Arch-Manche:

Archaeology, Art and Coastal Heritage - tools to support coastal management and climate change planning across the Channel Regional Sea: Technical Report

Arch-Manche

ARCHAEOLOGY, ART AND COASTAL HERITAGE

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Maritime Archaeology Trust
UNIVERSITEIT GENT
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1. Project Introduction

The Arch-Manche project has demonstrated how archaeology, art and maritime coastal heritage can be used to show long-term patterns of coastal change and the impact on human settlement. Study of this data allows understanding and modelling of past reactions to climate change to help with planning for the future. The results are important for Integrated Coastal Zone Management (ICZM) and can help inform sustainable policies for adapting to coastal climate change. The results of the project are timely due to predicted increases in coastal erosion, flooding and coastal instability affecting the Channel and Southern North Sea coasts.

Funded by the European Regional Development Fund through the Interreg IVA 2 Seas Programme, the project was led by the Maritime Archaeology Trust (MAT) (formerly the Hampshire & Wight Trust for Maritime Archaeology (HWTMA)) in the UK, working in partnership with the Centre National de la Recherche Scientifique (CNRS) in France, Ghent University in Belgium, and the research institute Deltares in the Netherlands. The common geology, structure and physical coastal processes at work across the partner countries require common coastal reactions to climate change across the Channel and Southern North Sea. In prehistoric times the Channel did not exist and was a landscape used by early human peoples, the traces left in the prehistoric archaeological record are therefore comparable across the region. Later historical development includes common maritime coastal infrastructure and coastal industries based on a shared climate that have left traces in the archaeological and artistic record.

This record can provide high resolution data on coastal change spanning thousands of years, contributing to an understanding of the evolution of coastal areas where there is a need to gain an overall understanding of past, present and future impacts on coastal communities. The Arch-Manche project used this data to enhance sustainable approaches to ICZM to help meet the challenges of coastal climate change through informing mitigation and adaptation strategies appropriate for differing coastal frontages within the Channel region.

Past coastal planning regimes have suffered from a poor understanding of the ongoing processes and natural trends that are shaping our coastal zones. Consequently, many coastal settlements are becoming increasingly vulnerable as the relationship between the land and sea evolves. Using archaeological, palaeoenvironmental and artistic resources the Arch-Manche project has demonstrated the value of the 'wisdom of hindsight' and leads to a position where coastal management decisions can be based on knowledge drawn from the long-term behavioural trends in the shifting boundaries of the sea.

1.1. Summary of the Project Approach

The Arch-Manche project brought together partners and sub-contractors from a number of organisations with a range of specialist expertise. Drawing on these skills allowed a new integrated approach to the use of archaeological, historic and artistic data for understanding coastal change. It also brought together partners working on the coast around the Channel-Southern North Sea area, providing a coordinated approach across the study area.

Maritime Archaeology Trust (UK): Specialists in the investigation of maritime and marine archaeology and heritage, with particular experience in submerged past and prehistoric environments, and the use of maritime archaeological data for understanding coastal change. This experience was used to lead the project and deliver aspects of archaeological investigations, data gathering, ranking of various data sources and analysis. Experience of artistic representations of the coast and their ranking, in addition to marine archaeological techniques have been shared with the partnership. MAT has taken a lead with the management of data across the project team and development of illustration and visualisation. This experience has been shared through partnership working.

Centre National Recherche Scientifique (France): the Arch-Manche team work within CReAAH, which is a department within the CNRS that specialises in archaeology and archaeosciences in north west France. The team has extensive experience in international and collaborative projects including coastal and island excavations and survey projects. Work has included a range of archaeological investigations, data gathering, scoring of various data sources and analysis. A focus on the scoring of historic photographs and the application of archaeological field techniques in the inter-tidal zone has enabled this experience to be shared through the partnership.

University of Ghent (Belgium): The Belgian team are from the Department of Geology and Soil Science, Ghent University, and are specialists in geology, geophysics, marine and coastal environments, data processing, and interpretation and visualisation. The team has a solid international reputation in the design and application of remote sensing techniques in offshore/nearshore/coastal environments. Work has included a range of geophysical and geotechnical survey techniques to investigate submerged and buried sites and landscapes and a focus on the scoring of historic maps and charts, this experience has been shared through partnership working.

Deltares (Netherlands): Deltares are a Dutch-based research institute that specialise in the reconstruction of palaeolandscapes, based on geology, geomorphology, archaeology and historical data. Work has included the use of the mapping of deposits through archaeology and geotechnical data for understanding change and how this is represented.

The partners have worked together to pool and share their specialist experience to deliver the project, which was based around three inter interlinked activities, (a detailed methodology is presented in Section 2 of this report). The activities were:

- Activity 1. Study of archaeology, palaeoenvironment and coastal heritage features to demonstrate coastal change;
- Activity 2. Study of artistic representations of coast, recording geology, geomorphology and coastal heritage; and
- Activity 3. Data integration and presentation, including use of GIS for cross-partner working and analysis on a Channel-wide scale.

The approach was applied across a number of case study areas which provided examples of differing coastal frontages across the Channel – Southern North Sea Region. Figure 1.1 shows the location of the project case study areas, Table 1.1 and Table 1.2 highlight the main geomorphological types and coastal change processes affecting the case study areas.

Figure 1.1. Arch-Manche case study areas and partners.

Case Study Area		Main Geomorphological Type/s						
		Tidal Basin	Estuary/Creek/ Low-lying land	Hard Rock	Soft Rock	Beach	Dunes	Landslides
UK	East Anglia		✓		✓	✓		✓
	Kent					✓		
	Hastings				✓	✓		
	Solent and IOW	✓	✓		✓	✓		✓
	West Dorset/East Devon			✓	✓	✓		✓
	West Cornwall			✓		✓		
	North Cornwall			✓		✓		
France	Cote d'Emeraude		✓	✓		✓	✓	
	Northern Finistere and Tregor		✓	✓		✓	✓	
	Cornouailles			✓		✓	✓	
	Quiberon			✓		✓	✓	
Belgium	Raversijde					✓		
	Scheldt Polder		✓					
	SW Netherlands	✓	✓					

Table 1.1. Main geomorphological types of the case study areas

Case Study Area		Main Coastal Change Processes				
		Natural Erosion	Natural instability	Natural Flooding	Breaching	Human Induced
UK	East Anglia	✓	✓		✓	✓
	Kent	✓		✓	✓	✓
	Hastings	✓	✓	✓		✓
	Solent and IOW	✓	✓	✓	✓	✓
	West Dorset/East Devon	✓	✓	✓		✓
	West Cornwall	✓				✓
	North Cornwall	✓		✓		✓
France	Cote d'Emeraude	✓	✓	✓		✓
	Northern Finistere and Tregor	✓				✓
	Cornouailles	✓				✓
	Quiberon	✓				✓
Belgium	Raversijde					✓
	Scheldt Polder		✓			
	SW Netherlands	✓	✓			

Table 1.2. Main coastal change processes affecting the case study areas.

1.1.1. Activity 1 – Archaeology, Palaeoenvironmental and Coastal Heritage Data

The historical evolution of the coast provides valuable information on past trends which can help develop future coastal climate change scenarios. Present coastal landforms have developed since the last Ice Age, studies of their evolution based on archaeology, palaeoenvironmental and coastal heritage features provides a seamless timescale from the Ice Age to the mid-20th Century. Archaeological evidence also demonstrates how people were impacted by coastal change in the past.

Evidence for Activity 1 was gathered through a desk based survey of maritime heritage and archaeological sites in case study areas within the partner countries, significant sites and areas were then selected for detailed research through in-depth inter-disciplinary research including fieldwork, scientific dating and analysis. A ranking system was also developed in order to allow archaeological, palaeoenvironmental and coastal heritage features to be assessed for their potential to demonstrate coastal change.

1.1.2. Activity 2 – Historic Paintings, Maps, Charts and Photographs

Oil paintings, watercolours and prints (1770-1940), historic photographs, maps and charts depicting the coastlines of the Channel region (Netherlands to Brittany on the Continental side and Norfolk to Cornwall on the English side) were systematically appraised to establish how they can contribute to understanding of long-term coastal change. Different ranking systems were developed or refined for each of the data sets (paintings, historic photos, historic maps and charts) allowing the partners to establish the reliability, accuracy and level of information that each of these artistic representations could provide.

Case study locations covering a range of coastal geomorphological types were identified across the partner countries and a survey was undertaken to identify artistic representations and compare various artistic styles, techniques and media within different ‘Schools’ of artistic work.

1.1.3. Activity 3 – Data Integration and Presentation

The large quantity and variety of data gathered through the activities was integrated and managed in order for the datasets to form the base for analysis and resulting illustrative, modelling and presentation materials. The database produced as a result of Activities 1 and 2 contains spatial information on the sites, features and artistic representations. This allowed a GIS platform to be developed in order to view and analyse the data. The data was also used to produce illustrative presentations in order to demonstrate coastal change visually, this includes Two Dimensional (2D) and Three/ Four Dimensional (3/4D) models showing progressive change across key case study areas. Additional work included reviewing the project results in relation to the use of the outputs with a range of target audiences such as museums, galleries, schools and educators, local residents and tourists.

1.2. Summary of the Geology, Geomorphology and Evolution of the Channel Region

Understanding the geology and geomorphology of the Channel Region has been essential in the development of project activities. These aspects have a direct relationship to the changing landscape used by human populations from prehistoric times through to modern day and are inextricably linked to coast processes and changes over time.

1.2.1. Geological Overview

The Channel-Manche and Southern North Sea Region of North-Western Europe can be divided into three quite distinct geographical zones, each with their own geological characteristics (Figure 1.2). The western-most zone comprises the coastlines of Devon and Cornwall in England and the regions of Brittany and the western part of Lower Normandy in France. These zones are largely composed of ancient granite rocks that range in age from Lower Palaeozoic to Miocene (500 to 20 million yrs BP) and are characterised by rugged durable coastal clifflines that also contain outcrops of volcanic rocks (Smith *et al.,* 1975).

The central zone is dominated by younger rocks ranging in age from the Jurassic period to the Eocene (200 to 40 million yrs BP). It is marked by a line of faults extending across the Channel from west Dorset & Kent to the Cherbourg Peninsula. It includes the Hampshire-Dieppe Basin, the Paris Basin and part of the London Basin, all of which are comprised of Palaeogene sands and clays, as well as extensive outcrops of chalk. As a result the coastlines of England and France bear striking similarities in terms of the geology and resulting geomorphological features across this central zone (Mortimore & Duperret, 2004).

The eastern zone comprises the coastline of East Anglia and of Belgium and the Netherlands. The coastal zone of England is geologically dominated by the Wealden Anticline, which is comprised of Cretaceous rocks, and the London Basin. The coastal zone of Belgium comprises largely Palaeocene and Eocene sediments, which are overlain by more recent Pleistocene and Holocene age sediments, resulting from fluvio-glacial, eolian (dunes) and marine sedimentation. The Dutch coastal zone and hinterland was formed by the relationship of the main river systems (IJssel, Meuse, Rhine, Scheldt) and the North Sea. As a result the Netherlands is mostly composed of deltaic, coastal and eolian derived sediments deposited during the Pleistocene glacial and inter-glacial periods and the recent Holocene period.

The varied geological exposures outcropping around the Channel-Southern North Sea coasts have resulted in the formation of a wide range of geomorphological features and have created coastlines of considerable variety, scenic beauty and interest. The present day coastal scenery has been formed over geological time with the diverse rock formations being created or deposited, uplifted during mountain-building phases, compressed, folded and faulted, before being affected by processes including glaciation, inundation, coastal erosion, and weathering by wind and rain.

The detailed mapping work undertaken by the Geological Surveys of the member states bordering the Channel have helped identify the inter-relationships between the terrestrial and sub-marine geology, resulting in an improved understanding of coastal evolution. For example, in the Channel-La Manche between England and France, terrestrial mapping has extended to include the continental shelf, allowing the British Isles and France to be set within the European geological framework illustrating many key structural features including major fault lines, sea basins and areas of shallower sea.

The geological history does, therefore, dictate the present day structure and scenery of the Channel and North Sea coasts. Along the coast the most marked differences are often created through contrasts between those more resistant rocks, which form headlands and uplands, such as those found in the west of England and along the Brittany coast, and the softer, usually sedimentary rocks, which form the lowlands and soft cliff line coastal frontages, such as those of the Hampshire and Paris Basins and along the coasts of Belgium and the Netherlands. Large parts of the Netherlands today are below sea level and have, in the past, been covered by the sea or flooded at regular intervals.

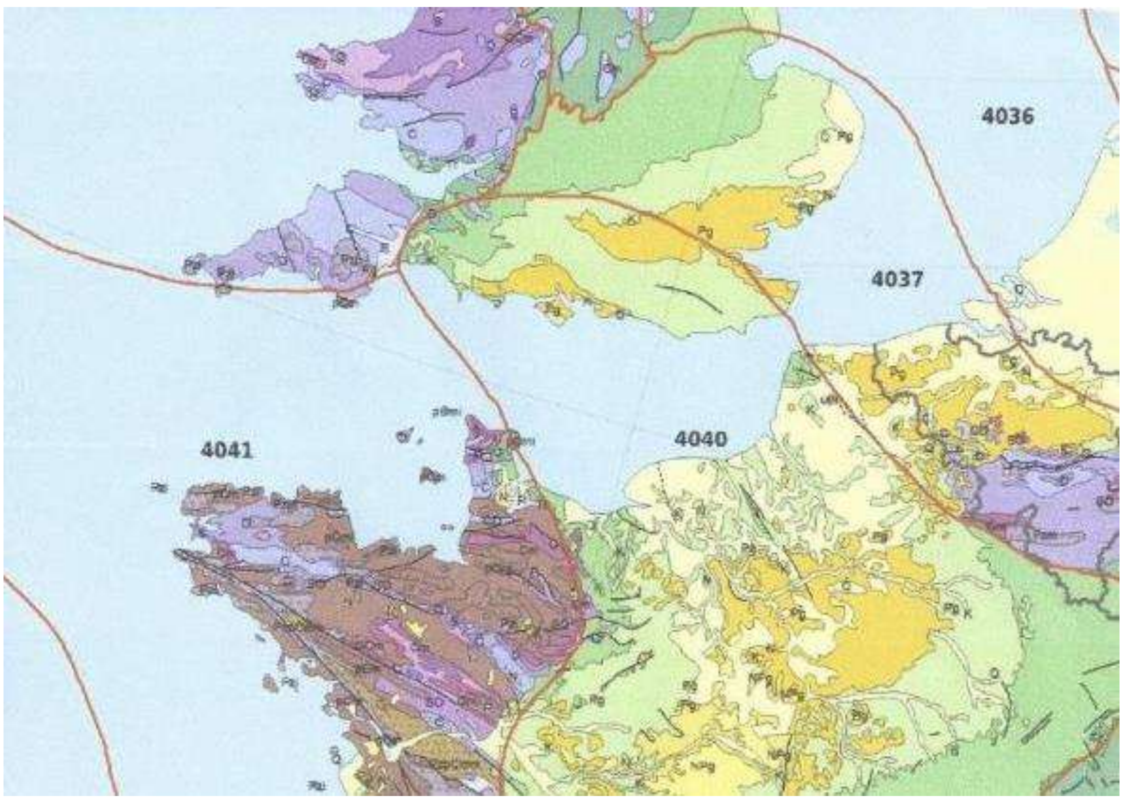


Figure 1.2. Summary geological map of the coastline of the Channel-Southern North Sea showing the relationships between the geology of the four partner countries. The oldest rocks are in the west of England and Brittany and western Lower Normandy, becoming younger. Image credit Commons Wikimedia.

1.2.2. The Evolution of the Channel-Southern North Sea Region

During the last ice ages the climate of NW Europe was extremely cold and ice sheets repeatedly covered the North Sea and large parts of the land. Sea levels fell considerably (up to 120 m during the last ice age, the Weichselian) because so much water was trapped in the growing ice sheets, and a wide 'land bridge' between England and the continent emerged. Whilst the landmasses of Northern Britain and Scandinavia (sometimes also Germany and the Netherlands) were covered by ice, a large glacial lake was formed behind the ice mass, fed by water from the mainland rivers (Rhine, Meuse, Thames, Elbe), and dammed to the south by the Weald-Artois ridge. At least during two periods in Quaternary history (Elsterian and Saalian ice age) this ice lake overspilled, resulting in a devastating flood causing dramatic deepening and widening of the Dover Strait and English Channel (Gibbard 2007).

Around 12,000 years ago the last ice sheet had largely melted, and rivers were again flowing out into the North Sea. Sea levels started to rise (but were still > 60m below present day levels), and sea water entered the southern North Sea again, through the Strait of Dover in the south and through channels along the Dogger Bank in the north. Still the land bridge between England and the continent was largely intact and early man and animals crossed over to England. Over the next three to four thousand years sea level continued to rise fast and the land bridge was gradually flooded. In the meantime the sea further invaded the English Channel. By 5000 yrs BP the present coastline was more or less reached in the Channel region.

1.2.3. Long-term Coastal Change

The Channel coastline is largely influenced by the overall geological structure and the geological periods that created major folds, escarpments, basins, valleys or other key topographical features. Elsewhere the influence of glaciation has sculptured the geology, whilst in other areas extensive deposits of more recent materials, including clays, gravel deposits, landslide debris and alluvium, form blankets masking the solid geology beneath. An examination of geological cross-sections illustrate the full extent of the folding, erosion and weathering that has taken place since the rocks were first deposited.

More recent factors that have led to the evolution and shaping of the Channel-Southern North Sea coastlines include wave size, wind speed, water depth, the strength of tides and the rates of relative sea level change, as well as rainfall and the frequency and intensity of storm events. In some locations changing rates in sea level have been dramatic over the last 30,000 years. This, in turn, has influenced the nature and severity of coastal erosion, a key factor in transforming the coastal landscapes. The influence of climate is also particularly important on the coast as rainfall and run-off carrying sediment from the hinterland down to the coast is very significant, whilst along the coast itself the rates of erosion and transport of materials by waves, tides and currents have led to the formation of beaches and sediment sinks resulting in accretion in some places and depletion in others.

The recognition of coastal change and practical experiences of the results of this over the last three centuries has clearly demonstrated that the Channel-Southern North Sea coastal zones are areas that are naturally dynamic and prone to significant changes over time and geographical extent. The factors that result in coastal change do not always operate at the same frequency, whilst some factors are more intense than others. Understanding the coastal response may be complex; particularly changes in the rates of erosion, landsliding or other factors may depend on certain thresholds being exceeded followed by periods of relative tranquillity until another threshold is exceeded. Some of the factors that lead to the more dramatic coastal changes may have, therefore, been influenced by activities in past decades, whilst others may have swift reactions. All this emphasises the need for particular care to be taken when examining coastal processes and the need to draw evidence from longer-term experiences rather than making decisions based upon data derived from a short time frame (McInnes *et al.*, 2006).

All round the Channel-Southern North Sea coastlines the influence of the geology on the coastal landscape is clearly illustrated through dramatic examples. On the Isle of Wight in southern England the more resistant chalk headland at its western end, which terminates in the famous Needles rocks (Figure 1.3), forms a marked contrast against the softer sediments to the north and to the south. In northern France the processes of coastal erosion and weathering have created a unique coastal environment of textbook landforms including sea caves, stacks and arches along the chalk cliff coastline of the Côte d'Albâtre in Upper Normandy (Figure 1.4).

Figure 1.3. Chalk cliffs at The Needles, Isle of Wight, UK. Image courtesy Wight Light Gallery.

Figure 1.4. The spectacular chalk cliff landforms of the Côte d'Albâtre, Etretat, Upper Normandy, France. Image courtesy Wight Light Gallery.

In southern England the dramatic rise in sea level during the Holocene by as much as 100m, resulted in aggressive coastal erosion, leaving many parts of the coastline in a vulnerable, over-steepened state. The effect of the erosion process has been to destabilise some coastal frontages, resulting in a legacy of landsliding and instability problems. The largest urban landslide complex in north-western Europe is the Isle of Wight Undercliff, which extends for 12km along the south coast of the Isle of Wight. A combination of coastal erosion and the effects of high ground water levels have promoted a series of landslide events within the complex, which continue to this day.

Apart from the processes of marine erosion and weathering, coastal change is taking place continuously through the natural transport of sediment around the coastline. The movement of sediments follow sediment transport pathways. These transport systems may be interrupted by major coastal headlands and estuaries or may be influenced by human activity, for example, by the construction of harbour walls or coast protection works such as groynes. Some famous examples of sedimentary features include Hurst Spit in Hampshire, which provides protection for the Western Solent (the sea separating the Isle of Wight from mainland England) and Chesil Beach on the Dorset coast in South-west England (Figure 1.5). Where rivers enter the sea estuaries, creeks and harbours exist. River systems carry sedimentary materials (usually finer silts) to the river mouth, where they may be deposited to form mudflats. Natural coastal processes may be complex in these areas with a wide range of interactions between the fluvial and coastal environments (Figure 1.6) (McInnes, 2008).

Figure 1.5. The famous Chesil Beach shingle spit in Dorset, UK, links the Isle of Portland to the adjacent coast. Image courtesy: Shutterstock.

Figure 1.6. Low lying coastal communities along the Channel –Southern North Sea coasts are vulnerable to flooding aggravated by sea level rise & post-glacial land settlement. This view shows the historic town of Yarmouth on the south west coast of the Isle of Wight. Image courtesy Andrew Butler.

Whilst the western part of the French Channel coast comprises rocks of great age including granite and volcanic rocks (Figure 1.7), which bear a striking resemblance to those found in Cornwall, the coastline to the east extending northwards through Normandy, Picardy and Nord-Pas-De-Calais as far as the Belgian border, are composed of softer rocks including the chalk, sands and clays which form part of the Hampshire-Dieppe and Paris Basins. The present French-Belgian North Sea coastal zone was shaped after the last Ice Age, when, especially between 10,000-5,000 BP, sea levels underwent a rapid rise and the gently sloping northern part of the Flemish coastal plain and the incised river mouth were flooded (Houthuys *et al*., 1993).

Figure 1.7. The hard rock coastline of Brittany in north-west France. Image courtesy: Shutterstock

Figure 1.8. Photo of Fairlight near Hastings on the coast of East Sussex, UK, Fairlight was developed close to the edge of an unstable coastline. Properties and assets have been lost as a result of both coastal erosion and landsliding. Photo courtesy of Wight Light Gallery.

East of Calais the shoreline consists of gently sloping sandy beaches backed by coastal dunes. These sandy beaches were built up over thousands of years by the action of wind, waves and tides on the supply of loose sand grains at the seaward side of the complex coastal barrier, perhaps an island barrier, whose location changed with time. At the same time, in the more sheltered areas landward of the coastal barrier, an intertidal flat developed by deposition of finely grained material and by intermittent peat formation (Houthuys, *et al*., 1993). The French-Belgian coastal plain extends for up to 20km inland from the beach barrier. Most of the plain's present day elevation is between Mean and High Tide sea level. As such, the sea would inundate the plain twice a day, should it not be protected by a continuous system of beaches, dunes and dikes.

