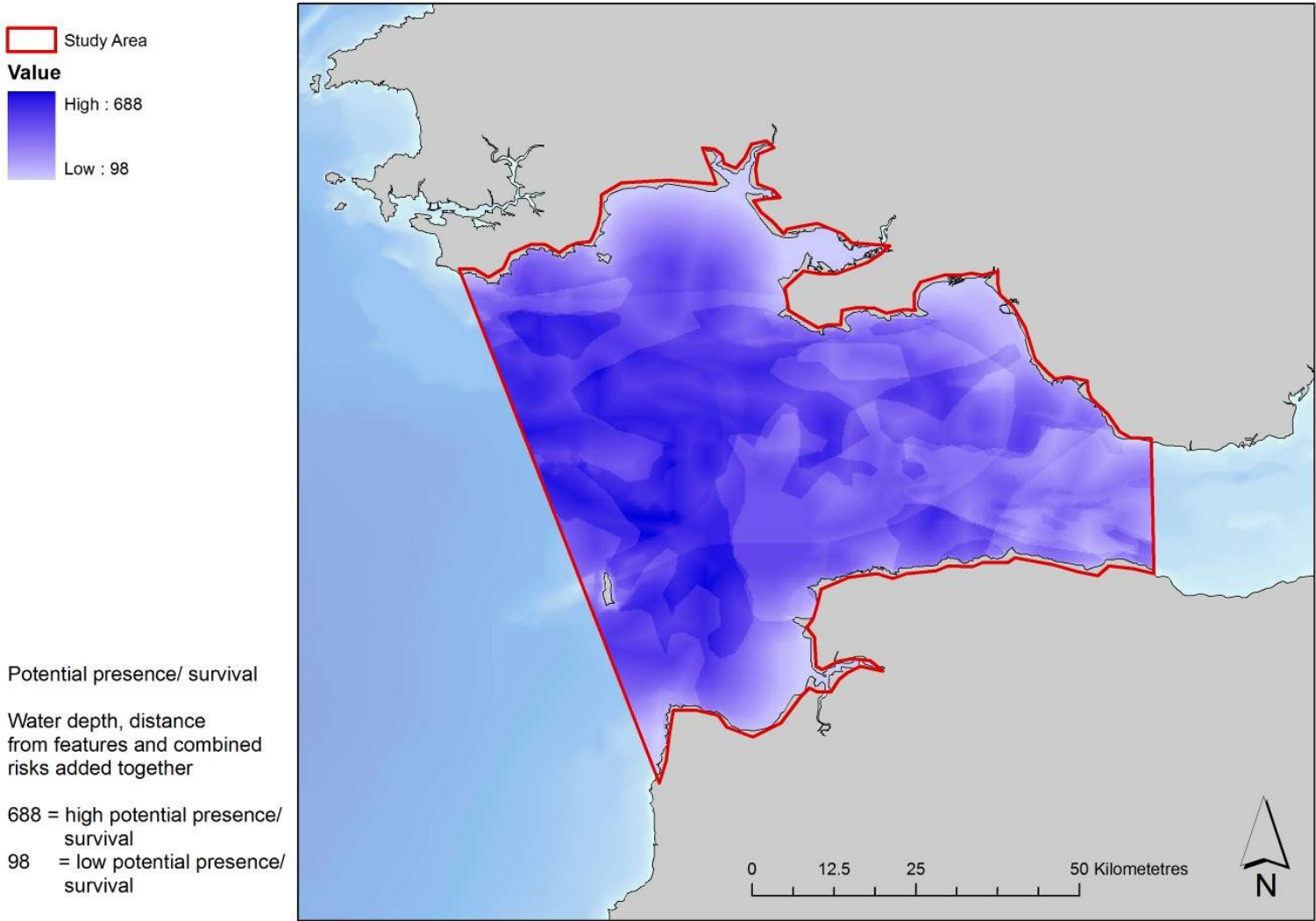


Figure 54: Potential presence/survival of archaeological features and deposits based on all contributory factors within the Bristol Channel study area