Figure 1.9. Dunes and beach – the Zeeland coast. Image courtesy: Shutterstock.

Figure 1.10. The beach at Knokke, Belgium. Image courtesy: Shutterstock

The Dutch coastline along the south-east part of the North Sea extends for approximately 350km and consists largely of straight sandy beaches (Figure 1.9) and various large-scale tidal inlets. Large stretches of the coastline have dunes that prevent the low-lying hinterland, which is in many places below sea level, from being regularly flooded. Where dunes are absent, sea defences have been constructed as a flood protection measure (Marchand *et al.,* 2012).

1.2.4. Conclusion

It is clear, therefore, that the geological structure of the study region provides the foundation for understanding the geomorphology and coastal scenery, but it is the natural processes of erosion and weathering that adapt the geological outcrops on the coast to form the continually evolving coastal landscape and shoreline. A consideration of coastal change issues does, therefore, require, first, an appreciation of the geology and geomorphology, an understanding of the natural conditions (forcing factors) such as the wave climate (its direction and energy), rainfall, wind and temperature. In addition, there is clear evidence of long term coastal change including rising sea levels.

The erosion and weathering processes are acting upon the coastal geology creating weathered material that is being transported around the coastline by longshore drift. An understanding of these sediment transport 'pathways' is also, therefore, fundamental to development of sustainable solutions for managing the shoreline. This approach has been developed in England through the mapping of coastal littoral cells on which coastal risk management and planning can be based.

This description of the geology, geomorphology and physical processes at work within the Channel-Southern North Sea region illustrates the wide variety of conditions that exist on its coasts. The geomorphology and the dynamic coastal environment have resulted in a range of hazards, risks and management problems arising from marine erosion, coastal cliff instability, landsliding, and flooding by the sea. Approaches to the management of these coastal zones are described in Section 1.5.

1.3. Summary of the Archaeology and History of the Channel and Southern North Sea

Human populations have been utilising the Channel – Southern North Sea area for hundreds of thousands of years. During this time there have been large-scale landscape changes which have impacted territories available and the resources within them. Over time the coastal zone has been favoured for human occupation and movement, resulting in traces of activity in this area. In historic periods settlement around the coast continues to be dense due to economic and environmental factors. Understanding the broader archaeological and historic developments across the region provides the context for the in-depth work within the Arch-Manche case study areas.

1.3.1. Palaeolithic

The presence of Palaeolithic technologies in the North Sea and Channel runs from approximately 900,000BP to 10,000BP, a period that witnessed huge cyclical changes transforming the climate, landscape, varying sea-levels and creating a continuous landscape linking Britain to the continent for the majority of the period. Britain was essentially a peninsula of north-west Europe, only cut off during brief interglacial highstands (Westley & Bailey, 2013:10). The earliest evidence of human occupation in Britain is from the site of Happisburgh dating to around 814,000 – 970,000 BP (Parfitt et al. 2010). From 500,000BP onwards north west Europe was occupied by the western European species Homo Heidelbergensis, associated with distinctive Acheulean handaxes. By the middle Palaeolithic the species evolved to Neanderthals, marked by Levallois and Mousterian technology. Anatomically modern humans ultimately replaced Neanderthals by the upper Palaeolithic and the use of lithic blades and bone implements are seen in the archaeological record. Brief interglacial highstands meant that occupation of Britain was not continuous and saw periods of inward migration and depopulation. Throughout this period the position of the coast would have varied dramatically, with purely terrestrial landscapes now found in modern maritime contexts (Westley & Bailey, 2013:12).

Figure 1.11. Lithics from the Palaeolithic site of Fermanville, France. MAT.

Few sites reflecting coastal or maritime adaptations are known as many sites on our current coastline, such as Happisburgh and Hengistbury Head would have been inland sites during the Palaeolithic. Fewer submerged Palaeolithic sites are currently known, with Fermanville on the French Channel coast being the only site which has been archaeologically investigated. The site contains over 2000 knapped flints, typically Levallois, thought to be evidence of Neanderthal occupation on the continental shelf during the last interglacial (Cliquet *et al* 2011). Another important collection of associated middle Palaeolithic flint artefacts has been isolated to aggregate extraction 'Area 240' situated approximately 11km off the Norfolk/Suffolk coastline. The tools were recovered during commercial dredging which was followed by targeted grab sampling (Tizzard *et al* 2011). The remainder of finds from this period are chance finds and collections dredged or trawled from the Channel and North Sea. Such finds are predominantly known from the Dutch coast, the Zeeland ridges containing a considerable faunal collection, as well as a Neanderthal skull fragment and Levallois lithics (Hublin et al 2009). Oyster dredging in the Solent region has also recovered many Palaeolithic handaxes, blades and Pleistocene fauna.

Sites like Happisburgh in Britain and Fermanville in France contain evidence of a dramatically different climate and environment, Happisburgh, now eroding from the modern cliffs, and Fermanville, now submerged under water, have the potential to provide information on long term coastal change and the environments occupied by early hominins in the Palaeolithic period.

1.3.2. Mesolithic

The change from the upper Palaeolithic to the Mesolithic corresponds with the transition from the last glacial to the current interglacial around 10,000 BP and is mainly identified through changes in lithic artefacts, ending with the appearance of the Neolithic in north-west coastal France around 4,500 BC and across the Channel to Britain by around 4,000 BC. The Mesolithic is marked by rapid sea level rise as warmer climates released large volumes of water from extensive ice sheets back into the oceans. Britain was first cut off from the French coast then mainland Europe as water flooded the continental shelf from the west and north (Bell & Warren, 2013:35). The changing landscape was not a simple inundation but witnessed complex isostatic and eustatic changes, as well as the effects of tectonics and varying localised uplift and subsidence, this report will not go in to detail on this as much work has been carried out in recent years (such as Gaffney et al 2009, Lambeck 1995, Shennan et al 2000).

Mesolithic occupation was based on hunting, fishing and gathering lifestyles, the main archaeological remains of these mobile peoples are scatters of lithic artefacts. Sequences providing evidence of sea level rise, such as submerged forests and peats have been found around the Channel and southern North Sea coasts, often preserved in submarine contexts and in the intertidal zone (Bell & Warren, 2013:37).

Mesolithic sites have been found on the coast and underwater in the Channel and southern North Sea regions. Bouldnor Cliff in the western Solent contains evidence of Mesolithic occupation now submerged in 11m of water. This unique site provides information on the palaeoenvironment, the process of inundation and subsequent erosion, excavation has also revealed worked wood, burnt flints, charcoal, string and hazelnuts (Momber et al 2011). The site of Beg-er-Vil in north west France is a large drowned landscape, now consisting of several small islands and a rocky peninsula, evidence here from the Mesolithic period includes a large shell midden and lithics, and the nearby Teviec island contains evidence of Mesolithic burial practices (Marchand & Dupont, 2013).

Figure 1.12. Left: worked and channelled timber recovered from Bouldnor Cliff. Right: Collection of flint flakes recovered from Bouldnor Cliff. MAT.

Recent research has shown that coastal resources were regularly exploited in this period, living on the coast would have had several advantages including transportation, communication, and access to resources, including a variety of marine foodstuffs (Bailey, 2004; Momber 2014). Although there is evidence on islands and peninsulas such as Beg-er-Vil in France, and the site of Culverwell on Portland, England (Palmer 1997), large areas of the Mesolithic landscape are now submerged in the Channel and southern North Sea (Momber 2013). Such areas are largely inaccessible and challenging to explore although recent work has started to identify and target these deposits (Gaffney et al 2009, Fitch 2011). This would have been a resource rich landscape in the Mesolithic and has the potential to provide a much more detailed picture on Mesolithic communities and their responses to large scale changes in the shoreline position (Bell & Warren, 2013:43; Peeters & Momber 2014).

1.3.3. Neolithic

By the Neolithic the rate of sea-level change had slowed considerably, although small and localised relative sea-level, erosion and sediment accumulation means that the Neolithic coastline may now be submerged in some areas or further inland in others. Many of the present day islands in Brittany are the last visible remnants of Neolithic landscapes which would have consisted of large coastal plains, sites like the Er-Lannic stone circle in Morbihan demonstrates this as half of the monument now lies some 1.5 metres under water. A set of Neolithic trackways off the north coast of the Isle of Wight are also now submerged with some sections visible at low water (Tomalin 2012).

The Neolithic period is marked by more sedentary communities involved in farming which spread across north west Europe by around 4500 BC through cultural diffusion and migration; it should be emphasised that this was not a simple and sudden change to farming, there may have been several centuries when hunter-gatherer-fishers lived alongside farming communities, particularly along the coastlines in our study area (Sheridan 2010:101).

By the Neolithic, Britain was cut off from mainland Europe, however, evidence from domesticated animals and cereals, as well as the concepts of early Neolithic monuments in Britain, provide evidence of long distance maritime networks and links to the continent from this period (Sturt & Van de Noort 2013:72). Along the Atlantic façade small megalithic closed chambers and passage tombs are seen in coastal areas of western Britain, and have a clear affinity with closed chambers and passage tombs from the Morbihan region of Brittany (Sheridan 2010:92). In eastern Britain dense concentrations of Carinated Bowl pottery have been found which is thought to originate from the Nord-Pas de Clais region of France in the early Neolithic (Sheridan 2010: 99).

The Channel and Southern North Sea played an important role in this period, the sea is often perceived as a barrier, however, archaeological evidence clearly indicates that is was ‘a medium through which people, ideas and material flowed freely’ (Sturt & Van de Noort 2013:74).

Figure 1.13. Excavation of the Neolithic Groh-Colle site on the coast of Brittany, France. Le Pessec 2013.

1.3.4. Bronze Age

The transition from the Neolithic to the Bronze Age is broadly thought to be around 2200-2000 BC (although this does vary across north west Europe, see Roberts et al 2013 for a detailed discussion on the complex chronology). This period witnesses large social, economic and technological changes and the archaeological record demonstrates long and complex exchange networks across the Channel and Southern North Sea. Most of this evidence is indirect, in the form of objects which have travelled large distances, direct evidence of links across these waters is much harder to find. Sewn plank boats like the Dover boat and Ferriby boats may provide evidence of maritime activities, although it is unclear whether these were used along the coasts and rivers, or to cross the Channel/North Sea, or both (Hill and Willis 2013:75).

The Bronze Age of western Europe has generally focussed on the Atlantic façade with evidence of networks represented by the appearance of Bell Beaker material culture, with primary subsistence strategies relying on arable and pastoral farming and living in relatively small settlements. However, despite these general trends the Bronze Age evidence also suggests huge regional variation in settlement architecture, craft-working, burial practices etc. As well as this, the definitive material of the period – Bronze, an alloy of copper and tin, demonstrates regular communication and interaction across the Channel and Southern North Sea as tin is only available in central Europe and south-west England (Roberts et al 2013:38).

By the middle Bronze Age more settlement sites and field systems become visible in the archaeological record, and in the Mid to Late Bronze Age many deposition sites containing large amounts of bronze objects have been found both on land and under water. There was clearly regular contact throughout the Bronze Age across the Channel and Southern North Sea, this was not just about trade, and there may have been a common social identity across these waters as communities were in regular contact. Evidence of clear regional identities does not necessarily suggest a lack of links between communities but may have been a reflection of the need to maintain regional identities as a response to regular contact (Hills and Willis, 2013:89).

The Channel and Southern North Sea coasts were still subject to localised relative sea-level changes in this period, Wootton Quarr (mentioned earlier due to Neolithic remains) also contains early Bronze Age structures only accessible at equinoxal spring tides (Sturt & Van de Noort 2013:64), and the site of Seahenge originally thought to have been built in a saltmarsh environment was recently exposed on Holme beach.

1.3.5. Iron Age

The Iron Age began around 800 BC, the middle of the period witnesses the start of a rise in the population, seen archaeologically through an increase in settled communities and mixed farming, as well as an intensification in salt extraction, with evidence found along the coast and in estuarine environments often associated with saltmarsh grazing (Hill & Willis 2013:75).

There is little evidence for the consumption of fish in southern Britain, some later Iron Age sites contain evidence of oysters, perhaps reflecting pre-conquest contact with the Romans, such as Silchester and Owlesbury in Hampshire and Alington Avenue in Dorset (Hills & Willis, 2013:83). There is also very little evidence of seagoing boats and ships from this period, logboat finds such as the Hasholme logboat, from this period are thought to have been used in calmer waters (McGrail 1990).

Metal objects were moving across the seas in large quantities in the Bronze Age, but evidence of trade from the early-mid Iron Age is scarce, it is not until the late Iron Age that trade becomes more visible. The lack of European objects in the Iron Age does not necessarily indicate reduced contact with the continent, similarities in artefacts and ‘fashions’ implies contact throughout this period. By the 2nd century BC there is a marked increase in contact across the Channel with a large range of materials including coins, pottery and foodstuffs from France and Belgium being transported (Hills & Willis 2013:88). This period also sees marked similarities in burial forms and material culture between southern England, northern France and Belgium, including the adoption in all countries of the same coinage indicating a common social identity (Hills & Willis 2013:89).

1.3.6. Roman

The effects of the Roman conquest on the Channel-Southern North Sea coasts is visible through the construction and development of coastal settlements, the building of Roman villas, ports of trade and maritime industries (including fishing, shipbuilding, salt production and maritime defences) as well as a much deeper change in the territory and political organisation of coastal communities with more formalised coastal and cross-Channel maritime networks. Although the Roman conquest of Britain was later than that of France, Belgium and the Netherlands, a huge amount of evidence of pre-conquest maritime connections and contact exist.

Maritime activity generally shifted focus eastwards along the Channel with London becoming a major port in this period as well as Dover, being the closest point to continental Europe. Ports on both sides of the Channel contain evidence of cross-Channel trade with lighthouses and similar navigational aids existing at the entrance to harbours such as Dover and Boulogne (Walsh, 2013: 97). Evidence of coastal industrial activity includes the remains of salt extraction sites, which existed in large numbers on both sides of the Channel.

Although general rates of sea level change had reduced by the Roman period, the coastline was still changing, particularly through local geological responses, human intervention and land reclamation (Walsh, 2013: 95), although in both the UK and mainland Europe there is evidence of the abandonment of coastal marshes possibly as the result of marine transgression. In the south west Netherlands tidal channels were used to drain high peat areas further inland with ditches and channels created to drain the land for habitation and to use the peat as fuel. Large scale peat extractions in this period had disastrous consequences as this lowered the ground level resulting in flooding and increased tide storage areas. In turn the tidal channels increased in strength and size, further eroding the peat, resulting in increased tidal storage capacity. By 350 AD the Roman peat areas became completely submerged.

1.3.7. Medieval

The Medieval period of north west Europe began around the 5th Century AD with the collapse of the Western Roman Empire. The movement of people continued in this period, with Anglo-Saxons in Britain and evidence of external invasions from Vikings along much of the Channel-Southern North Sea region. In the early Medieval period we see the development of coastal and estuarine ports, these include Southampton in the UK, Wijk-bij-Duurstede in Holland and Quentovic in France.

By the 11th Century AD the period is marked by a rapid increase in population, this may be down to the ‘Medieval Warm Period’ as well as technological and agricultural innovations. The warm period was followed by the ‘Little Ice Age’ causing significant climatic and environmental change, in particular a series of North Sea storm surges from the 13th-15th centuries. These changes altered settlement patterns, coastal industries, fortifications and infrastructure (Adams & Flatman, 2013:138). By the later Medieval period much of the population was diminished by famine, plague and war, most notably ‘The Black Death’ in the mid-14th century which led to changes in settlement patterns and increased specialisation in many industries.

Land reclamation and peat extraction continued across the region, the drowning of peat areas in the Netherlands after the extensive Roman peat extraction continued and by 800 AD the whole of Zeeland was flooded. Although later silting resulted in the expansion of salt marshes, coastal communities were still affected by large and frequent storm surges. Many of the salt marshes were later diked-in primarily for the grazing of sheep as the textile industry grew, however this process then in turn increased the severity of storm surges as it reduced the water storing capacity of the salt marsh area.

1.3.8. Post-Medieval

By this period the volatile society of the Medieval period was transformed with the emergence of larger nation states, this process was largely a maritime process as the emerging nation states competed and fought largely at sea (Adams & Flatman, 2013:140). This change is also clearly reflected in the 15th-16th Century changes in ship building across north west Europe from the late Medieval to Post-Medieval period.

There was increasingly sophisticated and far-reaching trade and communication links, with major roads and river networks facilitating the movement of people, goods and ideas (Adams & Flatman, 2013: 138), particularly the trade of wool, cloth and wine across the Channel-Southern North Sea region. The wine trade was particularly extensive from the late Medieval to Post-Medieval period, with a vast amount of evidence from the under crofts and cellars in the ports for the storage of wine to documentary sources detailing the scale and geography of the trade. Most notable was the trade between Bordeaux and England.

Although the coastlines of the Channel-Southern North Sea were not witnessing dramatic changes from sea-level and climate change in this period, the biggest changes to the coasts were through anthropogenic change. Land reclamation continued in this period, with the reclamation of coastal fens and marshes for agriculture common place as well as a complex embankment process in Belgium and the Netherlands closely linked to large scale peat extraction. Embankments in these areas were also used as flood defences, although later the dykes of Saeftinghe were breached and the whole area was intentionally inundated during the Eighty Years' War.

From 1650 AD the region experienced large changes with the maritime world expanding, particularly through the English maritime Empire and navy by the 18th Century and steamships dominating long-distance trade in the late 1800's (Dellino-Musgrave & Ransley, 2013: 164).

1.3.9. Modern

The Channel-Southern North Sea region witnessed two world wars in this period, the British empire fragmented and marine industries such as fisheries began to decline. Evidence of the two world wars can be seen all along the coastlines of the region with the remains of gun emplacements, pill boxes, anti-tank defences and military installations, many of which are now threatened by coastal erosion.

The impacts of sea-level and climate change were minimal in this period, with the majority of changes associated with localised events including the silting of rivers, storm events shifting and destroying spits, and coastal erosion. Again as with the preceding periods the major changes affecting the Channel-Southern North Sea coasts have been anthropogenic, most notably; port development, small-scale land reclamation and defences (both military and against the sea).

By the 1960's the increase in coastal management programmes, coastal conservancies and nature reserves meant that fewer reclamation projects were carried out (Parham & Maddocks, 2013:187).

1.4. Imaging the Channel-Southern North Sea Region

The development of artistic representations of the coast including maps and charts extends back over 500 years. Over time the style, diversity of media and accuracy of mapping techniques has developed. While some depictions are stylistic and subjective interpretations, others have been created from a more objective basis. Through art, maps and charts it is possible to view the earliest representations of the coast in different periods. This evidence provides early sources of information prior to the development of photography, which then shows a more empirical record or 'snap-shot'. Developing an understanding of these various media has been essential in the delivery of the Arch-Manche project and has provided background for the ranking schemes which have been developed and applied.

1.4.1. Art of the Region

1.4.1.1. The Origins of Coastal Landscape Art in the Channel-Southern North Sea Region

Landscape is a term that describes the scenery and environment of the countryside and coastline. Landscape paintings depict the natural beauty of the landscape and of coastal environments, often encompassing a broad view of the coastline, the sea and the sky, together with elements such as the weather and human activities. The word *landscape* started to be used in the English language from the early seventeenth century and is derived from the Dutch word '*landschap'*, which means 'an area of cultivated land'. Those landscape paintings which depict specific subjects such as parts of the coastline, buildings and structures, are called topographical views and are commonly seen in various types of prints (engravings, aquatints and lithographs) as well as in pencil drawings, watercolour drawings and oil paintings.

The origins of landscape painting date back to the fifteenth century where landscape scenery was incorporated in the paintings of artists such as Leonardo da Vinci (1452-1515) and Albrecht Dürer (1471-1528). In the Netherlands Pieter Brueghel the Elder (1525/30-1569) also developed stylised panoramas depicting life through the seasons, as well as the daily activities of residents of the countryside and coast. During the sixteenth and seventeenth centuries there was a great emphasis on portrait painting where English artists had learnt painting techniques from the Flemish artists Anthony Van Dyck (1599-1641) and Peter Paul Rubens (1577-1640).

The interest in art was accentuated by the desire of royalty, such as King Charles I (1600-1649) in England, and the nobility across Europe to become important collectors of works of art. During the late seventeenth century and eighteenth centuries wealthy young gentlemen were starting to travel more widely and they took the Grand Tour, gaining education and aesthetic inspiration from the classical remains and Renaissance art and architecture of Italy and Greece. Art patrons were particularly impressed by the works of artists such as Claude Lorrain (1604-1682), Nicholas Poussin (1594-1665) and Salvator Rosa (1615-1673), whose paintings evoked the classical landscapes of the Italian countryside and the grandeur of ancient Rome with its fine classical architecture.

In north west Europe the *Dutch Golden Age* of the seventeenth century saw a significant increase in the popularity of landscape painting, with many artists developing skills in the representation of the landscape. Dutch artists were also influenced by the Italianate landscapes but they developed their own particular skills, for example in the field of marine art. A decline in the popularity of religious paintings started in the eighteenth century; this led to the increased popularity of landscapes, for example in the Netherlands, resulting in this genre becoming the most popular for the next hundred years. The Dutch have a long tradition of marine painting with Willem van Velde the Elder (1611-1693) and his son, Willem (1633-1707) being leading exponents. Salomon van Ruisdael (1600-1670), Aelbert Cuyp (1620-1691) and Johannes Hermanus Koekkoek (1778-1851) and other members of his family painted both fine landscapes and coastal and estuary scenes with shipping. During the fifteenth to seventeenth centuries Flanders produced some of Europe's leading artists although their importance declined after the death of Rubens and the Eighty Years War in 1648. During the early nineteenth century there was a revival in Flemish art that is generally referred to as Belgian art thereafter.

In Europe landscape painting was influenced, first, by collectors and artists returning from the Grand Tour, resulting in an Italianate style being regarded as the height of fashion, whilst also works by artists such as Thomas Gainsborough (1727-1788) started, for the first time, to comprise portraits of landowners in the settings of their country estates. This approach was popularised by Van Dyck and other Flemish artists who were working in England and in this respect they influenced Gainsborough.

The French Revolution and the Napoleonic Wars prevented travel across large parts of Europe from 1793 until after the Battle of Waterloo in 1815. This led to an increased interest and discovery of the landscapes of countries such as Great Britain. In fact, from the middle of the eighteenth century, a number of British writers and travellers such as William Gilpin (1729-1797), sought to define and categorise human responses to natural phenomena. Edmund Burke (1724-1804) described the exploration of the 'sublime' and the 'beautiful' in the context of the landscape (Burke, 1757), whilst William Gilpin travelled across Great Britain in 1782 exploring the sites of wild landscapes such as the Scottish Highlands, Snowdonia, South Wales and the River Wye, the New Forest in Hampshire and the Isle of Wight, and set out his theory of the 'picturesque' landscape in a number of publications (Gilpin, 1786).

Figure 1.14. Coastal scene at St Helens, Isle of Wight, UK. Hand coloured copper plate engraving, 1813. Robin McInnes.

What we regard today as landscape painting developed particularly in the eighteenth century and was therefore strongly influenced by Dutch and Flemish artists from the seventeenth century onwards. As populations grew across Europe and with increased industrialisation in some areas, there was a new-found appreciation of the wild and open landscapes to be found outside the cities. Later in the eighteenth century, watercolour drawing started to become a popular medium and a speciality of English artists, who were encouraged by their patrons who sometimes took artists with them to record the scenes on their Grand Tour. Artists such as Francis Towne (1739-1816), Thomas Girtin (1775-1802) and Alexander Cozens (1717-1786) were leaders in the field of watercolour drawing, shortly to be joined by others including J. M. W. Turner (1775-1851), who continued the English tradition of taking tours around parts of the country and abroad, producing numerous drawings, some of which were subsequently worked up into major landscape paintings. The romance of the English landscape was now being interpreted in a new and more precise way by artists such as John Constable (1776-1837), Samuel Palmer (1805-1881) and J. M. W. Turner. At first, watercolour drawings were not accepted by the art establishment, such as the Royal Academy (founded in 1768) but, eventually, following the formation of the Society of Painters in Watercolours in England in 1804, they were increasingly accepted as a fine addition to the world of landscape art.

In France there is a long-standing tradition for capturing the landscape through art dating back to the Middle Ages. In Fact, French artists such as Claude Lorrain played a highly influential role in the development of landscape art across Europe through paintings of the classical landscapes and pastoral scenes of Italy. A friend of Claude Lorrain, Nicholas Poussin, was also a leading figure in the promotion of eighteenth century European landscape art. Some of the first French landscapes were those by Jacques Callot (1592-1635), who was influenced by the Dutch and Flemish masters. The founding of the Paris Academy of Painting and Sculpture in 1648 also gave strong support for artists of the period. The paintings of Jean-Honore Fragonard (1732-1806), Hubert Robert (1733-1808) and Claude-Joseph Vernet (1714-1789) continued to promote the concept of the classical landscape in France through the eighteenth century.

It was in the early nineteenth century that landscape painting developed more expressively in France. Artists such as Eugène Delacroix (1798-1863) and Gustave Doré (1832-1883) encouraged by the establishment of the '*Prix de Rome du Paysage Historique'* (Rome Prize for Historical Landscape) in 1817. As the Norwich School of Artists developed in East Anglia, in England, in the early nineteenth century another group of artists gathered in the village of Barbizon near Fountainbleau south of Paris for the purpose of drawing and painting in the open air. Key figures in this group of artists included Jean-Baptiste-Camille Corot (1796-1825), Jean-François Millet (1814-1875), Paul Huet (1803-1869), Charles-François Daubigny (1817-1878) and Théodore Rousseau (1812-1867). The Barbizon School established a tradition of fine French landscape paintings that would prove to become perhaps the most influential in Europe for over a hundred years, leading to the Impressionist and post-Impressionist schools exemplified by the artists Camille Pissarro (1830-1903), Edgar Degas (1834-1917), Claude Monet (1840-1926), Pierre-Auguste Renoir (1841-1919) and Alfred Sisley (1839-1899).

On the coast, artistic communities flourished in Normandy and Brittany. Jules Noël (1810-1881) painted extensively on the Normandy coastline. At Honfleur Eugène Boudin (1824-1898) taught Claude Monet to paint and Boudin produced numerous beach and coastal scenes whilst Alexandre Dubourg (1821-1891) painted the coastal scenery on the banks of the River Seine. In Brittany, Alfred Guillou (1844-1926), Emma Herland (1856-1947), and Henry Moret (1856-1913) painted genre scenes and the landscape whilst along the whole of the Channel coast English artists including J.M.W. Turner, Clarkson Stanfield (1793-1867), Richard Parkes Bonington (1802-1828) and many others travelled across the Channel to paint coastal scenes in watercolour and oils. English artists learnt the '*En plein-air*' technique of painting from the artists of Brittany and established colonies in England in Cornwall and on the Suffolk coast at Walberswick producing works often painted out of doors.

John Ruskin (1819-1900), the English art critic, believed that landscape painting was the most important artistic creation of the nineteenth century, leading to an increased appreciation of the natural beauty of the countryside and coastline. In his book '*Modern Painters*' (Ruskin, 1843) he argued that the principal role of an artist was to achieve "*truth to nature*" and to "*observe the reality of nature and not to invent it in the studio*". Ruskin also encouraged the development of a number of artists who became influential in the mid-nineteenth century and were known as the Pre-Raphaelite Brotherhood. These artists wished to capture nature in its precise detail and beauty, often through painting out-of-doors. The works of the Pre-Raphaelites and their followers coincided with an increased interest and understanding of both natural and earth sciences following the publication '*The Origin of Species'* by Charles Darwin (Darwin, 1859) and the development of the science of geology. Many of the best geological exposures were to be found around the coastline, and this was one of a number of factors that started to attract some of the leading artists and their patrons to the shorelines of the Channel to record the varied geology and scenery.

In England in the eighteenth century there was an increasing interest in the coast particularly after sea bathing was encouraged by King George III, who bathed at Weymouth on the south coast and, later, by King George IV, who built a summer palace, his Royal Pavilion, at Brighton (1787-1823). At the same time early travellers were starting to explore the picturesque coastal landscapes of Netherlands, Belgium, France and England, and were following the aristocracy to the coast, where they had built '*Cottages Ornées'* or seaside villas in attractive locations for both health and relaxation. As 'spas' or 'watering places' started to develop and increasing numbers of visitors travelled to the seaside, taking the advice of physicians on the benefits of the coastal climate for health, artists met the demands of their patrons and started to produce views of the coastal scenery.

Improved communications and the development of coastal fishing villages into popular seaside resorts and spas, together with the expansion of the road and railway network from the cities to the coast, led to an ever increasing demand for paintings of coastal scenery. Artistic 'Schools' developed all around the European coastline, often centred on particularly attractive, aesthetic locations where artists enjoyed working together and collaborating and developing individual styles drawing on the beauties of the coastal scenery, and the impact of the meteorological conditions, such as the sunlight on the water.

The nineteenth century was the great period of English coastal landscape painting with the cliffs, shores and dunes as well as the developing ports and seaside resorts being depicted. In addition to individual works of art numerous topographical books were written, often finely illustrated with a range of media including copper and steel plate engravings, aquatints and lithographs. Alongside original works of art, these provide a rich source of information on the changing and developing coastline over a period of some 200 years. Topographical books such as William Daniell's 'Voyage Round Great Britain' containing 308 fine aquatints (Daniell & Ayton, 1814); Clarkson Stanfield's 'Coastal Scenery' (1847); Finden's 'Ports, Harbours and Watering Places of Great Britain' illustrated with steel engravings (Finden, 1838) and in France 'La Normandie Illustraée' that included views of the coast (Benoist, 1852). Other English artists including John Wilson Carmichael (1800-1868), Alfred De Breanski (1852-1928), Edward William Cooke (1811-1880) and John Brett (1830-1902) produced accurate coastal paintings. Scenes along the shoreline, often showing fishing scenes or shipwrecks, were painted in watercolour by Thomas Miles Richardson Junior (1813-1890) and Edward Duncan (1803-1882). Whilst Myles Birket Foster (1825-1899) and Charles Robertson (1844-1891) captured the same scenes in finely detailed watercolours. It is this legacy of historical art works that provide the basis for informing this study on art and its contribution to understanding long-term coastal change.

Figure 1.15. Lulworth Cove, Dorset' by William Daniell RA, 1825. Aquatint. Robin McInnes.

Figure 1.16. 'Mevagissey, Cornwall' by William Daniell RA, 1825. Aquatint. Robin McInnes.

1.4.1.2. Art of the Channel-Southern North Sea Coastlines – Literature Review

The landscape art of the coastline and countryside bordering the Channel-Southern North Sea coasts has been described by a number of authors over the last 200 years. However, the Arch-Manche project is believed to provide, for the first time, a comprehensive description of the coastal art, its history and development, and the inter-connections between the coastal paintings of these four countries. Literature accounts that include descriptions of coastal art have, historically, considered the artistic output from the whole territory of each of the four countries rather than just their coasts except where artistic colonies have developed and thrived; such locations have merited more detailed descriptions.

The literature on coastal art comprises a hierarchy of publications ranging from European art overviews, which usually describe the range of artistic styles practised across the continent (e.g. Hook & Poltimore, 1986) through dictionaries or Catalogues Raisonneés of the names of artists and their works by country (e.g. Hardie, 1966; Mallalieu, 1976; Graves, 1984; Wood, 1995; Smith, 2000; Bénézit, 2006) to national art overviews including the development of art over time (e.g. Gilpin, 1782; Burke, 1757; Clark, 1949; Pevsner, 1956; Stechow, 1966; Haak, 1984;

Sutton, 1987; Wood, 1988; Silve, 1998; Turner (Ed.), 2000; Auricchio, 2004; Ellis, from 2004; Kopp, 2009; Roger, 2009; McInnes & Stubbings, 2011).

Other publications describe artistic colonies or 'Schools' (e.g. Hemingway, 1979; Marlais et al., 2004; Marsh, 2005; Newton (Ed.), 2005; Munn, 2006; Hardie (Ed.), 2009; Kerlo & Durac, 2006; Brettell, undated; Delarre et al., 2009; Dudley Barrett, 2010; Bergeret-Gourbin, 2010; Tapie, 2010; Cariou, 2005) and finally monographs on the works of individual artists including Duffy, 2011; Reynolds, 1984; Munday, 1996; Rodrigue and Cariou, 2005; Payne, 2011; Kirby Welch & Morton Lee, 2011.

Descriptions of coastal art that relate to the selected case study locations for Activity Two 'Art and coastal change' include for Cornwall – Newton (Ed.), 2005 and Hardie, 2009; for Dorset - The Public Catalogue Foundation, Ellis 2009; Johnson, 2011; for The Solent and the Isle of Wight key reference works include Drummond & McInnes, 2001; McInnes, 2008; for Hastings in East Sussex - the Public Catalogue Foundation, Ellis 2005; for the Kent coast - the Public Catalogue Foundation, Ellis 2004; for the East Anglia study area the key reference works include Munn, 2006; Walpole, 1987; Walpole, 2009 and McInnes & Stubbings, 2010.

1.4.1.3. The Influence of Dutch and Flemish Painters on the Development of European Coastal Art

Artists from the Netherlands, Flanders and Belgium have played a significant role in the development of European landscape art, particularly in relation to the coastal and marine environments. As a result, this overview of coastal art in the Channel-Southern North Sea region commences with consideration of the Dutch, Flemish and Belgian influences.

Flemish painting thrived from the early fifteenth century until the seventeenth century. Pieter Brugel the Elder (1525-1569) produced some early landscape paintings featuring village life through the seasons. During this time Flanders also produced some of the leading artists of the period, for example, Sir Peter Paul Rubens (1577-1640), Sir Anthony van Dyck (1599-1641) and Jacob Jordeans (1593-1678). Rubens had a powerful influence on visual art and Anthony van Dyck had a deep influence on English portraiture art rather than landscape painting. This, in turn, led to other European artists being attracted to work in this artistic centre of activity. Flemish Baroque painting (i.e. the artistic style that embraced exuberance and grandeur in Europe from the early 1600s onwards) flourished, particularly in the Antwerp School. It was not just Antwerp, however, that provided the setting for creativity, and both Brussels and Ghent were also notable centres of artistic production during this period.

However, the Siege of Antwerp (1584-1585) led to Flanders becoming separated and, therefore, independent from the Dutch Republic and this caused many artists to then flee to the Dutch Republic and led to the development of landscape painting. Flanders' influence declined partly as a result of the Eighty Years War (1568- 1648) and following the deaths of leading artists, such as Rubens in 1640.

The Dutch 'Golden Age' of painting refers to a period spanning roughly the seventeenth century. An independent Dutch Republic emerged after the Eighty Years War and this new nation became the most prosperous in Europe at that time. The Dutch Republic led the field in the subjects of art, science and aspects of trade. Haarlem and Amsterdam were strong centres for painting at this time. The 'Golden Age' of paintings can be said to fall into the general period of European Baroque art, but with less emphasis on idealisation of love and more emphasis on detailed realism. This provided an excellent backdrop for the development of naturalistic landscape paintings.

It was during the seventeenth century that landscape painting began to develop into a major genre in its own right. Flemish landscapes, particularly from the Antwerp School, provided some of the first examples of this growing genre. Artists such as Rubens, van Dyck and Jordeans were pioneers in this field. However, these early landscapes were often painted primarily in the studio of the artist and were, therefore, less accurate than the styles that later developed, such as, painting '*en plein air'* (out of doors) and the Pre-Raphaelite style of endeavouring to capture nature in its most realistic form.

Drawings began to be made out of doors and these would form the basis of the paintings that would, therefore, more accurately depict the landscape in its true form. Important figures in the move towards realism were Esias van de Velde (1587-1630), who painted landscape, genre and shipping subjects and Hendrick Avercamp (1585-1634) who painted some of the first Dutch landscape paintings. The Dutch seacoast provided popular subject areas and this, in turn, formed part of the catalyst towards seascapes developing as a more popular movement within the 'Golden Age'. Hendrik Vroom (1566-1640) can be, arguably, considered as the "*first 'Dutch' seascape painter*" (Royal Museums, Greenwich, 2012) and the father of Dutch marine painting, although he was "*brought up to a Flemish palette, which he maintained all his life*" (Archibald, 1982). Jan Porcellis (1583-1632) further contributed to the genre of marine painting through his development of tonal painting - a softening and blurring of outlines and a more atmospheric effect being achieved as a result, and it can be argued that it was "*only through this development that marine painting pure and simple could come into its own"* (Stechow, 1966).

Figure 1.17. 'The Beach at Scheveningen' by Adriaen van de Velde. Oil on canvas, 1658. Image courtesy: Commons Wikimedia, 2014.

The new Dutch Republic's strong economy was based heavily on sea trade and seascapes were seen as celebrating the vibrant activity off the coast. The "*economically successful Dutch Republic prompted increased specialisation*" in this new genre (Royal Museums, Greenwich, 2012). Naval conflict and also the natural dangers of the sea provided plenty of material for the artists of the time and as a result "*Dutch painters of seascapes were thorough connoisseurs of ships as well as of the water*" (Stechow, 1966), indeed, Jan van Goyen's (1596-1656) early sketch books produced a surprisingly mature themes during the earlier period of the seascape genre. Later artists of the period included Jacob van Ruisdael (1628-1682) "*primarily a landscape painter but also did some marines*" (Archibald, 1982), Albert Cuyp (1620-1691) and Phillips Koninck (1619-1688). Although sea trade provided a plethora of material for artists, many paintings also included detail of land, beaches, harbour viewpoints and views stretching across estuaries.

The strong trade links between the new Dutch Republic and the rest of Europe encouraged the export of artistic works; many Dutch, and Flemish painters also worked abroad. The most famous artists who exemplified this trend were Willem van de Velde (c.1611-1693) and his son, also Willem (1633-1707), who moved to London in 1672. Van de Velde the Elder had a love of the sea and ships and "*perfected his technique to a level never attained by anyone else*" and as a result the "*studio of van de Velde and his son Willem, dominated marine painting in England and their style and approach to their subjects were the models and inspiration for the first generation of English marine painters"* (Archibald, 1982).

The relationship between the Old Masters of the 'Golden Age' and the beginnings of English landscape painting began to develop as artists such as John Constable (1776-1837) and Richard Parkes Bonington (1802-1828) looked to the narrative realism of the Dutch Old Masters. In particular, Constable denounced the then fashionable Italianate artists for their lack of realism and instead took inspiration from the Dutch and Flemish artists of an earlier time. In 1824 "*a sensation was caused by the naturalistic landscape paintings of the English, although they in turn owed a debt to the Old Dutch Masters*" (Dudley Barrett, 2010). A new generation of landscape painting was developing as the English drew inspiration from the Dutch. Dutch art can be noted as being particularly influential on the Norwich Society of Artists (1803-1833) or 'Norwich School', due to the history of strong trade links between Norwich and the Netherlands. The Medieval wool trade "*resulted in large numbers of classic maritime and landscape paintings in merchants' manors*" (Dudley Barrett, 2010) and it was not unusual for local gentry to have impressive collections of Old Masters such as Jakob van Ruisdael and Jan van Goyen hanging on their walls. The Norwich School "*carried on the landscape tradition*, *directly and indirectly, from the Flemish and Dutch Masters*" (Dudley Barrett, 2010). In 1821, Joseph Stannard (1797-1830), of the Norwich School, visited Holland to study paintings and indeed, his "*work tended to be highly finished like that of the Dutch masters*" (Hemingway, 1987).

The influential role of Dutch, Flemish and Belgian artists on the development of land and seascape paintings cannot be underestimated. In particular, the prosperity of the Dutch Republic created an opportunity for strong trade links with the rest of Europe and this in turn enabled works of art, and therefore artistic styles, to permeate into other countries.

1.4.1.4. The Influence of The Grand Tour

Taking the Grand Tour of Europe formed a key part of the education for wealthy young aristocrats in the eighteenth century. They travelled across Europe for several months or up to two years, accompanied by a tutor, who would oversee their studies and safeguard their morals, as well as looking after the practicalities of travel arrangements and accommodation. These gentlemen would have received, through schooling, education in languages such as Latin and Greek, and they were familiar with some of the historical literature from those countries. The purpose of the tour was to appreciate and understand the meaning of the classical landscapes of Italy and Greece in particular. However, *en route* they travelled through the picturesque mountain scenery of the Alps, as well as some of the major European cities. "*Those on the Grand Tour did not travel straight to Italy, for at that time France was regarded universally as* *the repository of all that was refined in manners and style, with a Court and attached luxury trade that all other countries sought to copy"* (Hudson, 1993).

On arrival in Italy, the well-to-do young gentry were able to purchase examples of engravings and paintings after the masters or coastal and landscape scenes that had been painted by local artists for this 'tourist trade'. Often some of the most celebrated Grand Tour travellers were accompanied by their own artists and, later, photographers, who were able to capture the great sights on the tour. For example, the English aristocrat, Lord Palmerston, took the artist William Pars (1742-1782), whilst William Beckford was accompanied by the artist J. R. Cozens (1752-1797), (Hudson, 1993). During the middle of the eighteenth century, the War of the Austrian Succession was restricting travellers across parts of Europe, and it wasn't until the 1760s that the Grand Tour reached its height of popularity. The continuing discovery of important sights such as Herculaneum outside Naples in 1738, and Pompeii in 1748 continued to excite the imagination of travellers from north west Europe. Many of the gentry returning from the Grand Tour brought back treasures from their travels including works of art in the classical Italianate styles, as well as ideas of a perfect landscape inspired by artists such as Claude Lorrain, Nicholas Poussin and Salvator Rosa.

The taste for classical Italian landscapes had been inspired by some of the earlier Grand Tour travellers such as Joseph Addison (1672-1719), who made his tour in 1699 and recorded his experiences in his publication '*Remarks on several parts of Italy, etc'* (Addison, 1799). In crossing the Alps he said that "*the Alps fill the mind with an agreeable kind of horror*", and he commented on the concept of the 'sublime', which comprised the three pleasures of the imagination – greatness, uncommonness and beauty arising from visible objects. Addison's notion of greatness was integral to the concept of the sublime. These ideas were expanded further by the Statesman and writer, Edmund Burke in his 'Philosophical Enquiry into the Origin of Ideas of the Sublime and the Beautiful', written in 1757 (Burke, 1757). Burke argued that both beauty and the awe-inspiring experience of the sublime were perceived emotionally. Burke conditioned the thinking of a wide range of artists in terms of the way they treated the landscape and the development of the concept of 'picturesque' scenery across Europe.

In Great Britain in the nineteenth century travellers still perceived the wilder landscapes as sinister and dreadful. William Daniell and his colleague, Richard Ayton toured the coast painting and describing its scenery. Ayton wrote "...*here was the ocean in all its grandeur, ploughed up by a storm, and bursting with a continued and sullen roar against precipices of rock, awful for their vastness, black and dreadful, and exposing on their battered sides a combination of* all *rugged and horrid forms"* (Daniell & Ayton, 1814). The Grand Tour was hugely influential in the development of the aristocracy's interest in art and therefore, the movement of artistic works and styles across and around Europe. The development of landscape painting owes a huge debt to the movement around Europe of the gentry during their undertaking of the Grand Tour.

1.4.1.5. The Discovery of the Coast

The British aristocracy collected the works of leading artists such as Lorrain, Rosa and Poussin enthusiastically, and collectors were soon commissioning artists to paint views of their own landscapes but finished in the 'Picturesque' style. However, the Grand Tour and travel across Europe was effectively halted between 1793 on the outbreak of the French Revolution, until the Battle of Waterloo in 1815. This situation led to a search for picturesque landscapes in locations such as the British Isles, where travelling artists and writers were encouraging a renewed interest in the landscape. Wealthy gentry, with time on their hands, who previously might have been exploring the great sights of Europe now took a renewed interest in the landscape and coastline of Great Britain, encouraged after reading William Gilpin's descriptions of his first picturesque tour to South Wales in the summer of 1770. Gilpin (1724-1804) was less concerned about the topographical accuracy of the scene than with capturing the atmosphere of a '*picturesque landscape'* (Gilpin, 1809). An enlightened educationist, Gilpin defined picturesque as "*that kind of beauty which is agreeable in a picture"* and began to expand his principles of picturesque beauty through travels across the British Isles, to locations including the Scottish Highlands, the Lake District of North West England, South Wales and the New Forest in Hampshire and the Isle of Wight.

Figure 1.18. 'On the South Devon Coast' by Samuel Edward Kelly, c.1910. Watercolour. Robin McInnes.

Where the aristocracy travelled around the coastlines of the Channel-La Manche artists and engravers followed, recording images at the request of their masters, or producing their own publications, which were often lavishly illustrated. As early as the mid-eighteenth century visitors were being drawn to the coastline. These were principally those visitors in search of health, leisure and pleasure. In 1736, for example, the Reverend William Clarke and his wife stayed for a month in Brighthelmstone, a small town on the south coast of England. Clarke wrote to his friend, a Mr Bowyer, stating "*we are now sunning ourselves upon the beach at Brighthelmstone... the place is really pleasant. My morning business is bathing in the sea and then buying fish*" (Gray, 2006). King George III bathed on the beach at Weymouth in Dorset and, later, King George IV enjoyed sea bathing at Brighton, and established his summer palace, the Brighton Pavilion, in the town.