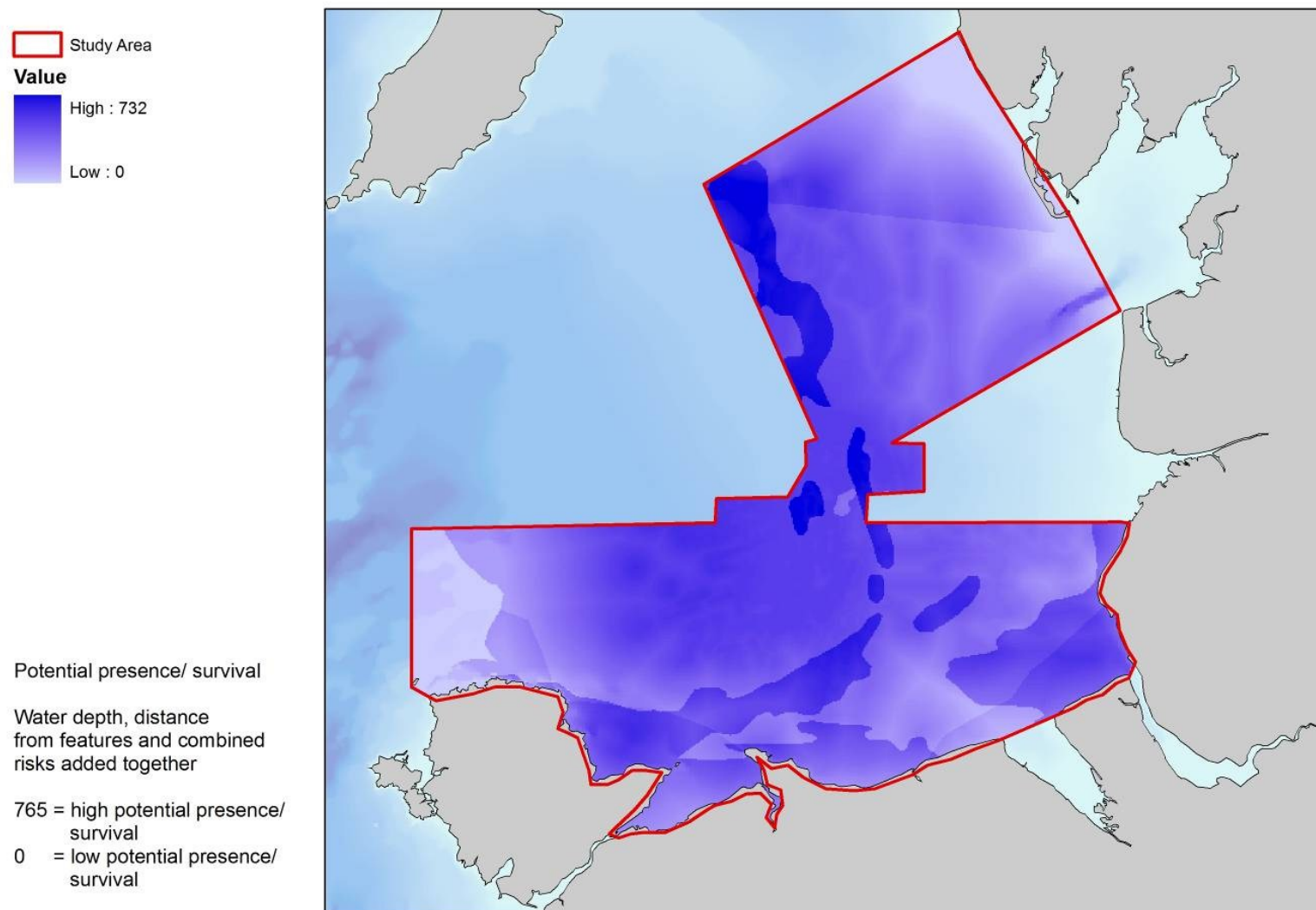


Figure 55: Potential presence/survival of archaeological features and deposits based on all contributory factors within the Liverpool Bay study area

7.6 Additional work by Dyfed Archaeological Trust

7.6.1 Further work was conducted on the datasets to allow better integration with the four regional Wales Historic Environment Records. This included additional simplification of complex feature sets, and the addition of extra fields into the shapefile attribute tables of the Landscape Characterisation Areas and the features themselves. Some of this information is shown on the Dyfed Archaeological Trust's website - www.dyfedarchaeology.org.uk