At the same time the early travellers were starting to explore the picturesque landscapes of the French and English channel coasts a fashion for sea bathing, particularly for the benefit of health, was in its infancy. However, by the end of the eighteenth century a number of small coastal towns were starting to provide rudimentary facilities for bathers. In locations such as the Isle of Wight off the south coast of England bathing places were provided on gentle beaches where people could enter the water easily on foot, or the beach would allow bathing machines to be towed down into the sea and later drawn up above high water mark. As the demand for access to the beach increased, sea walls were constructed to provide the necessary support for sea front pavements or carriage roads that formed the first 'esplanades'.

Initially known as '*spas*' or '*watering places*' rather than seaside resorts, their future was assured as an increasing number of scientists and physicians started to proclaim the benefits of the seaside for improving the health of invalids. Sir James Clark wrote in his '*Influence of climate on the prevention and cure of chronic diseases'* of the benefits of the climate of the south coast of the Isle of Wight for one's health (Clark, 1830). '*Watering places*' often developed where natural mineral waters were found emerging as springs from the coastal cliff lines. Local physicians, with claims that they could cure a range of ailments and diseases, often highlighted the benefits of taking these waters for health'. Elsewhere the use of seawater to cure a range of diseases was also promoted.

Around the Channel coastlines of north west Europe the rapid expansion of the railway network and improved road communications linked industrial centres and cities to the coast. Main railway lines extended out towards the rapidly developing seaside towns, where fashionable seafront promenades, piers, hotels and marine villas were being built to cater for the increasing demand. The rapidly increasing popularity of both sea bathing and yacht racing, combined with better communications both on land and across the Channel were all important factors in the development of the Channel coastline.

Figure 1.19. 'Vue de la Plage de Dieppe' by Edouard Hostein (1804-1889). Oil on canvas. This magnificent oil painting shows the seafront before extensive nineteenth century took place. Image courtesy of Château Musée Dieppe.

By the early 1900s there were approximately 100 well-established seaside resorts around the Channel coasts. Visitors, wished to have a record of the views of the coastline to take back with them as a souvenir of their vacation. Before the days of photography large numbers of artists painting in watercolour and oils captured the scenery of the coast and found a ready market with these often relatively wealthy tourists. Before the days of photography purchasers were seeking images that provided an exact reproduction of the coastal views they had enjoyed so much. As a result, many fine and accurate topographical paintings were produced of the coast during the nineteenth century in particular. Even after the introduction of photography in the late 1850s works of art were still required because it was to be many decades before the innovation of colour photography became widely used, and therefore, landscape paintings in full colour continued to fulfil an important role.

The relatively expensive guide books illustrated with engravings in the mid-nineteenth century could not be printed in sufficient numbers to meet the demands of increasing numbers of visitors to the Channel coasts. The invention of chromolithography in Germany and colour plate production of paintings to illustrate books allowed much larger print runs to be achieved. Publishers such as A. & C. Black in London commissioned authors and artists to write and illustrate books covering all parts of the European coast to meet the needs of the travelling public.

In 1894 British publishers were granted permission by the Royal Mail to manufacture and distribute postcards, which could be sent through the post. Postcards produced between the 1890s and the 1920s often provided views of coastal scenery and the seaside resorts; specially commissioned watercolour artists had printed them from works. These postcards form a rich resource available to those wishing to understand coastal change on account of the accuracy of many of the portrayals.

1.4.1.6. Pre-Raphaelite Coastal Landscapes

The Pre-Raphaelite movement "*fundamentally altered English approaches to landscape painting*" (Tate Britain, 2004) in the mid-Victorian period through the introduction of uncompromising attention to detail. Up until the seemingly radical Pre-Raphaelite movement, Victorian artists had opposed change and modernisation in the countryside and wished to make their pictures as "*sentimental and pretty as possible*" (Wood, 1997). The central pillar of Pre-Raphaelite landscape painting was, therefore, a new method of painting, "*looking carefully at nature, without recourse to conventional modes of composition and expression*" (Payne & Brett, 2010). The critics of the time were said to find the work of Pre-Raphaelite landscapes as reminiscent of the "*effects which could be achieved with optical instruments, particularly microscopes and the new science of photography*" (Payne & Brett, 2010).

In 1848 the Pre-Raphaelite Brotherhood (PRB) was formed by a group of young artists, poets and critics in London. The three founding members were Dante Gabriel Rossetti (1828-1882), John Everett Millais (1829-1896) and William Holman Hunt (1827-1919). The PRB was greatly influenced by nature and the artists tried to depict nature in its truest form through the laborious study of even the smallest detail. They were unrelenting in their quest for detailed realism and would spend the majority of their time working outside and not within the confines of a studio. A leading art critic during the Victorian era, John Ruskin (1819-1900), a geologist and botanist by training, said during his Edinburgh Lectures of 1853, that *"Pre-Raphaelitism has but one principle, that of absolute, uncompromising truth in all that it does, obtained by working everything down to the most minute details, from nature and from nature alone"* (Halsby, 1986). Indeed, one of the founding members William Holman Hunt is quoted as saying: *"I purpose…to paint an out-of-door picture…with every detail I can see, and with the sunlight brightness of the day itself"* (Payne & Brett, 2010).

John Ruskin played a prominent role in the development of Pre-Raphaelite landscape paintings, including coastal scenes, through his encouragement of the artists to "*go to Nature in all singleness of heart…rejecting nothing, selecting nothing and scoring nothing*" (Payne & Brett, 2010). John Everett Millais and William Holman Hunt were among the first of the PRB to endeavour landscape paintings based on the influence of Ruskin's principles; they were striving for "*total fidelity to nature*" (Wood, 1997). It was within this canon that the landscape paintings of

John Brett (1831-1902) developed, who soon became recognised as the "*head of the Pre-Raphaelite school of landscape painting*" (Payne & Brett, 2010). However, it is worth noting that although Brett was not actually a member of the PRB, he was strongly influenced by their works. Ruskin also heavily influenced Brett and upon reading Ruskin's essay *'Mountain Beauty'*, in Switzerland in 1856 Brett decided "*in a reasonable way to paint all I could see*" (Marsh, 2005).

Many of the wider circle of the Pre-Raphaelites also devoted their attention to "*pure landscape*" (Wood, 1997), i.e. detailed realism, particularly William Dyce (1806-1864) and John William Inchbold (1830-1888). William Dyce only painted occasional landscapes throughout his career, but did so with such detail and precision that it was enough to class Dyce's work "*among the leading examples of Pre-Raphaelite detail and finish*" (Staley, 2001). His detailed study of the geology, a developing science at that time, of the coastline in '*Pegwell Bay, Kent – a recollection of October 5th 1858'* is a true example of meticulous realism in landscape painting. Dyce's oil painting of Pegwell Bay was in fact considered to be so accurate that at the time it was suggested that Dyce had used a photograph to paint from and not from sketches, as was the traditional method. Staley (2001) argues that, "*if we compare Pegwell Bay with a contemporary photograph of the same locality, we can see that in this instance Dyce not only equalled, but outdid the camera in clarity and thoroughness"*

Figure 1.20. 'Pegwell Bay, Kent – a recollection of October 5th 1858' by William Dyce (1806-1864). Oil on canvas. This very detailed oil was painted at a time when the science of geology was developing. Dyce, an artist of the Pre-Raphaelite Brotherhood, wished to depict nature in precise detail. Photograph courtesy of Tate Images, 2014.

Along with Dyce, John William Inchbold is also considered to be one of the most prominent Pre-Raphaelite painters of landscapes and was much praised by Ruskin for his detailed landscape paintings. Inchbold's '*Anstey Cove, Devon*' 1853-4 provides an example of Pre-Raphaelite detail of the coastline: "…*the colours are bright throughout, and the foliate detail in the foreground is beautifully and delicately drawn*" (Staley, 2001).

The ripples of the influence of the Pre-Raphaelites were felt throughout the art world, and many artists were inspired by their methodical approach to depicting the natural world. From Ruskin's annual reviews of art, he declared that year on year more artists were beginning to emulate the detail used by the PRB. Ruskin and William Michael Rossetti (1829-1919), the longest surviving member of the PRB, even went on to claim, in 1862, that, "*landscape came almost entirely into the domain of Pre-Raphaelitism*" (Staley, 2001). Charles Napier Hemy (1841-1917) was a follower of the PRB and his work '*Among the Shingle at Clovelly',* dated 1864, clearly shows a very detailed study of the topography and geology of the coastline.

Edward William Cooke (1811-1880) also took a keen interest in depicting the geology of the coastline with great accuracy and precision. The paintings he produced of the English, French and Dutch coastline produced "*detailed images as intense and totally realised as any from the brushes of the Pre-Raphaelite brethren*" (Munday, 1996). Furthermore, E.W Cooke's paintings are now considered to be so accurate that in the twentieth century, his work took on an "*archaeological importance. If Cooke painted or drew it, it is reliably correct*" (Munday, 1996). Charles Robertson (1844-91) is a further example of a Victorian landscape and genre artist influenced by the PRB who painted coastal views with meticulous detail.

Figure 1.21. 'Yarmouth', 1891. Watercolour. Charles Robertson (1844-1891). Robertson was a follower of the Pre-Raphaelites and portrays the extent of the saltmarsh and mudflats on the north-west coast of the Isle of Wight in precise detail. Private Collection

The Pre-Raphaelite movement and its followers' deep fascination with the natural world and capturing every detail as precisely as possible were, arguably, as revolutionary in the art world as the achievements of the Impressionists of the same period (Tate Britain, 2004). Indeed, Staley (2001) argues that "*Pre-Raphaelitism as a movement marked an almost complete break in the continuity of the English landscape tradition*". The artists were revolutionising the art world by taking their canvases out of doors and working directly from nature; the natural world was not being romanticised and the artists were unrelenting in their pursuit of detail. By looking carefully at nature and trying to portray it as truthfully as possible, the Pre-Raphaelite landscape movement provides an accurate representation of the natural world as it was seen at that time.

It is for this reason that Pre-Raphaelite works can be of particular use for those studying the chronology of coastal change.

1.4.1.7. Artist Colonies on the Channel-Southern North Sea Coasts

Coastal art colonies began to emerge in Europe in the nineteenth century and thrived until the early years of the twentieth century. In the post Napoleonic War years and after the European-wide revolutions of the early 1800s there began a gradual movement of artists towards the coastal towns of Europe. The demise of this trend continued until the outbreak of the First World War and thereafter the move towards the acceptance of the harsh realities of modernity. Art colonies emerged as village movements and gradually grew in size throughout the 1800s. Between 1830 and 1914 approximately 3,000 professional artists participated in this movement from the densely populated urban areas (due to the population explosion caused by the Industrial Revolution) into countryside and coastal locations.

There were over eighty communities around the Channel-Southern North Sea coasts and these communities can be divided into three main types: First, villages with transient and fluctuating artist populations, for example Honfleur on the French coast and Katwijk on the Dutch coast; second, villages with semi-permanent visiting and residing artists, for example, Concarneau in France and St Ives on the Cornish coast; and third, villages with mainly stable groups of artists in residence, for example, Egmond on the Dutch coast and Newlyn in Cornwall and Walberswick in Suffolk, East Anglia.

Although colonies appeared right across Europe many were clustered in France and the Netherlands. Over thirty nationalities were represented and this provided a unique international flavour. Some artists settled in one location, for example, Eugene Boudin (1824-1898) at Honfleur in Normandy, France. As a result they usually became well respected and revered within these communities. However, many artists flowed between the colonies and sought inspiration from the varied destinations at which they worked, for example Stanhope Alexander Forbes (1857-1947), John Singer Sargent (1856-1925), and Henry Scott Tuke (1858-1929).

Figure 1.22. 'Katwijk Church, Netherlands' . Image courtesy Cdr J Morton Lee.

A strong driving force that provided cohesion amongst the many varied artists of this time was that they were, by and large, informed by the narrative realism of the Flemish and Dutch. A move towards depicting the often harsh realities of life and the scenery in small coastal towns was a common objective of these colonial artists. There were some artists who wished to capture the social realities and others who wished to capture a "*literal reality now revealed by photographic images*" (Gates, 2012) of the scenery.

Painting by the coast was seen as a way to revert to a simpler way of life away from the industrialisation of many European cities. For many, however, it was simply the feeling of being drawn towards water that provided inspiration for their work (Gates, 2012). Typically, the colonies were situated at the edge of the country they inhabited, providing the artists with a "*sense of relief and release just getting there*" and, furthermore, the extreme position "*adding to a sense of…other-worldliness*" (Dudley Barrett, 2010); the remote peninsulas and coasts of Cornwall, Normandy and Brittany are examples of this. Stanhope Forbes described the "*beauty of this fair district* [Newlyn, Cornwall], *which charmed us from the first, has not lost its power and holds us still*" (Hardie, 2009). The remote coastal areas had a "*distinct topography, and ethnic particularities*" which made it almost seem like a "*world apart from the rest of Britain*" (Messum's, 2012).

The artists of the colonies shared a further common aspiration and that was to paint *en plein-air* (i.e. out of doors). The artists were keen to embrace descriptive realism and the naturalist principles that inevitably followed on from this. They were eager to paint out of doors in front of the subject and capture the subject in its natural setting. The French painter Jules Bastien-Lepage (1848-1884) was the "*major influence for this approach*" (Wallace, 2007), as he created his figures in landscapes mostly outdoors. The School of Newlyners were particularly influenced by the continental approach to painting out of doors. Indeed, Stanhope A. Forbes is quoted as saying, "*Yes, those were the days of unflinching realism, of the cult of Bastien-Lepage*" (Hardie, 2009). Many members of the Newlyn School studied in the studios or ateliers of Paris, Antwerp and Munich prior to migrating to the English coast. As a result of studying together, many artists became friends whilst on the Continent and later enjoyed not only painting together in Newlyn, but socialising together too. Forbes was a successful artist in Brittany after completing his studies there, and when he returned to England, he searched for an equivalent to the French coast and this led him to Newlyn in 1884. As a result of his success, many artists chose to follow him to Newlyn and thus the School grew in size and reputation.

Newlyners painted mainly out of doors and they particularly liked to paint local people and places and the people going about their day-to-day business. They were keen to capture the daily hardships endured by the inhabitants of the local area, "*truth and accuracy were their bedrock goals*" (Messum's, 2012) and as result of the industrial and commercial revolutions in previous years, workers' lives were at the forefront of the consciousness of the artists. Narrative realism derived from the Dutch and Flemish art schools was a strong influence and, in time, the artists looked to the Pre-Raphaelite artists' "*naturalist traditions*" of using local locations and non-professional models and usually providing a strong moral overtone to their work. Notable artists of the Newlyn School include: Frank Bramley (1857-1915); Stanhope Alexander Forbes (1857-1947); Walter Langley (1852-1922); Samuel John 'Lamorna' Birch (1869-1955); Laura Knight (1877-1970) and Harold Knight (1874-1961).

The rocky coasts of Brittany and the harbours, estuaries and chalk cliffs of Normandy pre-empted the schools of Newlyn and St. Ives in Cornwall. Open air sketching had been a common occurrence on the Northern coastline since the 1820s, pioneered by painters such as Jean-Baptiste-Camille Carot (1796-1875), Paul Huet (1804-1869) and the Englishman Richard

Parkes Bonington (1802-1828). The growing rail infrastructure in France in the nineteenth century enabled many artists to move freely around the French countryside and the industrialisation of the cities of the North in the mid-century fuelled the desire of artists to 'escape' to the unspoilt coastline. Colonies in France grew in size and number particularly during the 1870s and were often based around particular hotels and also language groups.

The art colony in Etaples on the Channel coast of Northern France was most widely inhabited by artists during the period from 1880-1914. Many artists chose to stay in the area for many years, whilst others moved freely along the coastline of Normandy and Brittany. The first French artists to paint in Etaples were widely in favour of painting *en plein-air,* for example Charles-Francois Daubigny (1817-1878) and Eugene Boudin (1824-1898). Boudin was inspired greatly by the Dutch artist Johan Jongkind (1819-1891), who encouraged Boudin to paint outdoors. Indeed, in 1862, Jongkind, Boudin and a young Claude Monet (1840-1926) travelled to Honfleur, Normandy together to work on painting the coastline entirely out of doors. The influence of Jules Bastien-Lepage was also apparent during this earlier period of the colonisation of the French Coastline and artists tended to choose humble subjects for their work in order to capture the reality of 'everyday life' of the local residents.

The coastal towns of Honfleur, Dieppe, Deauville and Trouville were popular resorts for the growing numbers of holidaymakers looking to escape from the industrialised towns. However, they still provided artists with humble subjects, such as the fishermen and women. Traditional themes of capturing nature's elements and its impact on the local residents provided a source of inspiration throughout the nineteenth century.

The latter part of the nineteenth century was an important time for the development of art colonies in the Netherlands. The Netherlands had an old culture that could provide a solid pedigree of Old Masters traditional settings and a wealth of non-literary, genre subjects. French Pleinairism had provided many of Dutch artists with inspiration at this time and as a result, Dutch art colonies flourished. The French School of Barbizon were particularly influential in the Netherlands and the Schools of Hague and Laren were even called the Dutch Barbizon. However, the Netherlands had a rich history of landscape art to draw upon too and artists' colonies had been developing in the Netherlands from as early as the seventeenth century.

There were a number of key coastal art colonies in the Netherlands: Domburg, Veere and Katwijk were particularly influential. Even from as early as the fifteenth century, Veere was a notable and wealthy city, rich in art and culture. Art loving tourists and artists flocked there particularly during the 1890s.

The town of Katwijk on the coast of the North Sea in southern Holland was attracting landscape artists from that time and throughout the next two centuries. Between 1885 and 1914, Katwijk was host to at least 879 named artists from a total of eighteen different countries and was, at this time, experiencing its peak in popularity with artists. The hard and intensive life of local fishermen was a source of great inspiration and most artists at this time were drawn to narrative realism in their style of work. A number of painters from The Hague School resided in Katwijk, such as Bernard Blommers (1845-1914), Jan Zoetelief Tromp (1872-1947) and Max Liebermann (1847-1935) (www.euroartcities.eu). Blommer generally painted genre works depicting fishermen and their wives. He portrayed them in a literal fashion, showing the impoverished and robust way of life (www.macconnal-mason.com). Maritime subjects were also of interest to him. Zoetelief Tromp was a painter of genre, landscapes and coastal scenes and spent over ten years working in Katwijk. Liebermann also painted rural workers and scenes of everyday life and believed that *"painting should be the exploration of art as the honest study of* *nature"* (www.getty.edu). The results of working in artists' colonies confirmed the trend towards objective realism, a heightened sensitivity to light and fresh colour values.

The development of artist's colonies and their largely common goal of narrative realism, in effect an accurate portrayal of the harsh realities of life for coastal workers, enabled the development of a body of work that can be drawn upon as a relatively reliable resource when studying the ever changing coastline of La Manche region.

Conclusion

This overview of the art resources of the Channel coastlines illustrates a rich art history that can be interrogated to support understanding of long-term coastal change. The case study areas lie within a region that was painted more than any other part of Europe's coastline and which illustrates how landscape art developed since the sixteenth century. Most of the major European Schools of landscape and coastal art are also represented in the region. Section 2 explains how this rich art heritage can be evaluated in order to identify which artists and their works can be relied upon in terms of providing accurate depictions of coastal conditions at the time.

1.4.2. Maps and Charts of the Region

Historic maps provide an important source of information on studying coastal evolution. From the late Middle Ages onwards, maps rapidly increased in detail and quality. These maps can be used for coastal research, for instance by *georeferencing* the maps (fitting the historical map on the present day situation) and *digitizing* (drawing polygons, lines or points) elements like the evolution of the former shoreline in a GIS (Geographical Information System).

Although cartography is often regarded as a quite recent phenomenon since most remaining maps hail from the post-medieval period, the origins of cartography are to be found far earlier. Petroglyphs from the Stone Age show land use maps and places where herds were gathered. On Egyptian monuments depictions of land surveyors and their activities have been found. Land surveying techniques became more refined during the Greek and Roman periods. After the Roman Empire collapsed these techniques diminished in western Europe. The typical worldview of the Middle Ages was visualized in so called T-O-maps (Figure 1.23) containing three continents (Asia, Europe and Africa) surrounded by water and Jerusalem at the centre. More pragmatic were the "itineraria" (depicting how to travel from one to another place), the "portolans" (nautical navigation maps) and "isolaria" (maps depicting islands) that appeared at the end of the Middle Ages (De Maeyer et al 2004).

From the end of the 15th and in the 16th century major cartographical innovations took place. The main factors responsible for reviving land surveying and cartography were the rediscovery of ancient texts on land surveying, the great explorations, the development of book printing techniques, the development of the instruments used and the development of trigonometry. At the same time, the Low Countries, Germany and Italy became a centre of cartographical production (De Maeyer et al 2004:28-9). In Flanders, the Louvain University was an important centre of cartographical studies (Bossu, 1982:19). However, the still remaining maps of this era mainly focus on the regional or supraregional level. The maps of Pieter Pourbus (Brugse Vrije, 1561-1571) is one of the finest examples (Figure 1.24).

Figure 1.23. Typical T-O maps as found during the Middle Ages. Left an original example and right a reconstruction of the typical shape and contents of these maps. Left: http://kellyhayner.blogspot.be; Right: http://geography.about.com (05/04/2013)

Figure 1.24. Territorial map of the district of Bruges (Franc de Bruges) by Pieter Pourbus, 1561-71 (Groeningemuseum Brugge, I0220.I).

In terms of north west Europe the Flemish Cartographer Gerardus Mercator (1512-1594) sought to correct previous maps with his Mercator Projection. The first atlas containing maps was prepared by the Antwerp cartographer Abraham Ortelius in 1570, and a succession of eminent cartographers followed including Hertman Moll and Nicholas de Fer in the seventeenth and early eighteenth centuries. In fact the Low Countries led the world in the production of maps from the sixteenth century including Blaeu, de Wit, Hendrick Doncker and Pieter Goos.

Important cartographical innovators were at work at Louvain University: Gemma Frisius, who refined the trigonometry; Jacob van Deventer, who produced the famous maps of the Low Countries' provinces and very detailed city plans; and Gerard Mercator, famous for his projection system (Koeman, 1983). In the 17th century the centre of cartography shifted from Flanders (Louvain and Antwerp) to the northern Netherlands (Leiden University and publishers from Amsterdam (Bossu, 1982)), after which there is a large growth in the production of (more and more large scale and detailed) maps.

The first English attempt to compete with the Dutch was by John Seller with his publications *The English Pilot Books I and II* (Seller, 1671-72). During the seventeenth century maps were produced of the British coastline in order to try and reduce the number of shipwrecks in vulnerable locations, these being funded by insurance companies such as the East India Company.

In England, Blaeu and John Speed started to produce maps of each county from the early seventeenth century. Although these maps contained some topographical detail they were not generally accurate. On the coast the Warden of the Cinque Ports had been responsible for producing surveys and charts since the reign of King Henry VIII. However, it was Samuel Pepys, First Secretary to the Admiralty in 1673, who encouraged King Charles II to carry out the first complete survey of Britain's harbours and coastline. In England the preparation of accurate maps was encouraged further by a competition launched by the Royal Academy of Arts (RA) in 1759, which offered an annual prize for the most accurate survey of any county.

John Cary published an atlas of smaller English county maps in 1787, which became in great demand as people started to explore the coastline. In 1801 such private cartographers started to receive competition from the Ordnance Survey (OS) but the OS spent some fifty years on triangulation of the whole of England before their first One Inch OS Map was published in 1853. Maps were almost always included in topographical books from the late eighteenth century, and authors such as Sir Henry Englefield, an antiquarian and geologist, prepared one of the first geological maps and cross-sections of the Isle of Wight, Hampshire and Dorset coastlines with the assistance of his geologist friend, George Webster (Englefield, 1816). During the late eighteenth and nineteenth century maps became increasingly detailed and informative; John Roque, Bowen and Kitchen, John Cary, Thomas Moule and William Hughes being the best known.

However, the quality and detail varies widely between different maps, and simply using them with the assumption that they depict an accurate image of the former (coastal) situation, would probably induce large and unknown mistakes in the coastal reconstruction. Therefore it is important to analyse the quality of a map, before starting the actual interpretation, the methodology for this is outlined in Section 2.

1.4.3. Photography of the Region

The concept of 'photography' based upon the principle that exposure to light can alter some substances to create images, was developed in the early nineteenth century. After several early attempts at development of the process Louis Daguerre produced the first 'Daguerreotype' image in the 1830s and this eventually became available commercially. However, the exposure time took several minutes and this meant that there were limitations on the choice of subject matter.

Photographic processes were refined by William Henry Fox Talbot who managed to create photographic negatives on paper in 1835. Over the next five years, through experimenting with various chemicals, the method was much improved enabling the processing time to be further reduced. Early photography involved the use of large glass plates and although heavy and cumbersome some of the early images were extremely good particularly after the development of collodian emulsions. Early photographs were mainly portraits where the sitter could remain still. The quality was improved through the development of the bellows camera in Paris in 1847 allowing views to be focused for the first time. The development of photography coincided with the period of Victorian travel particularly to the seaside. From the late 1850s beach photographers were present in many resorts and spas and became extremely popular.

Those interested in coastal scenery, geology and heritage started to use this new medium to record their travels and finds; these now form a rich resource for research into long-term coastal change. However, photography continued to be a black and white process until the early 1900s when the autochrome plate was introduced in 1907. Up until the end of the Edwardian era art remained the only medium for depicting landscapes and coastal scenery in full colour.

Postcards originated in Vienna from 1869; this was followed in Great Britain the following year and soon they became widely available across Europe. Photographic images started to appear on postcards from the late 1870s and later included also reproductions of watercolour scenes of the coast.

During the 19th century the development of photography was gathering pace with experimentation using a range of equipment and chemical processes to capture images. One of the social processes driving development was the demand for portraiture from the emerging middle classes on the back of the industrial revolution. Although a number of photographs exist from the 1830s onwards it is not until the 1850s when a broader range of images are available including some wider viewscapes.

The real expansion in photography occurred in the 1880s when the modern photograph process became established with the use of paper or film rather than photographic plates. The first widely available Kodac camera went on the market in 1888, meaning photography became available to the mass market (http://www.all-art.org/history658_photography3.html).

1.5. The Challenges of Coastal Management in the Channel – Southern North Sea Region

The Channel – Southern North Sea coastlines are subjected to the natural processes of weathering, coastal erosion, landsliding and flooding. The impacts of these processes vary from one part of the coastline to another depending on the geological structure, the durability of the rocks outcropping along the coastline as well as the relative exposure to the effects of waves and tides. Waves and currents transport natural materials around the coastline, eroding some places, transporting material by the process of longshore drift and depositing it elsewhere. Human activity has taken place on parts of this continuously changing and evolving coastline over thousands of years.

In those locations where anthropomorphic development has taken place efforts have often been made to protect people, property and infrastructure from the impacts of natural hazards such as coastal erosion and sea flooding. This has often been achieved through the construction of sea walls, which continue to provide vital protection for many historic coastal towns and seaside resorts as well as for assets such as power stations, oil refineries, port installations and coastal roads and railways. However, in some locations the construction of coastal defences has had a detrimental impact on natural coastal systems. This has sometimes impacted beaches and salt marshes through increased erosion or instability problems through downdrift.

Significant lengths of the coastlines bordering the Channel-La Manche and the Southern North Sea are densely developed. The most rapid urban development can often be traced back to the nineteenth century or before when, for both health-giving reasons and on account of the popularity of sea bathing, the coastline became popular for recuperation, relaxation and recreation. Development pressures have highlighted the need to reconcile the needs of a diverse range of coastal users without increasing damage or pressure on the natural environment.

The last twenty years have witnessed a marked change in the philosophy adopted by those with an interest in the coast. In particular there has been the recognition that there is a need for those involved in coastal management to work more closely together. An appreciation has developed of the fact that the natural processes taking place around the coastline are not restricted to administrative boundaries but operate over much longer sections of coast (called ‘sediment cells’) and that decisions on coastal issues can often be made most effectively by examining these longer stretches of coastline as an entity.

Figure 1.25. Victorian seaside developments at Hastings, East Sussex, UK, c.1890. Robin McInnes.

Figure 1.26. Bathing machines line the beach at Ventnor, Isle of Wight, UK, c.1900. Robin McInnes.

Coastal research promoted by the European Commission (European Commission, 1999, 2002, 2007, 2011, 2012) has demonstrated the need for the wide-ranging groups with an interest in the coast to work together in order to achieve what has become known as *Integrated Coastal Zone Management* (ICZM). Coastal risk management is just one part of this, but taking account of the assets worth billions of Euros that are protected by coastal defence structures it forms a very significant component of to this management process.

In recent years there has been an increasing recognition that, wherever possible, the natural physical processes of erosion, sediment transport and deposition should be allowed to prevail and that coastal defence can be achieved most effectively by trying to 'work with nature', for example by encouraging the build-up of beaches as a very effective form of natural coastal defence. Clearly the situation will vary from one part of the coastline to another and the most appropriate solution to any coastal defence problem must be considered taking account of all relevant factors. However, if we are to prevent further deterioration of the natural quality of our coastline much more thought must be given to achieving a better balance between the human, socio-economic and natural factors along the coast.

All the partner countries have appraised those assets that are at risk from natural hazards such as coastal erosion and flooding (McInnes *et al*., 2000, 2006; European Commission, 2004).The extent of coastal development has led to increasing demands for the implementation of sustainable strategies for the management of coastal risks. The cost of providing coastal defences form a significant item of public expenditure. It is very important; therefore, that local government and other organisations that plan and construct coastal defence schemes should ensure that the proposed solutions are effective in the long-term without detriment to the coastal environment.

Many professionals involved in coastal risk management around the Channel-Southern North Sea coastlines believe that meeting the challenges of climate change is the most important issue to be faced by decision-makers and the communities they represent. An enormous amount of research and investigation work is taking place in order that appropriate decision-making can be implemented through the planning and political processes. Steadily improving forecasting now being achieved at the regional and sub-regional scales will be of particular value alongside strategic coastal monitoring programmes (Parry, 2000; Foresight, 2004; McInnes *et al*., 2006, Channel Coast Observatory, 2014).

The climatic changes, predicted over the next century are expected to increase risks from coastal erosion in two ways. First, sea level is likely to rise by approximately 1m over the next 100 years, resulting in increased frequency of wave attack at the cliff base and more efficient debris removal from the foreshore as well as beach steepening. By the year 2050, the rise in mean sea level is predicted to increase the frequency of extreme High Water levels from once a century to, typically, once a decade.

Flood risk is determined not by the mean tide level but by the level of extreme tides that are caused by a combination of astronomical and meteorological events. Research is continuing to determine the rate of rise of these extreme tides, which identify the defence levels required. Since its establishment in England following the 1953 floods, the Storm Tide Warning Service has been developed to allow improved flood warnings and thereby reduce the risks to life from tidal floods. The key impacts of climate change are, therefore, rising sea levels, possible changes in wave direction and intensity and increases in rainfall with a predicted concentration in the winter, as well as a tendency for more unsettled weather patterns. It is necessary for those involved in coastal risk management to try and influence their own future ability to manage risks on the coast.

Clearly, the next 50-100 years are going to be challenging for those involved with managing the Channel – North Sea coasts. Considerable progress has been made at European, national and local levels but the response by politicians and practitioners varies. The implementation of sustainable policies for coastal risk reduction must involve solutions that are appropriate from a technical point of view as well as being justifiable economically and without detriment to the environment. An enormous amount of research is being undertaken by the European Commission, academic institutions, research centres, NGOs and those involved in central and local government. The exchange of information and dissemination of results is a fundamental requirement to achieving successful management of the Channel-Southern North Sea coasts. This is being achieved at the European level through networking as part of the Interreg, LIFE Environment and VIIth Framework Programme projects as well as by the various administrative tiers in member states. All organisations that are receiving funding for coastal research have a responsibility to ensure that results of their studies are properly disseminated; this philosophy is a cornerstone for European Union funding programmes.

Figure 1.27.Storm surges create huge waves in Freshwater Bay on the Isle of Wight during storms in January 2014. Image courtesy Anna Mustchin.

1.5.1. Assessing the coastal hazards and risks

The natural hazards of erosion, landsliding, breaching and flooding have significant impacts along the Channel – Southern North Sea coastlines. The costs of emergency action, remediation and prevention can often represent a significant burden to the communities affected, often local authorities with limited resources as well as for the government. It is now accepted that the impacts of climate change on the coast are real and that sea level rise, in particular, poses serious risks to coastal communities in terms of increased rates of coastal erosion, an increased frequency of landsliding as a result of a wetter climate, accelerated toe erosion and increased sea flooding.

When these hazards interact with society, coastal risks arise. Risk-based decision-making is seen to provide the means of addressing the challenges put forward by climate change and sea level rise. Risk-based approaches allow an appreciation of the degree of risk reduction and the residual risk that must be borne by society or individuals after mitigation measures have been implemented. In order to identify the risks to assets, it is necessary, first, to establish the current level of risk, and then to gain an understanding of the potential increase in frequency and magnitude of hazardous events as a result of coastal climate change.

The varied geophysical and climatic characteristics of the four partner Member States make them susceptible to a range of extreme natural events. Natural hazards such as coastal erosion, flooding and instability are common features of their coastlines and have the potential to pose significant threats to the coastal communities. Operating on different timescales they present a varying degree of risk, coastal erosion being a relatively gradual process whilst flooding and landsliding are more spontaneous, episodic events that may be relatively more difficult to predict and are potentially more costly to address as a result.

KEY TERMINOLOGY

HAZARD A threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period or area.

MITIGATION Actions that reduce the potential cause of an event e.g. reducing greenhouse gas emissions to help reduce the extent of climate change.

RESIDUAL RISK The remaining risk after coastal management has taken place, i.e. unexpected events and highly severe flooding.

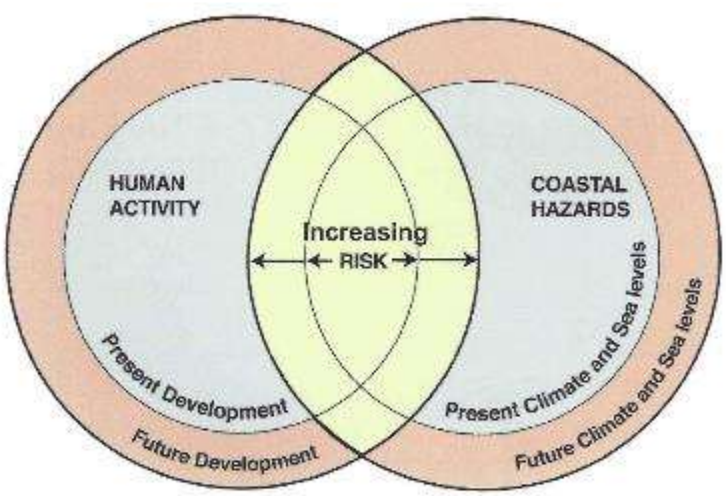
RISK Expected loss (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and preference period. Based on mathematical calculations, risk is the product of hazard and vulnerability.

Risk = Hazard x Potential Worth of Loss

Table 1.3. Key Terminology for Hazard and Risk.

1.5.1.1. Coastal Erosion Risk

Coastal erosion is a natural process that has helped to create the different landforms we see along the coast. The erosion process leads to change over long periods of time but may also promote more major landslide events or cliff failures through wave-induced undercutting and beach lowering. Sea level rise, as well as a predicted increase of frequency of extreme weather events, will have a significant impact on cliffs, slopes and beaches. The maintenance of beaches relies on the balance between the supply and removal of sediment. A rise in sea level, pushing the high water mark further up the beach, whilst more aggressive stronger waves and unpredictable weather events will increase the risks arising from beach change.



The concept of risk as the interaction of the human environment with the physical environment is illustrated. Only when the two systems are in conflict do hazards such as coastal erosion, landsliding and flooding become a threat to the community. Of particular importance is the fact that as urban development increases, intensifies or spreads into vulnerable areas so the potential impact of hazards also increases.

Figure 1.28. Coastal Hazards, Human Activity and Risk

Thus the hazard of coastal erosion will increase for coastal communities leading to:

- Risks to life, property, infrastructure and natural resources; and
- Destruction of natural or humanly formed-made defences, which, in turn, may result in retrogressive landsliding or flooding of the hinterland.

This highlights the importance of understanding the risks; identifying potential 'hotspots' and developing strategies that will inform land-use planning by ensuring decisions are compatible with specific local coastal conditions in the context of climate change (McInnes *et al.,* 2011).

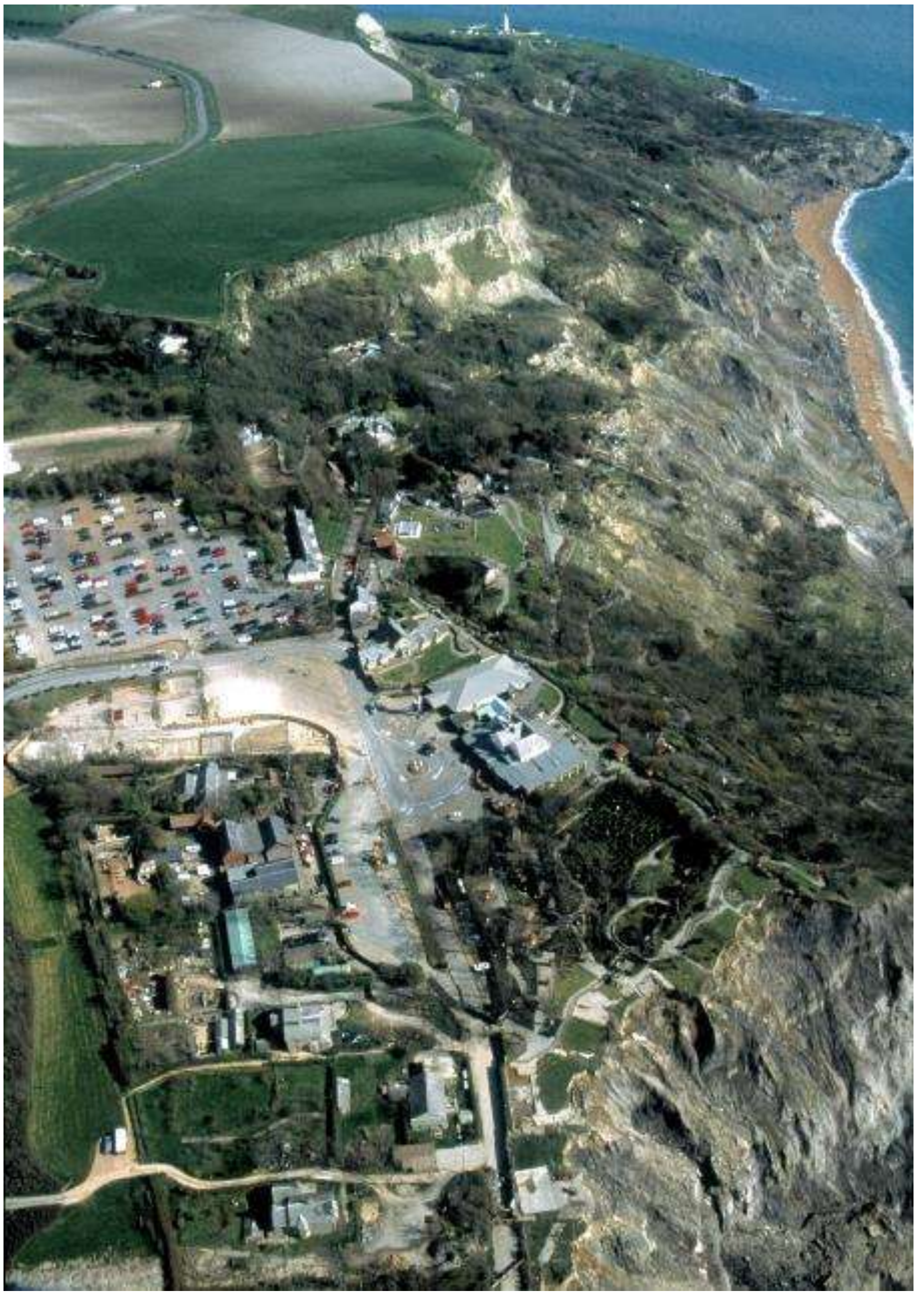


Figure 1.29. The village of Blackgang on the south west coast of the Isle of Wight, UK is attacked by south westerly storm waves. Erosion and instability problems have resulted in the loss of much of the village with the sea cliff retreating by over 300 metres in the last century. Image courtesy Andrew Butler

1.5.1.2. Landslide Risk

Over the last thirty years there has been a significant increase in landslide activity along the English and French Channel coasts, comprising both first-time failures as well as the reactivation of dormant landslides. These events have been promoted as a result of increased landslide toe erosion on the coast coinciding with increasing amounts of winter rainfall. In these locations ground instability poses significant risks to land use and anthropomorphic development. Landslide events have caused substantial damage and loss of property and assets, and problems have often arisen in the past because of the lack of co-ordination between land use planning and decisions over coastal defence and other strategies. Parts of the study area coasts have suffered from an inheritance of unplanned communities and developments built on eroding cliff tops and in other unsustainable locations – often, but not always, a result of nineteenth century development, or mass speculative development in the early twentieth century.

Whilst major landslide events inevitably lead to significant losses and damage to property in developed areas, minor, longer term failures can also have costly implications through disturbance of structures and damage. This again accentuates the importance of integrating natural hazard management into land-use development and planning policies, particularly as there are few mitigation measures that can be implemented to combat more major ground movement events that occur with little or no warning.

1.5.1.3. Saltmarshes

Coastal saltmarshes form the upper vegetated parts of intertidal mudflats, creating a 'living' buffer between land and sea and providing a valuable habitat for birds and invertebrate species. Saltmarshes are located in sheltered areas, regularly inundated by the sea between high water neap and high water spring tides. Saltmarsh systems are characterised by vegetation that shows distinct landward zonation from mudflat through to low or pioneer marsh, middle marsh, high or mature marsh and terrestrial vegetation. This succession is according to frequency of tidal inundation and species competition (Cope, S. in McInnes *et al*., 2011).

Figure 1.30. Newtown National Nature Reserve on the Isle of Wight, UK is at risk from inundation by the sea. This could lead to a loss of important inter-tidal saltmarsh and mudflat habitats. Image courtesy Andrew Butler

1.5.1.4. Erosion of Dune Coastlines

When dry intertidal sand is blown on or along with frequent, strong winds sand dunes develop. Sand becomes trapped around small objects such as strandline material, which eventually becomes vegetated, forming embryo dunes. As the embryo dunes increase in size they are less frequently covered by the tides, allowing more vegetation to colonise and in turn secure the system further. The survival of sand dune systems is very much dependent on a steady supply of sand and the ability of the vegetation to maintain ground cover whilst migrating inland with sea level rise. The extent of frontal dune erosion may increase over this century as a result of increased storminess and sea level rise, and this may have negative impacts on the extent of some dune habitats and the effectiveness of dune systems as flood defences (Pye *et al*., 2007).

Figure 1.31. Dune coast near Ijmuiden, Netherlands. Image courtesy: Shutterstock.

1.5.1.5. Barrier Beaches, Spits and Fringing Barrier Beaches

Barrier beaches are linear shingle features, attached to the coastline and backed by lowland or lagoons. Conversely, spit features are comprised of either shingle or sand, are attached to the coastline at their proximal end and are free standing at their distal end. Both systems offer a dissipative barrier against wave attack and often provide shelter to intertidal habitats. Barrier beaches and spits are dynamic features undergoing landward rollover through processes such as overtopping, overwashing and breaching. Where sediment input keeps pace with sea level rise the barriers will migrate onshore through landward rollover and spits will continue accumulating sediment at their distal ends. A continuous barrier beach, starved of sediment, will eventually be completely overwashed during a high storm or swell wave event or will breach to form two spits. Where sediment supply increases in time, these spits may re-seal to form a continuous barrier beach once again (Cope, S. in McInnes *et al*. 2011).

Figure 1.32. Hurst Spit, Hampshire, UK The Spit protects properties and rare saltmarsh habitats in the Solent between Hampshire and the Isle of Wight on the central south coast of England. Image courtesy Andrew Butler

1.5.1.6. Coastal Flooding

Coastal flooding, affecting villages, towns and cities along the Channel – Southern North Sea coastlines, can result from a combination of tide and surge levels that exceed the levels of sea walls but are more usually due to wave action in combination with high water levels. Near to the shore the maximum wave height is closely related to the water depth and the amount of wave run-up and overtopping is a function of the nature and configuration of the shoreline. Coastal defence infrastructure including sea walls, tidal barriers and related measures influence pathways and aim to control the impact that water flowing over defences or through breaches can have on the coastal floodplain. Sea walls often operate in combination with beach and foreshore management techniques such as beach recharge, groynes and breakwaters to control wave energy and improve the resilience of the coastal structures and limit wave overtopping.

Without suitable action it is expected that flood risk will increase to unacceptable levels affecting not just people and property but also businesses, hospitals and emergency services. The integration of flood risk into the planning and development process is one way of helping to reduce future costs for coastal communities in terms of economic, social and environmental losses.

Figure 1.33. The city of Portsmouth, Hampshire, one of Britain's great maritime ports, was developed on several low-lying islands. The city is densely populated and vulnerable to the impacts of climate change and sea level rise. Image courtesy Wight Light Gallery

1.5.2. Quantifying and Mitigating Risks

The risks resulting from natural hazards along the Channel – Southern North sea coastlines fall broadly into three categories: economic, social and environmental. The direct economic costs can be divided into two main categories:

- The costs of emergency provision and remediation in the occurrence of a hazardous event (most applicable to landsliding and flooding); and
- The financial costs of mitigation against the risks associated with natural hazards.