8 THE RESULTS IN CONTEXT - THE LATE PALAEOLITHIC AND MESOLITHIC LANDSCAPE

8.1 Bristol Channel – Palaeolithic (Figure 56)

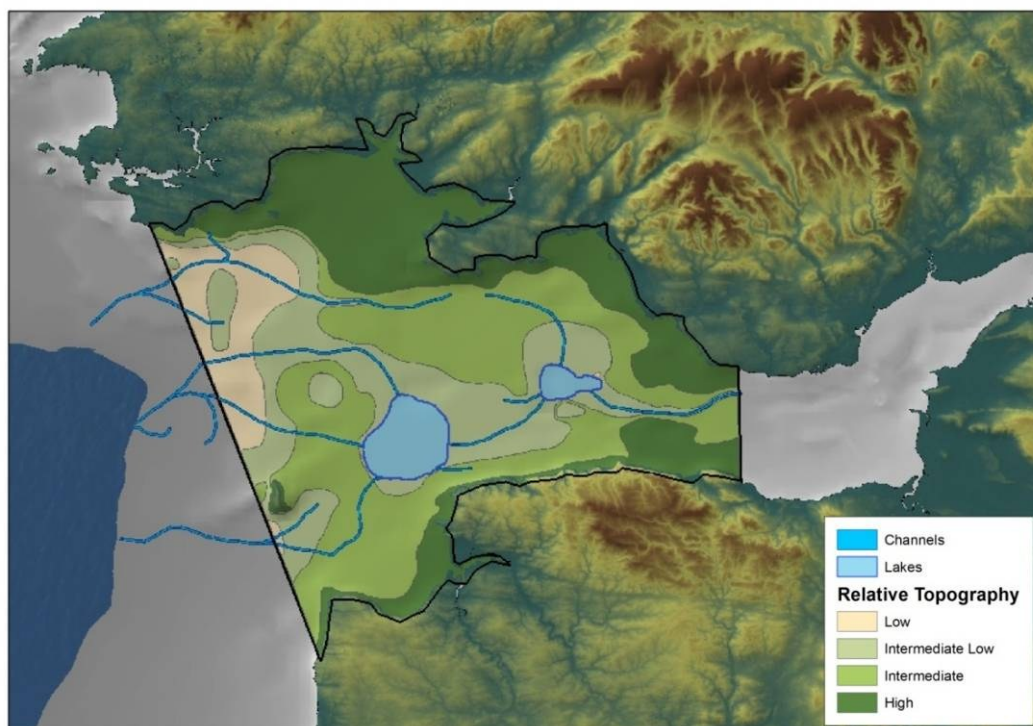


Figure 56: The Bristol Channel in the Late Palaeolithic (Aster DEM is a product of METI and NASA)

8.1.1 The area of the Bristol Channel valley, as it stood in the Late Upper Palaeolithic, was a largely open tundra, covered with herbs and grasses. The region would not have been affected directly by the last ice sheet but would have experienced periglacial conditions ahead of the ice. Soil formation and vegetation development lag behind climatic shifts, and vegetation would have been slow to establish. As soil development increased shrubs such as juniper (*Juniperus*) and willow (*Salix*) would have been established, closely followed, if the conditions were correct, by small areas of pioneer birch woodland (*Betula pubescens*). The final upper Palaeolithic stadial period saw a climatic reversal and the area, although not affected by glacial conditions, would have been subject to permafrost. How much this affected the valley cannot be quantified, but the cold climate would have restricted birch woodland to favourable locations, with open habitat taxa re-establishing elsewhere. The lack of vegetation diversity would have increased reliance on animals for food and derivative products. For example sinew would be of considerable value at a time when there were few plants suitable for the manufacture of fibre. It would have been used for sewing, the ligatures of weapon heads and the netting and snares used to trap birds and small game (Beasley 1987).

8.1.2 The relative topography map suggests that the low-lying valley was bounded on either side by higher ground that would later form Somerset and South Wales. The elevated landscape provided excellent vantage points for

hunting migratory animals and the valley would have constricted herd migration routes. In some areas there may have been access to networks of caves. Paviland, on the south coast of the Gower Peninsula, would have been an easy climb from the valley floor and would have provided people with shelter and protection from the extreme cold temperatures outside. This landscape therefore appears very similar to other Palaeolithic territories (e.g. the Cheddar Gorge, Stringer 2006, or the Dordogne, Jones 2007).

8.1.3 Animals were plentiful in this period. Not only were there species associated with the new temperate climate, but the last remnants of the cold stage megafauna, which may have been unused to human predation, may have also roamed the open tundra. The high sided valley would have naturally funnelled animals into a rich reserve of herbs, grasses and water sources suitable for grazing and hunting.

8.1.4 Within the base of the valley, the large rivers mapped by the project would have seen dramatic palaeohydrological changes and a general geomorphic disequilibrium. High fluvial output during this period resulted in sharp incisions of pre-existing valley floors. (Roberts 1998). The sediment carried by the rivers infilled, incised meanders and may have caused localised blocking of some palaeochannels, creating a ponding-back effect, peat formation and the development of lakes. The cold, turbulent and potentially dangerous waters may have been difficult to traverse and prevented access to riverine resource. The lakes, however, would have provided accessible resources; attracting both human and animal communities. The large lakes observed within the valley would have contributed greatly to the attractiveness of this landscape for Palaeolithic communities.

8.1.5 The data suggests that the Palaeolithic communities inhabiting the area were at least 100km away from the sea, so coastal resources may not have been used regularly. However, these may have become important seasonally and exploited during the winter seasons when other sources of food were not as plentiful.