Economic costs are the greatest in financial terms and are perhaps the most important from the perspective of local authorities and other organisations responsible for managing coastal risks. However, there are also other 'indirect costs' such as insurance costs, depreciation of property or land values and legal actions.

The cost of an emergency response may include emergency coast protection works, evacuation, provision of temporary accommodation, and mobilisation of emergency and relief services, cost of investigations, transport delays and other interruptions. Mitigation is also very costly and involves research into coastal evolution, hazards and risks and the preparation of high-level plans and strategies to support the formulation of planning policies; the cost of coast protection schemes including design and construction, as well as the cost of coastal monitoring.

The **social** costs of natural hazards are largely intangible. Fatalities can be measured in real terms whilst health-related factors such as stress and depression, which may be related to risk, cannot be measured in the same way. Other factors that may impact upon the individual or society are largely related to inconvenience and are also difficult to measure.

Environmental costs are difficult to quantify because natural hazards promote natural coastal change. There is a wealth of ecologically important sites in coastal zones of the partner Member States and legislation requires the protection of these sites from erosion or flooding in order that they are maintained in a favourable condition. Environmental mitigation and, where possible, enhancement often results in significant additional costs for construction projects (McInnes *et al.,* 2011).

1.5.3. Coastal Research, Demonstration and Networking Projects

The important role played by the European Commission in encouraging the implementation of integrated coastal zone management has been highlighted earlier. Research, studies and investigations have been undertaken through projects receiving financial support from the Framework Programmes, the LIFE Environment Programme and the Interreg projects relevant to the Channel-Southern North Sea coasts include: 'Coastal change, Climate and Instability' (LIFE Environment, 1997-2000); 'Response – Responding to the Risks from Climate Change on the Coast' (LIFE Environment Programme 2003-2006); 'EMDI – Espace Manche Development' (Interreg, 2004-2007); 'DEDUCE – Développment Durable des Côtes Europeénnes' (Interreg, 2004-2007); 'CONSCIENCE – Concepts and Science for Coastal Management' (FP6, 2007-1020); 'C-SCOPE – Combining Sea and Coastal Planning in Europe' (Interreg, 2008-2014); 'CAMIS – Channel Arc-Manche Strategy' (Interreg, 2009-2013) and 'CC2150 – Coastal Communities 2150 and Beyond' (Interreg, 2010-2013).

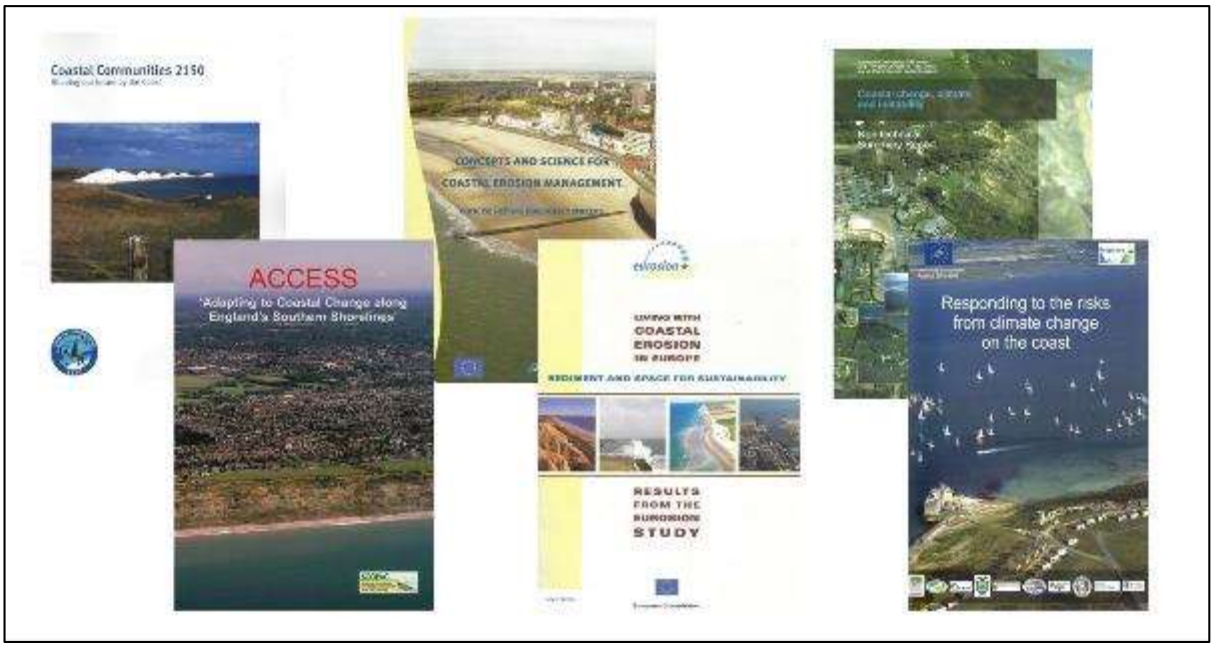


Figure 1.34. Some important studies that have provided valuable data and information on coastal hazards and risks.

Many of these projects have taken forward recommendations contained in the EU 'Recommendation on ICZM' (European Commission, 2002) and from the EUrosion project (DG Environment, 2004) and the more recent 'OURCOAST' project (DG Environment, 2009-2012). Coastal zone management has been developed actively in the four partner Member States bordering the Channel – Southern North Sea (England, France, Belgium and the Netherlands) in response to risks from coastal erosion, sea flooding and landsliding. Policies, management arrangements and research initiatives in the partner Member States are outlined briefly below.

1.5.4. Coastal Management: England

1.5.4.1. Coastal Risk Management

In response to the EU 'Recommendation on ICZM' the government published its 'Strategy for Promoting an Integrated Approach to the Management of Coastal Areas in England' in 2009 (Defra, 2009). This strategy has been implemented by Coastal Fora such as the Solent Forum and the Dorset and Devon Coast Forums along the south coast of England. This ICZM framework policy document included within it the concept of 'coastal risk management'.

Policies concerning coastal risk management, instability and land-use planning developed at a national level are principally implemented at the level of local government or by the Environment Agency in England. Planning systems are designed to regulate the development and the use of land in the public interest. Such legislation usually aims to provide:

- Guidance, which will assist in planning the use of land in a sensible way and enable planning authorities to interpret the public interest wisely and consistently;
- An incentive, with local authorities stimulating development by the allocation of land in statutory plans; and
- Development control to ensure that development does not take place against the public interest and to allow people affected by development to have their views considered.

Since the mid-1980s, however, there has been a notable change in perception about the way in which coastal risk managements' problems are managed. These changes reflect a growing appreciation that the past approach was not in the public interest, namely that:

- Approval of developments in vulnerable areas can lead to demands for expensive publicly funded coastal defence works;
- There are possible adverse effects of development on the level of erosion or flood risk on adjacent coastal frontages;
- Coastal defence works can have a significant adverse effect on the interests of other users in the coastal zone; and
- Coastal defence works can encourage further development to take place in vulnerable areas, increasing the potential for greater losses when extreme events occur.

In addition to coastal erosion large parts of the coastline are vulnerable to the effects of coastal flooding. Flood defence policies usually aim to reduce the risk of flooding to people and the developed and natural environments by encouraging the provision of technically, environmentally and economically sound and sustainable measures. This objective can be achieved by:

- Encouraging the provision of an adequate and cost-effective flooding warning service;
- Encouraging the provision of adequate flood and coastal defence measures, which are economically, technically and environmentally sound and sustainable; and
- Discouraging inappropriate development in areas at risk from flooding.

In 2008 the Environment Agency was given by the government a *Strategic Overview* responsibility for the management of both flood and coastal erosion risks. The Agency works in close partnership with local authorities through the Coastal Groups to achieve sustainable coastal risk management involving:

- The preparation of 'Shoreline Management (coastal defence) Plans' to agree policies for management arrangements;
- Preparation of more detailed coastal defence strategy studies, particularly relating to sediment transport along the open coast, linked to estuarine studies, which identify the most appropriate and economically justifiable coastal defence option for each frontage taking account of all factors; and

- The undertaking of more specific local studies relating to the construction of a particular coastal defence scheme.

In England funding is made available by Defra to coastal protection authorities (who, together with the Environment Agency and Internal Drainage Boards, are known as Operating Authorities), through the Environment Agency, for schemes that are technically sound, environmentally acceptable, economically justifiable and cost-effective. A key feature of the powers is that they are permissive rather than mandatory; the coast protection authorities are not obliged to carry out the works. This clearly limits the role of the State to providing only defences that are deemed to be in the national interest. However, this subtle distinction can cause considerable public misunderstanding and frustration.

Through its Regional Flood and Coastal Committees (RFCCs) the Environment Agency implements flood and coastal defence policy. More recently, as part of the restructuring of coastal risk management nationally, the RFCCs now also assist delivery of the Environment Agency 'Strategic Overview' which includes coastal erosion as well as flood risk management. Local Authorities also have permissive powers to carry out flood risk management works and decisions are made through Coastal Defence Strategies as to who is best placed to manage any particular scheme.

1.5.4.2. Coastal Cells and Coastal Groups

Research commissioned by the government approximately 20 years ago suggested that the English coastline could be divided into major sediment cells; a sediment cell being defined as a length of coastline which is relatively self-contained as far as the movement of sand or shingle is concerned and where interruptions to such movements should not have a significant effect on adjacent sediment cells. The boundaries of the sediment cells generally coincide with the mouths of large estuaries or prominent headlands. These sediment cells form discrete units which broadly coincide with the establishment of seven strategic 'Coastal Groups' comprising local authorities, the Environment Agency and other interested organisations who have key roles in coastal risk management.

One of the first coastal groups to be established in England and perhaps the most influential is the 'Standing Conference on Problems Associated with the Coastline' (SCOPAC www.scopac.org.uk), which was founded in 1986. This group has played an important role in strategic coastal risk management in central southern England as an intermediary between the Environment Agency, central and local government as well as delivering a valuable sub-Regional research programme.

1.5.4.3. Shoreline Management

Shoreline Management Plans (SMPs) provide a large-scale assessment of the risks associated with coastal processes and allow the development of a policy framework to reduce these risks to people and the developed, historic and natural environments in a sustainable manner. In doing so, these 'high level' documents form an important contribution to the national strategy for flood and coastal erosion risk management. A key role for Coastal Groups has been encouraging the successful development and implementation of Shoreline Management Plans (SMPs) and the implementation of coastal risk management in practice.

Shoreline Management Plans – Aims and Objectives
AIM: A shoreline management plan should provide the basis for policies for a length of coast and set the framework for managing risks along the coastline in the future. OBJECTIVES: The objectives of an SMP need to be in line with the government's Strategy for managing risks from floods and coastal erosion (www.defra.gov.uk/environ/fcd/policy/strategy.htm) and should: • Set out the risks from flooding and erosion to people and the developed, historic and natural environment within the SMP area; • Identify opportunities to maintain and improve the environment by managing the risks from floods and coastal erosion; • Identify the preferred policies for managing risks from floods and erosion over the next century; • Identify the consequences of putting the preferred policies into practice; • Set out procedures for monitoring how effective these policies are; • Inform others so that future land use, planning and development of the shoreline takes account of the risks and the preferred policies; • Discourage inappropriate development in areas where the flood and erosion risks are high; and • Meet international and national nature conservation legislation and aim to achieve the biodiversity objectives.

Table 1.4. The aims and objectives of Shoreline Management Plans.

1.5.4.4. Monitoring Coastal Change

In England a 'Strategic Regional Coastal Monitoring Programme' commenced in 2002; an initiative involving thirty one Local Authority and Environment Agency partners in south east England. The programme, which is funded by the government, has now extended across England with the aim of providing a consistent, repeatable and cost-effective method of monitoring the coast to inform coastal risk management.

Large-scale coastal monitoring programmes such as this provide a systematic approach to collection, management and analysis of data for strategic and operational management of coastal erosion and flood risk. The programmes are risk-based and integrate the requirements of coastal local authorities with coastal defence responsibilities at both strategic and operational levels.

The need for better prediction of large-scale coastal evolution relates particularly to impending problems arising from sea level, rainfall and wave climate changes. Broad scale studies can provide information about mean shoreline trends and identify fluctuations from these trends but the ability to predict large-scale coastal evolution has been limited by the lack of long-term strategic coastal monitoring data. The inability to carry out robust assessments at broad scales has been criticised and has highlighted the need for a strategic approach to regional monitoring (Bradbury *et al*., 2007).

This strategic approach to coastal monitoring provides a basis for capturing the data required to make reliable assessments of processes and to predict future changes. The accuracy of predictions improves dramatically with an extended length of records and hence long-term data sets (ideally 20-30 years duration) are required, with data collected at a variety of spatial and temporal scales, to provide optimal decision-making. This aim lies behind the risk-based design of a national monitoring programme, providing a tiered framework of data collection and analysis that enables detailed information to be filtered and cascaded to a range of potential applications.

Figure 1.35. Coastal monitoring programmes provide valuable data to inform coastal risk management. Image courtesy Channel Coastal Observatory

1.5.4.5. Key English Coastal Research Projects 2000-2014

• **'The Investigation and Management of Soft Rock Cliffs'**: Prediction of recession rates and erosion control techniques (Ministry of Agriculture, Fisheries and Food (MAFF) Research and Development Programme, 1994-2001). The objectives of the research programme included the development of analytical methods of predicting cliff erosion rates for the wide variety of differing situations around the coast (Lee & Clark, 2002).

• **'FutureCoast'** (Defra R&D, 2000-2002): This was a regional-scale study of the whole coast of England and Wales designed to inform the approach used in the second round of Shoreline Management Plans (SMPs). FutureCoast provided a robust geomorphological framework for conceptualising coastal evolution. It included a 'cliff erosion database', which defined 'cliff behaviour units' and provided projections of potential erosion rates with or without coast protection measures in place (Halcrow, 2002).

• **European Union (EU) LIFE Environment Project 'RESPONSE'**: 'Responding to the risks from climate change on the coast' (Isle of Wight Centre for the Coastal Environment and partners, 2003-2006): The objective of this project was to develop sustainable strategies for local authorities and other stakeholders across the European Union to manage natural hazards in the coastal zone through demonstration of an innovative regional-scale methodology for coastal evolution studies and risk mapping, taking account of the impacts of climate change. Sustainable strategies for managing coastal and natural hazards inform land use development and planning by ensuring decisions are compatible with specific local coastal conditions and also future challenges (McInnes *et al*., 2006).

• **'Risk Assessment of Coastal Erosion – RACE'** (Defra Research & Development Programme, 2005-2008): The aim of the RACE project was to develop, test and disseminate a robust and consistent probabilistic method for assessing the hazard and risk of coastal erosion. The approach was supported by data and information from the FutureCoast cliff erosion database, monitoring programmes and risk-based inspections. The outputs represent hazard and risk in a manner comparable with the RASP (Risk Assessment of flood and coastal defence for Strategic Planning) method used for flood risk assessment (Halcrow, 2006).

• **'National Coastal Erosion Risk Mapping - NCERM'** (Halcrow, 2010): NCERM maps erosion/instability around the coastline of England and Wales, taking account of the influence of current coastal defences and management policies. A key aspect of the work is capturing local knowledge and expert opinion using web-based mapping techniques to allow local operating authorities to verify, interrogate and amend input data and provide a live visualisation of the outputs generated. When it is completed, the project will complement NaFRA to provide a complete representation of flood and erosion risks along the coastlines of England and Wales.

• **ACCESS –** Adapting to Coastal Change Along England's Southern Shorelines (Coastal & Geotechnical Services, Halcrow & Channel Coast Observatory). This study commissioned by SCOPAC assessed the consequences of increasing coastal risks at study sites drawn from forty *Coastal Hotspots* along the coastline of central southern England. The report made recommendations on coastal data collection and management, asset valuations and dissemination procedures (McInnes et al. 2011).

1.5.5. Coastal Management: France

The French coastal zones bordering La Manche exhibit similar physical characteristics to those of the south coast of England, sharing also the similar challenges imposed by risks arising from coastal erosion and cliff retreat, landsliding and flooding, all of which are being exacerbated by the impacts of climate change and sea level rise. Over the last 20 years France has adopted a pro-active approach to the management of risks, taking on board the European Commission's 'Recommendations on Integrated Coastal Zone Management', as well as encouraging national research and 'bottom-up' initiatives at the local level.

The coastal zones bordering La Manche have seen progressive development since the eighteenth century in a similar way to the south coast of England, and the colonisation of the coast has been described in detail (Corbin, 1988). The development of the French Channel coast continued steadily and more recent studies (Debouldt, 2010) describe the rapid growth, which has increased considerably over the last 30 years. This issue of coastal development and its resulting impacts compared with that other EU Member States were investigated as part of the EUrosion project (European Commission, 2004).

Coastal communities on the French Channel coast face three particular natural hazards - retreat of the shoreline and coastal cliffs through erosion by the sea, coastal flooding, and changes in the patterns and extent of dune systems. Natural processes have been aggravated by human intervention; in particular public works projects on rivers have reduced the sedimentary contributions on the coast, whilst sand extraction from beaches and dunes has further depleted the supply of sediments. Port and harbour developments have, in some cases, interrupted the sedimentary transport processes along the coast, whilst further development, including seafronts, promenades and sea walls, have also had the effect of cutting off sediment supply in some locations. Although the EUrosion study (European Commission, 2004) found that a significant proportion of the French coastline remained in a state of equilibrium, erosion was occurring along 25% of the coastline, whilst only 10% was experiencing accretion.

1.5.5.1. Coastal Management

France embraced the concept of integrated coastal zone management (ICZM) during its meeting of the Inter-Ministerial Committee on the Sea in April 2003, where it announced its compliance with the Recommendation voted by the Council of Europe and the European

Parliament of May 2002 (European Commission, 2002). As part of the associated Demonstration Programme on ICZM a number of pilot sites experimented with ICZM including locations along the French coast of La Manche (the Côte d'Opale and the Rade de Brest). Over the next five years a process of implementation of coastal management initiatives at the regional and sub-regional levels continued. Later, in 2007, following a call for projects, French government grants were provided to assist coastal management projects at the Côte d'Opale, the Baie De Somme, the Seine Estuary and Le Havre, Havres De Coutances, the Baie of Mont St Michel, the Pays de Brest and the Rade de Brest. Altogether across France twenty-five ICZM projects were selected, most of which were initiated by groups of Communes or by a single Commune (Deboult *et al*., 2008).

1.5.5.2. Coastal Risk Management

In parallel with the wider policy work on ICZM more detailed consideration of the management of natural hazards had commenced in the early 1980s. In 1981 the position of Secretary of State for the Prevention of Natural Risks was created for the first time, and dialogue increased between the government and insurance companies particularly in relation to coastal territories. Natural disaster insurance (often known as 'Cat Nat') requires that such insurance is included as an obligatory extension of insurance for property damage, as well as loss of profits. This additional contribution, set at 6% on motor vehicle insurance and 12% for other properties, provided financial resources available to address insurance claims in the event of natural disasters.

The requirement for such an insurance system was demonstrated when disastrous coastal storms affected northern and western France on a number of occasions between 1982 and 2009. In particular, the storm event of December 1999 and the associated coastal flooding, affecting provinces including Pas-de-Calais and elsewhere, resulted in losses and damages amounting to 230 million Euros (Debouldt, 2010). The early 1980s saw the increased recognition of the need for policies for natural disaster prevention to be integrated with land use planning in coastal zones. Restrictions in urbanisation imposed through legislation such as the Law Littoral in 1986, following the establishment of the Conservatoire du Littoral (1975), with its aim of acquiring coastal land for environmental preservation and control urbanisation, represented further important steps.

As in England, the philosophy of aiming to control and physically stop coastal erosion through construction of sea walls, breakwaters and other forms of hard defence was gradually being replaced in France from the mid-1990s with the development of coastal risk management strategies. Risk strategies were developed based on an improved understanding of natural coastal processes and natural hazards. 'Natural Risk Exposure Plans' (PERs) created alongside the 'Cat Nat' insurance initiatives in the early 1980s evolved with the implementation of the Law Barnier in 1995, and the establishment of 'Plans for the Prevention of Risks' (PPRs), these remain today the main tool for the management of natural risks. The PPRs are planning documents attached to 'Local Zoning Plans' (PLUs) that regulate the use of land at the local level.

By 2007 270 coastal communities benefitted from approved PPRs being in place, and this represented 30% of coastal communities in France. The PPRs, supported by the Barnier Law, have provided a tool for the management of natural risks along the coastline of La Manche and elsewhere. The law makes the provision for the expropriation of properties and indemnification of affected residents where it is uneconomic or environmentally unacceptable to carry out coastal protection measures. An example of the implementation of this approach was in the village of Criel-sur-Mer in Upper Normandy, where, between 2004 and 2006, a row of coastal properties at risk were demolished and the owners compensated, thereby allowing the coast to continue to retreat naturally.

Figure 1.36. Chalk cliffs at Criel-sur-Mer, Upper Normandy. The properties on the cliff edge were demolished and property owners compensated for their loss under the provisions of the Law Barnier. Image courtesy Robin McInnes

Figure 1.37. Vulnerable coastal villas at Mesnil-Val, Upper Normandy.Image courtesy BRGM

1.5.5.3. Coastal Research

Apart from the European Commission and French government funded studies and projects described above, coastal research has been undertaken by organisations such as IFREMER who, although having primary interest in the marine environment, have also been actively involved in the fields of sustainable development and integrated coastal zone management.

Elsewhere, funding through the European Union 6th Framework Programme allowed the creation and development of the European Encora network (www.encora.org).

The Conservatoire du Littoral, the French Geological Service BRGM and others have undertaken a range of research projects with financial support from the government and the European Commission, whilst networks of regional and local authorities have further developed coastal management through the LIFE Environment and Interreg programmes. Coastal management networks along the French Channel coast such as the Syndicate Mixte de Côte d'Opale and, more widely, the Arc Manche network have played influential roles in raising awareness and implementing sustainable coastal management on the French coast.

1.5.6. Coastal Management: Belgium

The Belgian coast extends for a distance of 67km from the nature reserve of Zwin in the north east bordering the Netherlands to Dunkirk and the Cote D'Opale of France to the south west. Most of the Belgian coast is low-lying with over 85% of its length below 5m. Approximately 60% of the coastline is relatively stable although 40% is eroding. Nearly two thirds of the coastline is protected by hard defences whilst the remainder is defended by soft engineering measures including beach replenishment, sand fences and Marram Grass. Behind the man-made coastal defences and beaches are developments as well as extensive low-lying polders, which are largely devoted to agriculture.

The coastline of Belgium is densely developed with hotels, holiday apartments and infrastructure to support the tourist industry and the economy more widely. Coastal defences are vital to protect these assets in the face of sea level rise and climate change impacts.