8.2 Bristol Channel -Mesolithic (Figure 57)

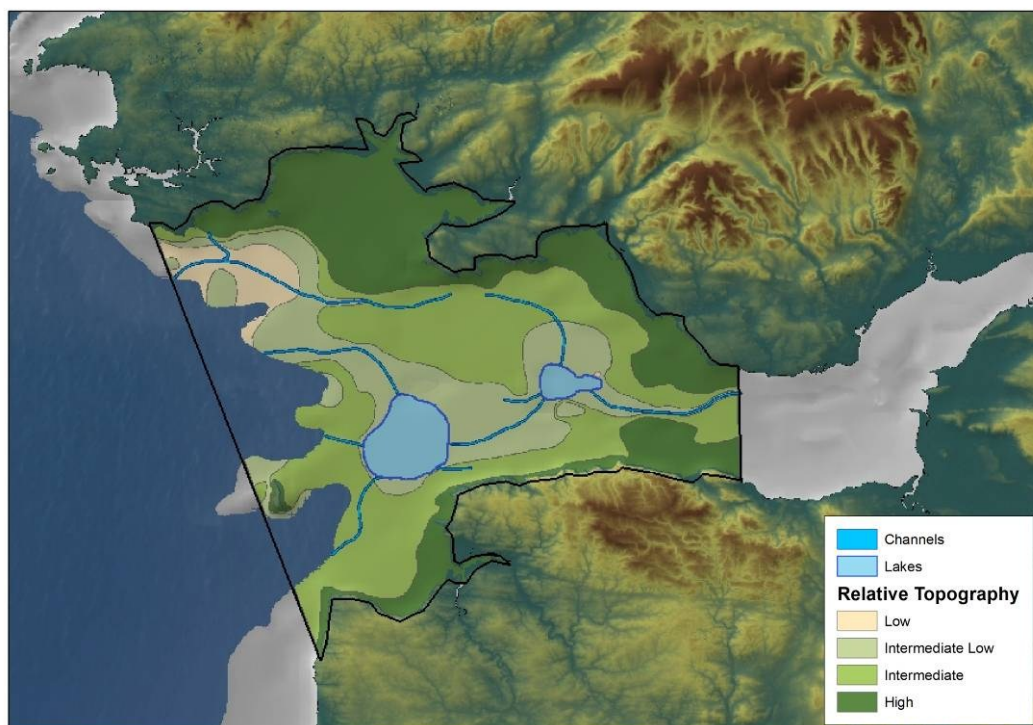


Figure 57: The Bristol Channel in the Mesolithic (Aster DEM is a product of METI and NASA)

8.2.1 Holocene sea-level rise during this period (10,000BP) created a considerable shift in the coastline into the study area. The change within the landscape would have been obvious to Mesolithic communities and adaption to the new conditions would have been vital.

8.2.2 The rising sea-level would have submerged some areas of the landscape relatively quickly and much of the landscape within the study area may have been lost within 1000 years of the onset of the Mesolithic. At the same time a great number of ecological zones may have been created in close juxtaposition. On excavated later Mesolithic intertidal sites such as Goldcliff, Westwards Ho!, Minehead and Woolaston, we see focused activity during times of the greatest environmental dynamism (Bell 2007; Brown 2005), and this suggests we should expect significant human activity around the advancing coastline during this earlier period. The relative topography map suggests that a wide-ranging subsistence economy could be practised within this relatively small area, maximising resource access within a relatively small seasonal round and reducing physical labour for hunting and gathering groups. Relatively permanent camp sites may have been situated on higher ground and small working parties could be dispatched to the valley below.

8.2.3 The mapping shows that the inundation of the valley resulted in the Isle of Lundy forming a promontory sticking out into the emerging Bristol Channel, and this would have been a centre of activity during the Mesolithic (Schofield 1994). The main drainage pattern mapped by the project for this period remains broadly similar to that of the Palaeolithic. There are a number of drowned Pleistocene

valleys around the coastline that would have been flooded during the Mesolithic. These features would have been corridors for tidal waters. This would have created areas of rich wetland resources inland providing excellent channels of movement for both human and animal communities.

8.2.4 At the onset of inundation most of the area characterised as possessing a low relative topography would have been submerged. Despite this, a considerable portion of the study area remained accessible to human occupants. As the inundation proceeded, only portions of the areas currently identified as high relative topography, remained emergent. These areas would have formed islands in a mostly drowned landscape. Such islands would be a focus for Mesolithic activity; as such places would have provided direct access to fresh water and brackish resources.

8.2.5 During the Mesolithic, communities living in this landscape would have witnessed a rapid spread of open, mixed deciduous forest woodland, with hazel (*Corylus avellana*) and elm (*ulmus*) establishing an open canopy forest. The canopy closed within 500 years with the establishment of oak (*Quercus*), Lime (*Tilia cordata*), alder (*Alnus glutinosa*) and ash species (*Fraxinus excelsior*) (Roberts 1998). This strongly seasonal, high productivity woodland would have provided hundreds of edible plant species for human groups - available at a relatively low energy cost. However, the dense closed nature of the woodland would at times have been an obstacle to communities, making hunting and passage difficult. However, the presence of fluvial channels and lakes within the landscape would provide open areas which would have facilitated population movement. The fringes of these areas are likely to have been maintained by communities, who may have burned the vegetation around water zones to maintain access to the water resource and to encourage new plant growth.

8.2.6 The regular longitudinal river profiles associated with the Pleistocene-Holocene transition suggest lower energy river systems than the previous period, and these may have been more suitable for travel using the logboats of the period. The rivers still produced high yields of sediment that in-filled deep Pleistocene channels and continued to contribute to the ponding up of lakes within the valley. Rivers continued to attract foci for human activity throughout the Mesolithic. There is little evidence for specific activities taking place at river locations, however intertidal archaeological sites, such as Goldcliff, have demonstrated that the eel and salmon, which migrated up and down the river, were highly valued resources (Bell 2007).

8.2.7 Coastal caves on the Gower peninsula and Caldey (Lacaile and Grimes 1955) continued to be used. The topographic maps suggest that these caves, in addition to shelter and protection, would still have provided excellent viewing platforms onto the valley below. Sites such as Gough's cave provide evidence of human burial and emphasise the special significance these locations had to local communities.

8.2.8 The hill top locations around the Bristol Channel would have provided excellent viewpoints into the valley, eventually becoming cliff tops directly above the sea. The elevation of these sites provided excellent contexts for hunting camps, offering views into the wider landscape and the coastal zone. One of the largest concentrations of flint tools from this study area is located at Hawcombe Head. This high elevation site on Exmoor dominates the landscape (Riley and Wilson-North 2001; Bell 2007). It is likely other hill tops and elevated areas with coastal views were utilised by hunters in a similar way.

8.2.9 Upland and inland locations close to the study area were a focus of human activity and groups using these areas would have also utilised the lowland coastal and riverine resources. The patterning of Mesolithic sites within the larger area may suggest that these locations were chosen because of their access to the coast. Following this the data has been used to suggest that upland locations formed part of an overall territory movement for the communities, using the river valley as axes of movement (Bell 2007).

8.3 Liverpool Bay- Palaeolithic (Figure 58)

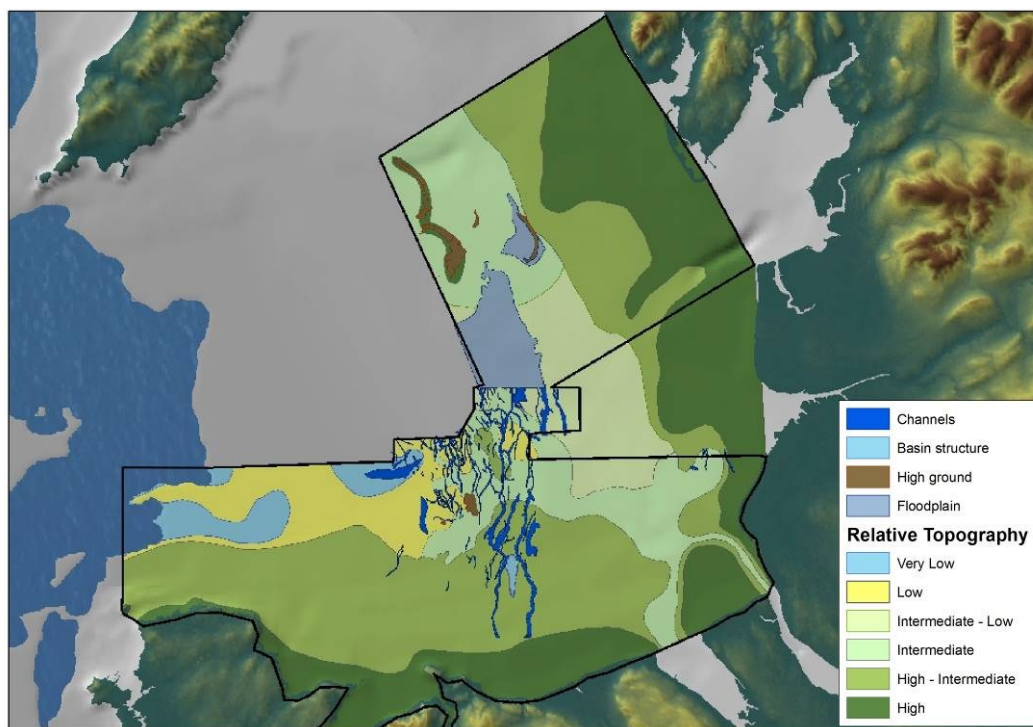


Figure 58: Liverpool Bay in the Late Palaeolithic (ASTER DEM is a product of METI and NASA)

8.3.1 During this period much the study area within Liverpool Bay was above water and a relatively low-lying landscape. During the stadial (13 000–11,500cal BC) the wider landscape around Liverpool Bay began to accumulate snow and ice, and by 12,700cal BC an icecap had formed over the Western highlands of Scotland (Roberts 1998). Northern upland areas that were close to the study area would have developed localised valley or cirque glaciers, while the low elevation area of the bay would have been gripped by periglacial conditions.

8.3.2 The landscape as a whole would show the effects of the previous Devensian ice sheet and its de-glaciation (Lowe and Walker 1997). This would have left a complex arrangement of postglacial and de-glaciation landforms that scarred the landscape. These features would have been apparent to human populations in Liverpool Bay, especially upstanding features including moraines and drumlins. These high points would have provided views across the landscape and could have been used to spot game. The floor of the bay suffered from significant glacial scarring and there are a number of deep major incisions into the lithic strata below (Jackson *et al* 1995). Kettle holes are also a key feature of this bay, with a number, close to the eastern side, achieving depths of between 50-100m (Jackson *et al* 1995). Several of the depressions within the data may well represent such features and these would have contained a partial fill of sediment and water creating a small lake, or watering hole, depending on diameter. Such bodies of water, if not frozen, would have provided important watering places for animals and human communities.