1.5.6.1. The History of Coastal Management

In Belgium coastal zone management is an activity in which all the administrative tiers of government have roles – national (Federal), regional (Flemish), Provincial and Local government. This has necessitated close collaboration in terms of developing coastal policies. Following its participation in the EU Demonstration Programme on ICZM (1996-1999) a 'Co-ordination Centre for Integrated Coastal Zone Management' was created in 2001 (www.west.viaaderen.be). In response to the 'Recommendation on ICZM' (European Commission, 2002) a 'National Belgian Report on the Implementation of 'Recommendation 2002/413/EC' was published jointly by North Sea & Oceans Steering Committee and the Co-ordination Centre (Co-ordination Centre, 2002); this report was updated subsequently for the European Commission to cover the period 2005-2010 (Coordination Centre West Flanders, 2010).

The report described the various initiatives and actions that had been implemented including the use of sustainability indicators to monitor the state of the coast, the establishment of a coastal forum, improved integration between the competent bodies in the field of ICZM, improving integration between the various policies and instruments, developing the concept of adaptive management and active participation in a range of research and demonstration projects (Coordination Centre for ICZM, West Flanders, 2010). The Centre continues to play a proactive role in coastal management at the European and national levels.

1.5.6.2. Flood Risk Management

The Belgian coastal plain and the Scheldt estuary are both threatened by sea level rise. Low-lying polders are most vulnerable to sea level rise where drainage off the land is a significant problem during rainy periods. Freshwater lenses developed within the coastal dune systems are also vulnerable to sea level rise, leading to the issue of saltwater intrusion (Lebbe et al. 2008).

Land at risk from flooding in Belgium comprises a zone up to 15km in width and is located on average 2m below annual storm surge level (Verwaest et al, 2009). Some sections of the coastal defences are at risk of breaching, for example between Nieuwpoort and Zeebrugge, where they are narrower, as well as in some of the harbours where overtopping may occur. Historically the most serious flood event on the Belgian coast was the 1953 storm, which also led to serious loss of life in the Netherlands and England. A failure of the present defences would have very serious consequences and a risk-based approach is adopted towards investment in flood and coastal defence.

1.5.6.3. Coastal Research

The vulnerability of the Belgian coast to flooding has necessitated an active programme of research that has been undertaken within universities, research institutions and by the Co-ordination Centre and others with financial support from EU funding. The Flanders Marine institute (VLIZ) was established in 1999 and has evolved into the central coordination and information platform for marine and coastal scientific research in Flanders. As a partner in various projects and networks VLIZ also promotes and supports the international face of Flemish marine science research and education (www.vliz.be).

In Belgium programmes including LIFE Environment/TERRA and Interreg, in particular, have supported research, demonstration projects and networking often addressing common challenges around the Channel – Southern North Sea region. These included the EU Demonstration Programme on ICZM (1998-2000), the SAIL and DEDUCE Interreg IIIC projects (2004-2007) (www.vliz.be/projects/SAIL and www.deduce.eu), which helped develop indicators for sustainable coastal management, the Interreg IIIB COREPOINT project (2004-2008 corepoint.ucc.ie), which aimed to orientate coastal research towards problem solving at the local level, and the Interreg IVB IMCORE project (2008-2011 www.imcore.eu), which investigated issues surrounding the management of coastal change.

1.5.7. Coastal Management: The Netherlands

The Netherlands is situated on the delta of three of Europe's largest rivers - the Rhine, the Meuse and the Scheldt, that discharge into a shallow regional sea - the North Sea. Without flood defences more than half of the area of the country would be flooded. The Netherlands is threatened from one side by storms that can generate huge surges, due to the shallow sea and the funnel shaped geometry of the Southern North Sea, and from the other side by river flooding (De Ronde *et al.*, 2003).

Coastal erosion is a continuous process along parts of the sandy shorelines of the Netherlands. Since 1990 policies have been put in place with the objective of controlling erosion through beach nourishment. This approach has proven effective in terms of retaining the coastline at its 1990 position, however, there is increasing concern with regard to the availability of essential sediment reserves in deeper water particularly in view of sea level rise, increased offshore dredging and the construction of new harbours.

The south-east section of the North Sea coast consists of straight sandy beaches with large-scale tidal inlets. Long stretches of the coast have dunes that prevent the low-lying hinterland, which in many places is below sea level, from being regularly flooded. Where dunes are absent, defences have been constructed as a flood defence measure.

1.5.7.1. The History of Flood Risk Management

The 1953 big storm caused a flooding disaster that resulted in enormous damage and led to nearly 2,000 deaths in the Netherlands. In 1995 fluvial flooding was so serious that flood defences could no longer be guaranteed and 200,000 people together with many millions of animals were evacuated. Following these events, flood safety standards were developed and, in 1996, a new Flood Protection Bill including a five-yearly inspection of all flood defence structures and dunes was implemented.

The coastline of the Netherlands, including all the estuaries, has a total length of approximately 1,000km. The coastal frontage directly facing the North Sea is about 350km long, of which 75% consists of dunes, ranging from less than 100m up to several kilometres in width. The primary function of the coast is, therefore, to protect the low-lying hinterland from flooding.

Although a new policy for coastal defence of the Netherlands dune coasts commenced in the 1980s, it was in 1990 that the Dutch Parliament decided to adopt a new policy called 'Dynamic Preservation of the Coastline' in order to stop further retreat of the coast, meaning that the entire coastline would be maintained at its 1990 position. Further erosion would be reduced or prevented by beach nourishment. Sand nourishment has been a common measure to combat coastal erosion in the Netherlands since the end of the 1970s. When a nourishment project is carried out, sand excavated from the bottom of the North Sea (outside the -20m depth contour), is added to the near shore zone (De Ronde *et al*., 2003).

The strategic objective of the 'Dynamic Preservation' policy was to implement a sustainable safety level and preservation of values and functions in the dune area. This objective was translated into the tactical objective to maintain the coastline at its 1990 position. The National Spatial Strategy (2004) reaffirmed the strategic objective of the large-scale coastal policy in the Netherlands, rephrasing is as, "to guarantee safety against flooding and to preserve spatial quality of the coastal zone" (Waterhout, 2008). As an additional large-scale tactical objective, the Strategy defined the preservation and improvement of the 'Coastal Foundation': the area between dunes and the -20m depth contour. The 'Coastal Foundation' is a new large-scale coastal state indicator acknowledging sand as 'the carrier of all functions'.

Since the thirteenth century the 'Water Boards' held the responsibility for the maintenance of the flood defence systems and the management of water levels. These Water Boards are, in fact, the oldest democratic institutions in the Netherlands. The contribution that citizens have to pay to a Water Board was, and is today, related to the value of their property. The Water Boards also regulate the water levels in the polders. In the first half of the twentieth century there were more than 2,500 Water Boards but over the years this number has been reduced significantly and there are currently about 85 Water Boards left. A further reduction is likely as part of efforts to create strong unitary authorities.

In 1798, the institution Rijkswaterstaat was founded to give national guidance on water management, as it has been recognised that certain aspects could be better addressed at a national level. Rijkswaterstaat is the executive body of the Dutch Ministry of Transport, Public Works and Water Management (De Ronde *et al.*, 2003). The Minister is responsible to Parliament (States General) for all aspects of flood defence and water management. The twelve Dutch provinces form the link between the central government and the local authorities fulfilling important roles in the fields of spatial planning, regional, environmental policy and integrated water management policy.

Management relationships are also clearly visible in the event of high water conditions; wherever possible the responsibilities rest with local authorities. Water Boards judge the strength of the defences, municipalities carry responsibilities for the safety of citizens and provide public information; and if necessary the regional co-ordination is handled by the Province. Only in very special situations is co-ordination transferred to a national level.

Sand dunes and other coastal defences protect those parts of the Netherlands that are situated below sea level. The design levels of these flood defence structures are related to extreme storm surge water levels (which are related to the frequency of occurrence extreme storm events). Dunes and defences along the coasts of the provinces of Noord-Holland and Zuid-Holland are designed to withstand the effects of a storm that has a probability of occurrence of once per 10,000 years. This roughly corresponds to a storm surge level of +5m Dutch Ordnance Level. For the less populated parts along the Dutch coast, such as the province of Zeeland and the Wadden Islands, the design level is based on the frequency of occurrence of an extreme storm event of once every 4,000 years and once per 2,000 years respectively. The risk of coastal flooding is expected to increase in the future, because the probability of occurrence of flooding and the socio-economic values in the coastal zones are both expected to increase.

Without management interventions, the erosion lines would continue to advance in a landward direction due to sea level rise. In addition, relative sea level will also rise without climate change-related sea level rise due to the post-glacial subsidence of the North Sea basin. Climate change may lead to more frequent and more intense storm conditions, which could reduce the effectiveness of the dunes as flood defences. It is, therefore, of great importance to gain an improved understanding of how different people and coastal economies can adapt in the long-term (de Ruig, 1998).

1.5.7.2. Research

The Netherlands Centre for Coastal Research (NCK) is a co-operation of Dutch universities and institutes engaged in coastal research and management. Founded in 1991, the NCK aims at increasing the quality of coastal research in the Netherlands, enhancing the exchange of knowledge to the applied research community, reinforcing coastal research and education capacities at Dutch universities and strengthening the position of Dutch coastal research in a United Europe and beyond.

NCK research (interaction) is concentrated in five themes, Seabed and Shelf, Beach and Coast, Tidal Inlet Systems and Estuaries, Sand and Mud and finally Hydrodynamics. Added value is realised by carrying out joint research programmes in the Netherlands, as well as abroad, through exchange of senior research staff between partners and via dissemination of knowledge during dedicated meetings as well as the annual NCK days.

NCK activities have contributed importantly to the establishment of strong relationships between research and management groups of various NCK partners. This has actively stimulated the development of in-depth knowledge through interaction of key specialists from different backgrounds, facilitating a multi-disciplinary approach towards coastal problems and improved links between specialist knowledge and end-user interests.

1.6. Summary

Past coastal planning regimes have suffered from a poor understanding of the ongoing processes and natural trends that are shaping our coastal zone. Consequently, many coastal settlements are becoming vulnerable as the frequency of coastal erosion, flooding and coastal instability events increase, and the relationship between the land and sea evolves.

In prehistoric times the Channel did not exist but it was an area of low lying land used by early humans. Archaeological traces left in the landscape are common across the region, showing how people adapted to coastal change and a rising sea level. Later historical development includes comparable maritime coastal infrastructure and coastal industries that are represented in the archaeological and artistic record. The evidence can provide high resolution data on coastal change spanning thousands of years. This contribution to our understanding of coastal evolution enhances our appreciation of past change and provides tools to help predict future impacts on coastal communities.

The Arch-Manche project has sought to advance our understanding of the scale and rate of long-term coastal change by addressing sources including archaeology, palaeoenvironmental data, works of art, maps, photographs, as well as historical literature accounts. A unique aspect of this project is the combination of data sources to extract maximum amounts of information. By characterising areas of long-term erosion, coastlines under ongoing stress can be identified. Some areas subject to human intervention have been stabilised while others have not and the effect of hard defenses in one area can have a knock-on impact elsewhere. Long-term assessments over broad areas are necessary to recognise cumulative consequences, while an understanding of long-term coastal responses can provide continuity to help predict future trends.

The next section will look at the methodology used in the project for assessing these various data sources, this will be followed by detailed case study reports, analysis, conclusions and recommendations.

Complimenting this technical report is a non-technical guide, *'Coastal Management: A guide to using archaeological, palaeoenvironmental, historical and artistic resources'*. Click here to download a copy in English, or here for a copy in French, hard copies are also available from the Maritime Archaeology Trust. The project results are also available through our interactive portal www.archmanche-geoportal.eu.

2. Methodology

This section of the report provides information on the various data sets used by the project partners and the methods used to assess this data on how it can contribute towards an understanding of coastal change. For the four main data sets; archaeology/palaeoenvironmental data, historic photos, historic artworks and maps/charts, ranking systems were developed in order to identify and rank the potential value of the data to the study of coastal change. See Section One for an introduction to the project.

Once the data had been collected it was entered onto a project database and ranked using the agreed ranking systems, this data could then be viewed geographically along with the results of the ranking in order to enable detailed analysis and comparison of the results across the partner study areas. In the UK, France and Belgium fieldwork was also carried out in areas identified as having high potential, this involved in-depth inter-disciplinary research, fieldwork, scientific dating and analysis of significant sites and areas of coastline in the partner countries.

2.1. Data Sources

The Arch-Manche project looked at archaeological and palaeoenvironmental data, historic paintings, historic photographs, maps and charts from case study areas in England, France, Belgium and the Netherlands. This section provides an overview of the sources consulted in order to obtain this data.

2.1.1. Archaeology and Heritage Features

An initial desk based survey of maritime heritage and archaeological and palaeoenvironmental sites was carried out. Areas of the coastline which have archaeological or palaeoenvironmental information that can help tell the story of past change were identified i.e. monuments, fishtraps, shipwrecks, submerged landscapes or defensive structures. Data was gathered and ranked using the methodology outlined below, this was then added to the project database and GIS.

2.1.1.1. UK

In the UK data collection for the Arch-Manche project involved repositories of historic environment records across the case study areas, details are provided in Table 2.1. Information on sites and finds varied in quantity and quality between the individual county records, sites were therefore later ranked based on their potential, with further research carried out where necessary. Several literary sources were also consulted in order to provide the general archaeological and historical background of the case study areas and to contribute to the data sources listed below when further research was required, these are listed in the references section.

Data group	Format	Supplier
Sites and Monuments records (National)	Digital, GIS Shapefiles	NRHE, National Record of the Historic Environment
Sites and Monuments records (County Based)	Digital, GIS Shapefiles	HER, Historic Environment Records
Wrecks	Digital, GIS Shapefiles	UKHO, United Kingdom Hydrographic Office
Palaeoenvironmental Data	Access Database	English Heritage Peat Database
Sites and Monuments records (Coastal Specialist)	Digital, PDF reports	RCZA, Rapid Coastal Zone Assessments
Sites, Monuments, Wrecks, Palaeoenvironmental	Digital	MAT, Maritime Archaeology Trust archives

Table 2.1 List of data sources for the UK archaeological and palaeoenvironmental data

All data was transformed into British National Grid co-ordinates (OSGB 1936) prior to querying in ArcGIS. Data was then cleaned, this involved removing records which fell outside the limits of the case study areas and a buffer of 500 metres inland from the high water mark was also used so all sites further than 500m inland were removed. In order to prevent duplication of data the GIS shapefiles from the various data sources were overlaid, any duplicate points were then identified on a site-by-site basis and the dataset with most comprehensive details was used.

Unfortunately, despite several attempts it was not possible to obtain GIS data for several of the Rapid Coastal Zone Assessments (RCZA's). In some areas any new information obtained from the RCZA had already been incorporated into the relevant HER. However, for the Solent region the only RCZA data available was from the New Forest in Hampshire.

After the data was cleaned, sites were then added to the project database and ranked. Details of the database are available in section Data Management.

2.1.1.2. France

The archaeological and palaeoenvironmental data presented in this report has been obtained from the Atlas des Patrimoine (Culture Ministry), available online, (http://atlas.patrimoines.culture.fr/atlas/trunk/), and from the databases of scientific research groups: AMARAI (Association Manche Atlantique pour la Recherche archéologique dans les Îles) association, and CeRAA (Centre regional d'Archéologie d'Alet, Saint-Malo). Extensive documentation was also provided by the Archéosciences laboratory of the Rennes1 University, which is a component of the federative research group Unité Mixte de Recherche 6566 du CNRS-CReAAH (Centre de Recherche en Archéologie, Archéosciences, Histoire). Another important resource centre for maritime history, and especially shipwrecks studies, is the ADRAMAR (Association pour le Développement de la Recherche en Archéologie MARitime) which provides an important documentary set, now available online (Atlas Ponant et Atlas des 2 mers: http://adramar.fr/atlas/). Several books concerning the history of the region have been consulted and used (see the references), there is an abundance of historical literature for this region, due to it past rich history and popularity with tourists.

2.1.1.3. Belgium

For the Belgian case study reports, no extensive desk based survey of maritime heritage, archaeological or palaeoenvironmental sites was carried out. There are available inventories of these kind of sites (or artefacts), a number of websites and publications. However, specific information on the *intertidal* area remains scarce. A selection of source include:

Information for the whole of Flanders (BE) can be found at:

- http://cai.erfgoed.net (database of archeological finds in Flanders)
- https://dov.vlaanderen.be (database of subsoil in Flanders, including numerous corings etc.)
- https://inventaris.onroerenderfgoed.be (database for built heritage)

Maritime information can be found at:

- www.maritieme-archeologie.be (contains a database of shipwrecks)

- www.a2s-geoportal.eu (sites in the Channel and North Sea areas, as well as in the intertidal zone)
- www.sea-arch.be (project regarding archeological heritage in the North Sea)

Specific information for Raversijde can be found in:
- PIETERS, M. et al., 2013. *Het archeologisch onderzoek in Raversijde (Oostende) in de periode 1992-2005,* Brussel, AOE. (Ordering through www.onroerenderfgoed.be).

Specific information for the Waasland polder area can be found at/in:
- www.a-d-w.be (Archeological Facility Waasland)
- CROMBÉ, P. (ed.) 2005. *The last hunter-gatherer-fishermen in Sandy Flanders (NW Belgium); the Verrebroek and Doel excavation projects.* Gent: Academia Press.

2.1.1.4. Netherlands

In the case study areas from the Netherlands no desk based research and ranking was carried out, the focus here was on the use of evolution maps created by Peter Vos from the research institute Deltares. Results from archaeological fieldwork carried out on two sites, Vergulde Hand West and Yangtze Harbour were also used within the project analysis. This work was conducted on several campaigns by several institutions including Deltares, City of Vlaardingen, TNO Geological Survet and Utrecht University.

2.1.2. Art

The art case studies focussed on England and France (together with a sample of artworks from the Dutch and Belgian coastlines). In order to establish the art resource available for this study it was necessary to review the topographical paintings, drawings and prints held by the principal national, regional and sub-regional collections covering the coastal frontages in these countries. To achieve this objective, on-line reviews, literature searches and some visits were made in order to identify the most relevant paintings, drawings and prints. These are detailed below.

2.1.2.1. England

This section summarises the national sub-regional and private collections reviewed as part of the project.

Primary National Collections		
Name	**Location**	**Brief Description**
The National Maritime Museum	Greenwich, London	Collections include cartography, manuscripts, public records and maritime art.
The Victoria and Albert Museum	London	Collections include prints, drawings and photographs. Also houses the National Art Library, with over 750,000 books.
The Tate Britain	London	UK's national museum of British art from 1500 to present day.
The British Museum	London	National collection of prints and drawings from the 14th century to the present day.
The National Gallery	London	Collections of over 2,300 paintings from the mid 13th Century to 1900.
The Witt Library	Courtauld Institute, London	Collections of reproductions from 1200 to the present day.

Table 2.2. UK National Collections of art assessed for the project.

Primary Sub-Regional Collections	
Name	**Case Study Area**
Norwich Castle Museum & Art Gallery	East Anglia
Great Yarmouth Museum	East Anglia
The Mo, Sheringham	East Anglia
Aldeburgh Museum	East Anglia
Dunwich Museum	East Anglia
Colchester & Ipswich Museums	East Anglia
Canterbury City Council Museums & Galleries	East Kent
Dover Collections	East Kent
Folkestone Museum	East Kent
Maidstone Museum & Bentlif Art Gallery	East Kent
Turner Contemporary, Margate	East Kent
Margate Old Town Local History Museum	East Kent
Ramsgate Museum	East Kent
Kent Record Office	East Kent
Hastings Museum and Art Gallert	Hastings
Hastings Library	Hastings
Hastings Fishermen's Museum	Hastings
Royal Pavilion & Brighton Museum	Hastings
East Sussex Record Office	Hastings
Southampton City Art gallery	Solent & Isle of Wight
Southampton City Council Archive Service	Solent & Isle of Wight
The Cope Collection, University of Southampton	Solent & Isle of Wight
Portsmouth City Museum and Archives	Solent & Isle of Wight
Royal Naval Museum, Portsmouth	Solent & Isle of Wight
Hampshire County Council Art & Museum Service	Solent & Isle of Wight
Island Heritage Service, Isle of Wight Council	Solent & Isle of Wight
The Russell Cotes Museum, Bournemouth	West Dorset & East Devon
Dorset County Council Archives	West Dorset & East Devon
Dorset County Museum	West Dorset & East Devon
Lyme Regis Museum	West Dorset & East Devon
Devon Record Office	West Dorset & East Devon
The Royal Albert Museum & Art Gallery, Exeter	West Dorset & East Devon
Plymouth City Museum & Art Gallery	West Cornwall
Falmouth Art Gallery	West Cornwall
Cornwall County Council Record office	West Cornwall
The Cornish Studies Library	West Cornwall
Penlee House Gallery, Penzance	West Cornwall

Table 2.3. Sub-Regional UK art collections assessed for the project

Private collections

A number of yacht clubs hold coastal paintings. Most commonly these are yacht paintings but some collections hold coastal artworks together with books and albums of watercolours and engravings. Many of the works held by the yacht clubs are essentially yacht portraits but their background setting against the coastline can, in some instances provide, useful information on topography and coastal scenery particularly where works are executed by some of the best known coastal painters in Great Britain.

Literature Sources
The literature sources relating to works exhibited are comprehensive and comprise reviews of the artists and their works exhibited at principal London exhibitions (Graves, 1901), together with catalogues and dictionaries published by the museums themselves or interested publishers such as The Antique Collectors Club. The published works of this kind do, therefore, represent a considerable resource of assistance to this study (Wood, 1978; Russell, 1979; Archibald, 1980; Lanbourne *et al.*, 1980; Mallalieu, 1984; MacKenzie, 1987).

In relation to antiquarian and more recent publications for each of the case studies key works were consulted including, for East Anglia (Parkin, 1788; Beatniffe, 1809; Dickson, 1811; Stark, 1828/34; Clarke, 1921; McInnes and Stubbings, 2010); for East Kent (Gilpin, 1804; Moses, 1817; Unknown, 1813); for Solent and Isle of Wight (Tomkins, 1796; Pennant, 1801; Gilpin, 1804; Woodward, c.1848; Mudie, 1840; King, 1845; Brannon, 1821-76, Turley, 1975, 1977; McInnes, 2008). Finally, for West Dorset-East Devon and the West Cornwall case studies (Hutchins, 1774; Borlase, 1769; Englefield, 1816; Britton & Bayley, 1832; McInnes & Stubbings, 2011). More recently a comprehensive review has been undertaken of the oil paintings contained in public collections for all the English Counties and major art galleries (Ellis (Ed.), 2004).

Online Sources
As part of research the Public Catalogue's Foundation (PCF) volumes and BBC Your Paintings online resource was used www.thepcf.org.uk and www.bbc.co.uk/yourpaintings. The PCF was launched in 2003 as a registered charity and based in London (www.thepcf.org.uk). Over the last seven years the PCF has been photographing oil paintings and collating information about each painting. In doing so it has been working closely with collections across the United Kingdom. This provides access to some of Britain's large publicly owned collections of oil paintings held national collections, galleries, civic buildings, regional and local museums, and heritage centres.