8.3.3 The rivers within the bay were likely to have possessed large braided channels and these would have been dynamic. The bay may not have appeared

hospitable to human communities. This, however, does not mean it was not utilised, the channel diversity would have made this an excellent location to fish, especially during the seasonal salmon run.

8.3.4 Permafrost may have limited soil and vegetation cover in the area surrounding the bay, and, although it may have attracted the remnants of the cold stage fauna, the area may not have held significant resources for communities. Species grazing the available vegetation and drinking from the multiple channels in the bay may have been predated by hunters based in the limestone caves on the western edge of the study area. The remains of a megaloceros (Giant Elks) have been found in a cave overlooking this bay (HER512; HER 511).

8.4 Liverpool Bay – Mesolithic (Figure 59

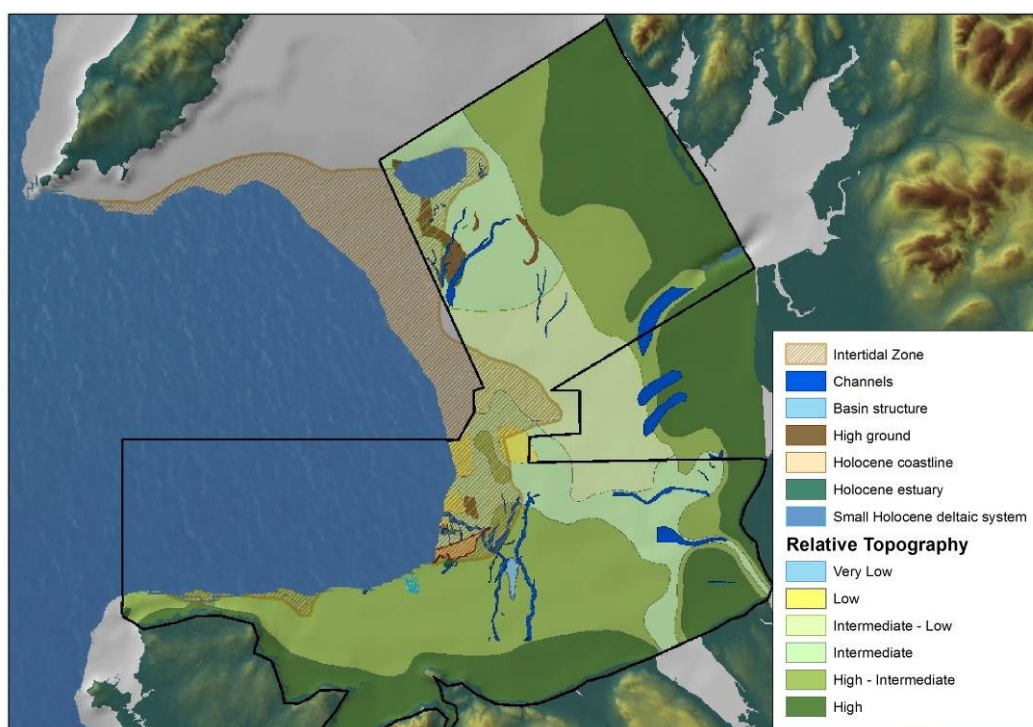


Figure 59: Liverpool Bay in the Mesolithic (ASTER DEM is a product of METI and NASA)

8.4.1 During the Mesolithic Liverpool bay was a dynamic and constantly changing landscape. Soils within the bay area would have been thin and immature during the Early Holocene. As they developed woodland would have colonised the areas previously occupied by pioneering vegetation. As sea-level increased and the coastline moved further into the bay, the lowest areas would have been affected by salinity, which produced a reversed hydrosere sequence. Thus the area was transformed from dry land locations to areas of fen, brackish vegetation, reed swamps and saltmarsh. Similar conditions existed on the Esk estuary during the late Mesolithic and human groups were exploiting these environments (Bonsall *et al* 1994). It is possible that similar activities occurred during the Early Mesolithic in the project area.

8.4.2 Some large glacial features, like the kettle holes in Liverpool Bay, would not have been filled by the terminal Pleistocene sediment deposition and these would have developed their own Holocene sediment stratigraphy through the development of kettle bogs and fresh water basins. Some kettle holes are near the present day coast and would have provided wetland resources for Mesolithic populations (Bonsall *et al* 1994).

8.4.3 The relative topography map suggests that the inundation of the landscape proceeded relatively rapidly. Several coastal features, including an extensive intertidal zone, were identified during study of the seismic data. The intertidal area at the start of the Holocene was extremely large, and it is possible that there would be significant areas of deep muds that would have been unsuitable and even dangerous for human utilisation. The perimeters of the intertidal area would

have been more accessible to human use and would have been exploited for resources. Such use is evidenced for slightly later periods of the Mesolithic by the presence of human footprints in intertidal muds (e.g. Gonzalez *et al* 1996).

8.4.4 Several major Holocene fluvial systems were located draining into this wide landscape and many of these re-use earlier Pleistocene structures. The glacial channels would have been deeply incised originally, and partially or totally in filled at the very end of the terminal Pleistocene. At this time geomorphic disequilibrium created braided rivers and gave way to more longitudinal river profiles (Roberts 1998). The rivers of the Mesolithic would then have been associated with much calmer, low energy river systems. These would have carried less sediment as a consequence of the developing vegetation cover across the landscape, and would have provided excellent opportunities for Mesolithic populations to use the courses to travel to gather raw materials, such as flint and chert (e.g. Cowell 1992). Some relict braided Pleistocene channels close to the coastline are likely to have become anastomosing channels with long term vegetation islands, back swamps, and floodplains (Rapp and Hill 1998).

8.4.5 The data records the presence of several channel systems which may be related to the course of modern rivers, specifically the River Mersey and the River Dee, both of which are associated with Mesolithic settlement (Cowell and Innes, 1994 and Hodgson and Brennand 2006). These large channels would have provided excellent corridors of movement for Mesolithic communities wanting to access the resource rich landscape. Whilst these river pathways have not been fully traced to the coastline, it is a possibility that passage from the dry land into the wetlands would be available through such corridors. The dynamic nature of the bay and the complex patch work of vegetation zones and variable fluvial courses may have made the landscape potentially quite difficult to navigate. The main tributaries would have been a focus of early and late Mesolithic activity (Bonsall *et al* 1994), with the immediate adjacent high ground occupied by activity camps/ areas. The cliff tops, overlooking the bay, provided excellent views for locating prey in the lowland alluvial plains, and would eventually become cliff tops sites overlooking the sea (Cherry and Cherry 2002). In the early Holocene the valleys may have been integral to hunting strategies where animals could be funnelled into the valley floor to be culled by human communities.

8.4.6 The changing character of the land would have been apparent to contemporary human communities. The vegetation succession associated with landscape change would have taken place at differential rates depending on exposure to saline water, the flow direction of the tides, the topographical position of that specific area and the geological substrate beneath it. The general vegetation succession expected would, moving inland from the coastline, be; coastal waters, salt marsh, reed swamps, fen bogs, and, finally, dry land. Different areas however, may not have followed this sequential order and there is room for stages to be skipped and even reversed. The overall picture is of one of landscape unconformity, vegetation diversity and differing relict fluvial channel patterns which would have provided a diverse and dynamic landscape in which to live.

8.4.7 All of the different ecosystems within this landscape would have produced an array of valuable material resources as well as excellent hunting opportunities. Within this wider picture of vegetation change, the remaining elevated topography and locations of rock outcrops would have provided areas of dry ground within a whole range of hydrosere sequences. As the landscape was inundated numerous island locations would have been formed within the developing bay. These are likely to have been utilised by human communities to provide easy access to coastal and wetland resources (Middleton 1997).

9 CONCLUSIONS

9.0.1 The West Coast Palaeolandscapes project sought to use the existing 2D and 3D seismic datasets and related datasets to explore the landscape through the late Quaternary and specifically during the Holocene. To achieve this goal, the project located numerous data sources which were compiled in order to attempt an extensive landscape analysis. The density of data was suitable to produce landscape mapping that was suitable for archaeological research and landscape characterisation. As such the project was successful in addressing Aim 1 of the project.

9.0.2 Through the identification of landscape features within the seismic data, and the mapping of topographic features within the seismic data it was possible to address Aim 2 of this project. The mapped data has, for the first time, allowed an appreciation of topography within the study areas and associated landscape features. The results will support future research both within these marine areas and the surrounding coastal zones.

9.0.3 The information provided through mapping supported the generation of additional datasets exploring the potential for survival of archaeological or archaeo-environmental deposits within the area. These data are preliminary in nature. Several of the information layers are of relatively low quality but this situation could be improved through acquisition of additional datasets and future survey programs. Aim 3 has been completed and will be of great assistance in understanding the potential distribution of the resource within the study areas.

9.0.4 The final aim of this research was to generate broad scale landscape characterisation mapping for the two study areas. This was also completed and the product will be useful for developmental and research purposes.

9.0.5 As a whole, the project has been completed successfully and demonstrated that almost any part of the United Kingdom coastline that contains relict or palaeolandscapes is probably susceptible to some level of exploration. Having achieved this, national curators should feel encouraged to promote exploration elsewhere in British waters and even in those areas which, previously, were deemed inaccessible because of the lack of appropriate data for study. Today, the significant submerged landscapes off the west coast of Wales, north east England or the entire eastern coast of Scotland can now take their place within research agendas with some confidence that the archaeological resources they contain can, for the first time, be explored, managed and protected.

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Software

ArcGIS – www.esri.com (accessed 17/03/2011)

Kingdom - <http://www.seismicmicro.com/>(accessed 17/03/2011)

11 GLOSSARY

Anastomosing – An anastomosing stream system is a network of multiple channels that divide and reconnect.

Automatic gain control – This method uses the average seismic signal level which is fed back to adjust the gain applied to the seismic data.

BGS - British Geological Survey.

Boomer - a device for high resolution seismic reflection profiling used to identify and map larger objects beneath the seabed at depth.

Carr – A phase in the succession from true fen wetland to woodland characterised by emergent woody species, shade-tolerant herbs and understorey plants. Fens are characterised by their alkaline chemistry as opposed to acidic bogs.

Creswellian - A British Upper Palaeolithic culture named after the type site of Creswell Crags in Derbyshire. It dates to between c. 12,500 and 12,000 BP

Devensian stage - used by British geologists and archaeologists to refer the most recent extended cold period lasting between c. 80-10,000 years ago. .However, it was only cold enough to allow ice sheets to develop on the British mainland during its later stages.

Dimlington Stadial - an extreme cold phase between 22,000 and 13,000 years ago when ice sheets and glaciers developed across northern Britain and extended south to the Midlands. This may well have driven humans south and out of Britain.

Epi-Ahrensbergian – A European late Upper Paleolithic culture which was present during the Younger Dryas. This is thought to be related to the British Long Blade Industry.

Federmesser - A toolmaking tradition of the late Upper Palaeolithic era, and is found on the Northern European Plain. This follows the Creswellian Culture at 12,000BP and is in turn replaced by the Long Blade Industry some time after 10,500BP

GISP - Greenland Ice Sheet Project

Holocene - the geological epoch beginning c. 9600 BC to the present. The Holocene is part of the Quaternary Period. It has been identified with MIS 1 and can be considered an interglacial. This period is intimately connected with the rise of modern human civilisations.

Hydrosere - a plant succession which occurs in a freshwater lake.

Interglacial - a warm stage between cold stages.

Interstadial - a short warmer phase which alternates with colder stadial phases during a glacial period.

Isostatic rebound model – A model of the rise of the crust of the earth due to the rebound caused by the removal of an ice sheet.

Loch Lomond Stadial - was a brief cold period between 13,250 to 11,450 BC and following the Bölling/Allerød Interstadial. In Europe it has been called the Younger Dryas and most recently Greenland Stadial 1 (GS1).

Magdalanian - A culture of the Upper Paleolithic in western Europe, dating from around 17,000 BP. It is named after the type site of La Madeleine in the Dordogne region of France. The British Creswellian Culture is thought to be a related offshoot of the Magdalanian culture.

NSPP - North Sea Palaeolandscape Project

Pinger - a high resolution seismic reflection profiling device. Pinger profiling is generally used to resolve features less than 0.5m and lacks the depth penetration of other methods, such as Boomers.

Pleistocene - a geological epoch dating 1,800,000 to 11,500 years BC and associated with the world's recent period of glaciations. It follows the Pliocene and is succeeded by the Holocene epoch. The end of the Pleistocene corresponds with the end of the Palaeolithic age used in archaeology.

Quaternary - a geological time period following the Pliocene and lasting from c. 1.8 million years ago to the present. The Quaternary includes 2 main subdivisions: the Pleistocene and the Holocene.

Remote Sensing - generally involves the acquisition of information of an object or phenomenon, by the use of a sensing device that is not in physical contact with the object. This may mean the device is housed in an aircraft, satellite or ship. Within terrestrial archaeology a variety of hand-held or carriage mounted sensors are frequently used. Sensors include active and passive formats depending upon whether they simply record reflected or emitted energy/radiation or whether the sensor itself is an emitter. The most common land-based techniques include magnetometry and aerial photography (passive techniques) and resistance/resistivity and radar (active techniques).

SEG-Y – is the standard file format developed by the Society of Exploration Geophysicists for storing geophysical data. It is an open standard, and is controlled by a non-profit organization.

Sparker - a high resolution seismic reflection profiling device. Sparker profiling is utilised to identify and map larger objects beneath the seabed at depth, due to its greater penetration as compared to other sources such as CHIRP.

Stadial - an intense cold stage within a glacial often corresponding and alternating with warmer interstadials. The intensity of cold associated with the first known stadial in Britain resulted in the formation of cirque glaciers in upland Britain including the Lake District, North Wales and Loch Lomond.

Timeslice – A 2D horizontal slice through a seismic volume at a given time interval.

Upper Palaeolithic the period between 40,000 and 10,000 years ago, when stone tool assemblages made by anatomically modern humans (*Homo sapiens sapiens*) appeared in Britain.

Voxel - is a volume element, representing a value on a regular grid in three dimensional space. A voxel is analogous to a pixel, which represents 2D image data.

Würm glaciation - a glacial episode c.24,000–9,600 BC. At the height of Würm glaciation, most of western and central Europe and Eurasia was open steppe-tundra, while the Alps presented solid ice fields and montane glaciers. Scandinavia and much of Britain was under ice during the late Devensian and Dimlington stadial..

12 APPENDIX 1

This is a copy of the pilot project (West Coast Palaeolandscapes Project, Project Number 1920, EH Ref. 5238), in which the techniques and methodology used within this project were developed. The pilot project report is therefore provided to give context to the main project, and to provide background information which may not be provided within the main report.

Original page numbering has been retained for internal consistency and referencing purposes, and should be regarded as a standalone document in its own right.