Initially the PCF's main focus was publishing a series of hard copy catalogues with thumbnail images of the oil paintings in each collection; over 40 of the planned 90 catalogues have been published. In 2012 the task of photographing the nation's 212,000 oil paintings was completed. Then the focus turned to publishing on-line. Through a partnership with the BBC all the paintings can now be viewed on-line at www.bbc.co.uk/yourpaintings. On-line access allows users to search paintings by various criteria and to view larger images, whilst collections will be able to update their painting records website.

2.1.2.2. France

The rich art history of France, including landscapes and coastal scenes of Brittany, can be seen displayed in the great national collections of Paris and of some of the other major cities these are outlined in table 2.4 below.

National Collections	
Name	**Brief Description**
Paris Musée D'Orsay	Forward programme of the *Painters' Trail in Cornwall*: Paul Gauguin (La Belle Angele), Paul Sérusier (Talisman), Emile

	Bernard, Claude Emile Schuffeneckers, Charles Lavai Charles Filiger, Jan Verkade and Maurice Denis
Saint-Germain-en-Laye Musée du Prieuré	The property presents works of symbolism and including paintings by Nabis Maurice Denis, Paul Gauguin, Emile Bernard, Charles Filiger Paul Sérusier, Jan Verkade and M. Luce
Rennes Musée des Beaux-Arts	A large collection of paintings from the fourteenth century through to the various contemporary movements. Paintings from the nineteenth and early twentieth centuries include works by Eugène Boudin, Jules Noel, Henri Moret, Charles Cottet, Maurice Denis, Lucien Simon, Jean-Julien Lemordant, Georges Lacombe, Émile Bernard, Paul Sérusier and Maxime Maufra
Loches Musée Emmanuel Lansyer	The museum contains paintings by Lansyer Emmanuel (1835-1893).

Table 2.4. National Collections in France assessed for the project

The collections reviewed at the Sub-Regional level focussed on Brittany. Brittany has numerous excellent art collections held in the museums and art galleries of its larger cities and towns. The dramatic coastal scenery, the regional culture and history created tremendous interest among painters attracted by the sea in motion, the open skies as well as the local customs and costumes; many of these artworks contain a wealth of topographical information. Important collections are highlighted in tables 2.5 and 2.6 below.

Sub-Regional Collections	
Name	**Brief Description**
Brest Musée des Beaux-Arts	17th – 20th Century depictions, including the School of Pont-Aven.
Morlaix Musée Des Jacobins	Museum of Fine Arts, French and foreign works from 16th – 20th Century.
Nantes Musée Des Beaux-Arts	French, Italian, Flemish and Dutch paintings, particularly from 19th-20th Century but also from 1250 to present day.
Saint-Brieuc Musée D'histoire De Saint-Brieuc	Paintings and sculptures
Vannes Musée De La Cohue	Paintings, drawings and prints

Table 2.5. Sub-regional collections in France assessed for the project

Museums on the 'Road of Painters'	
Name	**Brief Description**
Quimper Musée Des Beaux-Arts	The collections include significant Flemish and Dutch paintings of the seventeenth and eighteenth centuries. Two rooms are devoted entirely to the School of Pont-Aven and inspirational Breton paintings of the nineteenth and twentieth centuries.
Quimper Musée Départe-mental Breton	Housed in the former bishop's palace, the museum is dedicated to temporary exhibits illustrating the history of the Breton regional company until today. Archaeology, history (furniture, advertising materials, photographic backgrounds, tiles), ethnography (furniture, costumes).
Le Pouldu Maison De Marie Henry	Reconstruction of the house of Mary Henry. The house includes documents relating the history of joint Pouldu, Mary Henry, the Buvette de la Plage and painters who lived there (Gauguin, Meyer de Haan, Sérusier Filiger, Maufra, Lavai).
Locronan Musée De Locronan	The museum has a permanent collection of paintings and sculptures (Beaufrère, Chief Iron Knight-Kervern, Dauchez, De Lassence, Desire-Lucas, Eschbach, Floc'h, Labitte, Lawrence Sidaner, Morchain, Simon).

Loctudy Musée De Kérazan	Manor Kérazan presents paintings and drawings from the sixteenth to the twentieth centuries, landscapes and seascapes. A small room is devoted to landscapes and characters of Cornwall and Vannes, a large room with paintings and drawings by Auguste Goy (1812-1871), valuable evidence of the Breton life in the last century. Among the collection of art are works of Maurice Denis, Charles Cottet, Georges Desvallières and Lucien Simon; in the grand salon paintings of the nineteenth and twentieth centuries include eight Breton subjects.
Pont-Aven Musée De Pont-Aven	Established in 1985, the museum is mainly dedicated to temporary exhibitions to publicize the painters who have distinguished themselves in Pont-Aven in Brittany and the late nineteenth to early twentieth century. The media room has an exhibition explaining the significance of the School of Pont-Aven.

Table 2.6. List of museums on the 'Road of Painters' assessed for the project

Art resources used for the Brittany case studies were drawn from various sources, either books (Delouche 2003), private and public galleries and, importantly, useful information was provided by online resources, in particular the Jocande database containing artworks and other objects from public & private museums (www.culture.gouv.fr).

For all the case study areas of Brittany, the art approach benefitted also from the academic work led in the Rennes 2 University by E. Motte (Motte, 2013, under the direction of H. Regnauld, with assistance from M.-Y. Daire and R. McInnes. The theme of the dissertation was: "*Representation and Evolution of the Shoreline: What do regional paintings teach us about the Breton coastal environment*").

2.1.3. Maps and Charts

The focus of historic maps and charts focused on collections in Belgium and the Netherlands, however, some sources were also consulted in England and France. The data sources are described below.

2.1.3.1. Belgium and the Netherlands

Maps of the coastal region of Flanders and the Waasland (polder) area were reviewed for these case studies. Coastal Flanders and the Waasland area have been extensively mapped, often linked to the numerous embankment enterprises. Early examples of land surveys of coastal Flanders include references as early as 1190 in Furnes and from 1282 in Bruges (Janssens, 2006:89). The oldest cartographical products date from 1307 and 1358 and concern a depiction of the "moershoofd" (peat reclamation axis) East of Aardenburg and Oostburg-IJzendijke (Gottschalk, 1955-58). Regular land surveying, however, remained absent for a long time (Janssens, 2006). The Waasland area also had an early tradition of land surveying. In the aftermath of the famous "Slijkkoop van Aendorp" (concerning the selling of tidal marsh and peat lands by Duke Filips the Good as Lord of Beveren) the land was extensively measured. Trial documents from 1469 mention two different measurements of the entire area, and an additional third one requested by the trialing parties (Archives Beveren).

Over following centuries numbers of land surveyors grew, but this increase could not keep up with the large demand for measurements and maps (often related to embankment practices). In 1696, the shortage of land surveyors in the Waasland area was clearly demonstrated by the desperate advice of the aldermen to the "Secret Council" to try to increase the number of land surveyors (Janssens, 2006).

The combination of the rapid development of mapping techniques, the need for measurements for new embankments and the certified quality of land surveyors resulted in a large number of maps of the coastal plain and the Waasland area. Luckily, numerous maps have been preserved. It is important to note that the most interesting maps are not often found in open access internet databases, but in (local) archives, for instance the (State) Archives in Brussels, Ghent, Beveren and Middelburg. Some of these are small scale maps or maps with very low reliability (depending on the purpose of the map), but one type of map proved to be particularly interesting for our study area; proceeding almost every embankment, various maps depicting the tidal channels were made. Many of these maps were ordered by or linked to the Arenberg family (who obtained most of the former Seigneury of Beveren) since they took part in the embankment of the Oud-Arenbergpolder (finished in 1688) and fully directed the embankment of the Nieuw-Arenbergpolder (finished in 1784) and Prosperpolder (finished in 1846) (Verelst, 2002).

In summary the maps were chosen out of a database of around 300 historical maps, found in the (State) Archives of Brussels, Ghent, Beveren and Middelburg. Many maps were found in the Arenberg Archives, a subsection of documents within the State Archives of Brussels.

Online inventories include:

- http://www.arch.be/ for the (State) Archives of Brussels, Ghent and Beveren.
- http://www.zeeuwsarchief.nl/ for the Archive of Middelburg.

2.1.3.2. UK

Within the scope of the project, research into historic maps and charts of the UK case study areas was restricted to online searches. The main sources consulted are detailed below.

A primary source for the Hastings case study area was through a project coordinated by the University of Portsmouth Geography Department entitled *Old Sussex Mapped*. The aim of the project is to create a database for old maps covering the counties of the UK. This builds on the *Old Hampshire Mapped* project started by Jean and Martin Norgate through which maps of the Solent and Isle of Wight case study area were also obtained. Other maps from the Solent and Isle of Wight case study area were provided by Professor Robin McInnes.

The primary resources for Suffolk were Hodskinson's Map of Suffolk in 1783 (a complete map of the county) and a 1st edition Ordnance Survey (OS) map from 1880-1890. OS maps have been used in several case study areas, these were available from *Digimap* an online service where maps can be downloaded for use in ArcGIS. Ordnance Survey is the UK's national mapping authority and in 1995 they digitised 230,000 maps of Britain.

Although not possible in the scope of Arch-Manche, further detailed studies into historic maps of the UK will provide more information on changes to the coast, potential sources include;

- United Kingdom Hydrographic Office (UKHO) archives
- National Archives
- National Maritime Museum
- Admiralty Library
- British Library

2.1.3.3. France

The main source of maps and charts for Brittany has been the online Gallica database, where the Maps and Charts department is extensively represented (http://gallica.bnf.fr/html/cartes/cartes). Most of the old marine charts are related in particular to trade, but also military defences. They often tell us about harbours, shelters, and watering places, but also the pitfalls of anchorages, rocks and major landmarks for navigation (e.g. coastal shipping). Defensive points along the coast are highlighted on the maps created during the wars (e.g. 17th and 18th c.), particularly those which included major offshore sailing (especially in the 19th century).

The Cassini family father and son, between 1750 and 1815, made the first topographical map of France. Charts before the eighteenth century are imprecise and difficult to exploit. However, one of the most informative for the coastal landscapes of this area is the "*Carte(s) des Ingénieurs géographes du Roy*" (18th century), which provides very accurate details especially along the coasts. The origins of these charts is linked to the fact that France had surveyors or topographic engineers before any other European army.

2.1.4. Photographs

Historic photographs were primarily collected for case study areas in France and the UK, with a smaller sample from Belgium. The data sources are outlined below.

2.1.4.1. France

The photographic postcards consulted for the project belong either to private or public collections (Biet & Bouze 2007), as well as the Regional ancient postcard conservatory (http://www.cartolis.org/).

As a major documentary resource, the documentary set of the ancient Laboratoire d'Anthropologie de Rennes (created by P.-R. Giot during the 1950's) includes negative and positive photos on plate glass, films, slides and paper photos, the oldest of which date from the second half of the 19th century. These pictures represent an exceptional information source for the comprehension of the emerging prehistory and archaeology in Brittany. The documentation used in the project is limited to pictures belonging to the period from the late 19th century to about 1939 and feature a link with the coastal areas (Lopez-Romero & Daire, 2013).

2.1.4.2. UK

All historic photos for the UK case study areas were found through online searches. Some key national sites include the *Francis Frith Collection*, the collection was founded in 1860 by the Victorian photographer Francis Frith, the site now contains over 365,000 photographs from 1860-1970. Another useful resource is from the *Britain from Above* project, the website contains images from the Aerofilms collection and includes thousands of aerial photographs dating from 1919 to 2006. More local collections were also searched, such as the Carisbrooke Castle Museum Image Library where historic images are being digitised and added to the website, this site contains many images of the Solent and Isle of Wight case study area.

2.1.4.3. Belgium

A small number of photographs were assessed in the Belgian case study areas of Raversijde and Scheldt polder. These were obtained through online searches. Photographs from the Raversijde area were found at http://beeldbank.oostende.be/, this image library includes collections of photographs and postcards as well as drawings, maps and prints of Ostend which have been digitised by the Municipality of Ostend. For the Scheldt polder area the following website was used; http://www.waaserfgoed.be/. This database contains a selection of photographs, newspaper pages and historical records obtained from local history groups, archives, libraries and private collections from the Waasland region.

2.2. Ranking Methodologies

In order to assess the reliability and accuracy of historic paintings, maps and charts a ranking system was developed. For historic photographs the ranking system was used to assess the potential of an image to provide information on coastal change, and for archaeological and palaeoenvironmental data the ranking system provided a relative value on the potential of each site to provide information on coastal change. All the data was ranked and entered into the database and project GIS. The methodology used to rank each dataset is outlined below.

2.2.1. Aims, Objectives and Implications of using the Ranking Criteria

The aims of the ranking criteria are to consider the attributes of all types of archaeological and palaeoenvironmental sites, finds and deposits, art works, photographs, map and charts, to assess their ability to provide information relating to processes or causes of coastal change. The ranking and ranking system has been used to highlight sites or sources of evidence so that their value can be readily assimilated in the revision and implementation of coastal management strategies. It should be noted that the rank assigned does not place particular archaeological, cultural or artistic values on sites or sources that have been listed on the coast.

The purpose of the ranking was to assess the potential of a range of types of data sources to inform the decision-making of coastal managers. While it might be considered contentious to attempt the ‘grading’ of sites in certain circumstances, it was deemed appropriate to test such a system for answering specific queries on what could be a measurable occurrence – coastal change.

Some key benefits of the use of ranking criteria are:

- Providing a standard against which all sites and data sources can be judged.
- Securing an overview of the collection of archaeological and palaeoenvironmental sites, art resources, photographs, maps and charts.
- Providing an accountable system for the assessment of sites and sources in relation to coastal change.
- Highlighting areas or sites that should be prioritised by coastal managers.
- Identifying archaeological and palaeoenvironmental evidence that will clearly demonstrate the nature of long-term coastal change to a range of audiences.

Some limitations of the use of ranking criteria are:

- Achieving a universal consensus on the ranking system proposed can be difficult, particularly when dealing with a relatively large geographical area and a large number of potential ‘end-users’.
- It is not easy to devise a ranking system that allows for flexibility while avoiding potential misinterpretation.
- The ranking system can only test present knowledge of the archaeological and palaeoenvironmental resource. The ranking, and possibly the system, will require review and change as knowledge develops.
- Ranking systems are always reliant on the ‘scorer’. Consequently, they are still prone to subjectivity.

Despite these caveats, the project ranking criteria have provided a workable assessment of the available data sources in the partner case study areas.

2.2.2. Archaeological and Palaeoenvironmental Ranking

Initial project data gathering focused on the acquisition of key sources and the assessment of a broad range of historical and palaeoenvironmental data sets available in the case study areas. Further details on the data sources consulted are available in section Data Sources . An initial process of data cleaning was carried out in order to assess the potential of the data to contribute to understanding of climate change. The remaining sites and features were then ranked in order to provide a relative value on the potential of each site to provide scientific information that may be beneficial to practical decision-making in the long-term management and protection of the coastline. Particular importance has been attached to potential information concerning the past behaviour of the coastline and to chronological information concerning the nature, scale and pace of sea level rise and coastal change.

Ranking has also taken account of the fact that rates of change vary between different parts of the partner case study areas. Experience of a rise in sea level will also vary at different locations. Such contrasts arise from differences in coastal geomorphology and from variations in 'down-warping' or crustal behaviour within the deep geology of the Channel coasts.

In areas of coastal instability, archaeological and palaeoenvironmental sites have a particular role to play in establishing proven histories of localised ground movement. These are particularly valuable in sectors subject to landslide movement and other coastal changes. Thus the ranking criteria sought to identify those sites that might best offer evidence for measuring the magnitude and rate of coastal change. Ranking has also considered the value of sites where further research might strengthen current understanding of causation and periodicity.

2.2.2.1. The Criteria Explained

The ranking criteria have been developed to quantify the value of an archaeological or palaeoenvironmental site for its potential to inform coastal managers of past changes to the coastline. Below is a description of each ranking criteria used.

Sea Level Change

- *Does the site contain evidence of changes in sea level?*

The sea level is continually fluctuating. During the period since the last Ice Age (The Holocene) the dominant trend has seen a rise in sea level. Each site, whether it is archaeological, palaeoenvironmental material or a coastal heritage feature has the potential to inform on sea level changes. Indicators can include, artefacts, sediments, diatoms, foraminifera and marine induced features.
An initial review of each site determined either 'yes', 'no' or 'don't know' on whether the site contains evidence of changes in sea level. Then each site that had a 'yes' response was ranked on the potential of the information it contains, this is based on a 1 to 3 score.

Rank	Level	Example
1	Low	A low score was given to items that have not been static very long or do not have secure contexts, so have limited amounts of information on relative sea level change. Examples include: • A modern hulk or shipwreck which would not be old enough to demonstrate change in water levels if recently abandoned.

		• A dated but unstratified find which only provides broad potential dating evidence at a particular period
2	Medium	A medium score was given to sites that have the potential to provide an index point for sea level at a point in time. This provides a fixed reference point and can help calibrate the sea level curve for a region. Examples include: • A stratified artefact or site dating from a period when sea level was lower e.g. a Neolithic trackway or medieval oyster bed. • A datable coastal defence feature • A dated wreck site • A dated abandonment of a building, site or structure due to a rise in sea level
3	High	A high score was given to material that can demonstrate a record of changing sea level. This includew evidence indicating rising, static or falling sea levels. Examples include: • A good quality core through Holocene sediments which were deposited during rising sea level. This would need to have datable evidence such as vegetation horizons. • A set of coastal prehistoric trackways which show changes in location depending on sea level. • A historic building with datable adaptations for sea level rise.

Table 2.7. Archaeological Ranking for Sea-Level Change

Environmental Change

- *Does the site/ feature/ deposit provide evidence of environmental change?*

Since the last Ice Age, local environmental conditions have been adapting to a fluctuating climate, the underlying trend has been global warming. Assessment of environmental material and sources of data can demonstrate the nature of a landscape at a point in time. Indicators within archaeological material include, soils, sediments, insects, pollen, flora, fauna and snails. Material from related periods which can be assessed may provide a picture of the environmental and geomorphological evolution. This would demonstrate how an area has adapted to a rising sea level and changing climate. The drivers behind the change could be natural or human impacts, so for more recent periods the extent of human impacts is likely to be more extensive. There are also more extensive sources of data for more recent changes such as aerial photographs which can be combined with physical evidence to determine changes to local environments.

As with the previous criteria an initial review of each site determined either ‘yes’, ‘no’ or ‘don’t know’ on whether the site contains evidence of environmental change. Then each site that had a ‘yes’ response was ranked on the potential of the information it contains, this is based on a 1 to 3 score.

Rank	Level	Example
1	Low	A low score was given to sites with little datable material that were able to tell us about past environments. Examples include: • A coastal feature such as a gravel spit which has developed as a result of long term environmental change, but does not have specific information on date or environment • Evidence of coastal salt working without specific dating
2	Medium	A medium score was given to a site that has the potential to provide an indicator of the environment at certain period. Dates available for the material or artefacts would be broad rather than absolute. Examples include: • Coastal Bronze Age occupation site with information on land use, diet etc.

		• A core through a deposit that has been dated by relative comparison rather than scientific dating • A dated wreck site where there is a monitoring program in place to provide evidence of sediment changes
3	High	A high score was given to material that can demonstrate a record of the changing environment through a long period of time. Examples are: • A good quality core from submerged or buried terrestrial deposits having dated material, archaeological evidence and a well preserved range of environmental material associated with mineragenic deposits.

Table 2.8. Archaeological Ranking for Environmental Change

Temporal Continuity

- *Does the site contain material that could provide evidence of temporal continuity?*

Temporal continuity is the link that relates past events to each other and the yardstick against which we can assess change. For sites most relevant for understanding of coastal change this is likely to include those which show a relationship to changing shoreline conditions over time.

As with the previous criteria an initial review of each site determined either 'yes', 'no' or 'don't know' based on whether the site contains evidence of temporal continuity change. Then each site that had a 'yes' response was ranked on the potential of the information it contains, this is based on a 1 to 3 score.

Score	Level	Example
1	Low	Sites, palaeoenvironmental material or artefacts which contain evidence from single events or are datable to one period only.
2	Medium	Sites which are known to contain datable evidence of changing sea level, environmental, or climatic change but have yet to be analysed.
3	High	Sites with long datable sequences which have been analysed. Sites would provide evidence of changing sea level, environmental, or climatic change over a period of time that straddles a series of geomorphological events.

Table 2.9. Archaeological Ranking for Temporal Continuity

Non-ranking Criteria

The following criteria are descriptive terms which helped provide a physical and managerial context for the ranked material.

Site Status

- An indication of current status

This criteria provided information on whether sites, features or deposits are known to still be in existence and whether the site includes remains that are above or below the ground, or both.

Code	Level
EA	Site/ deposits exists and are above ground
EB	Site/ deposits exist and are below-ground
EAB	Site/ deposits are both above and below ground
D/R	Site has been destroyed (or recovered)
UN	Don't know

Table 2.10. Current Site Status for Archaeological/ Palaeoenvironmental Data

Coastal Context

- Coastal context indicating the spatial relationship of the site to the coast line

ID	Term	Description
1	Marine (below low water)	Sites that are fully submerged at all states of the tide
2	Intertidal	Sites which become uncovered during low tide
3	Above High Water	Sites which are fully terrestrial
4	Estuary	Sites within estuaries which are fully submerged, distinct from Marine as can be a substantial distance from the sea coast
5	Hard Cliff	Generally expected landward of Mean High Water
6	Soft Cliff	Generally expected landward of Mean High Water
7	Barrier beach	Generally expected landward of Mean High Water
8	Dunes	Generally expected landward of Mean High Water
9	Lagoon	Generally expected landward of Mean High Water
10	Saltmarsh	Generally expected in intertidal area
11	Sandy foreshore	Generally expected in intertidal area
12	Rocky foreshore	Generally expected in intertidal area
13	Sandflats	Generally expected in intertidal area
14	Mudflats	Generally expected in intertidal area
15	Coarse sediment plains	Generally expected in marine area
16	Fine sediment plains	Generally expected in marine area
17	Mud plains	Generally expected in marine area
18	Mixed sediment plains	Generally expected in marine area
19	Sand banks with sand waves	Generally expected in marine area
20	Exposed bedrock	Generally expected in marine area
21	Unknown	

Table 2.11. Coastal Context for Archaeological/ Palaeoenvironmental Data

2.2.2.2. Conclusions

The ranking methodology was integrated into the project database and GIS allowing sites to be ranked as they were entered, the results were then presented spatially in the project GIS with the size and colour of the dot reflecting the rank. This facilitated analysis allowing areas of high potential to be clearly seen, the portal could also be queried in order to see the results of the ranking, see the individual case study reports in Section 3 for the results. The total score was normalised to a value with a maximum of 100 enabling comparison with results from the other ranking systems.

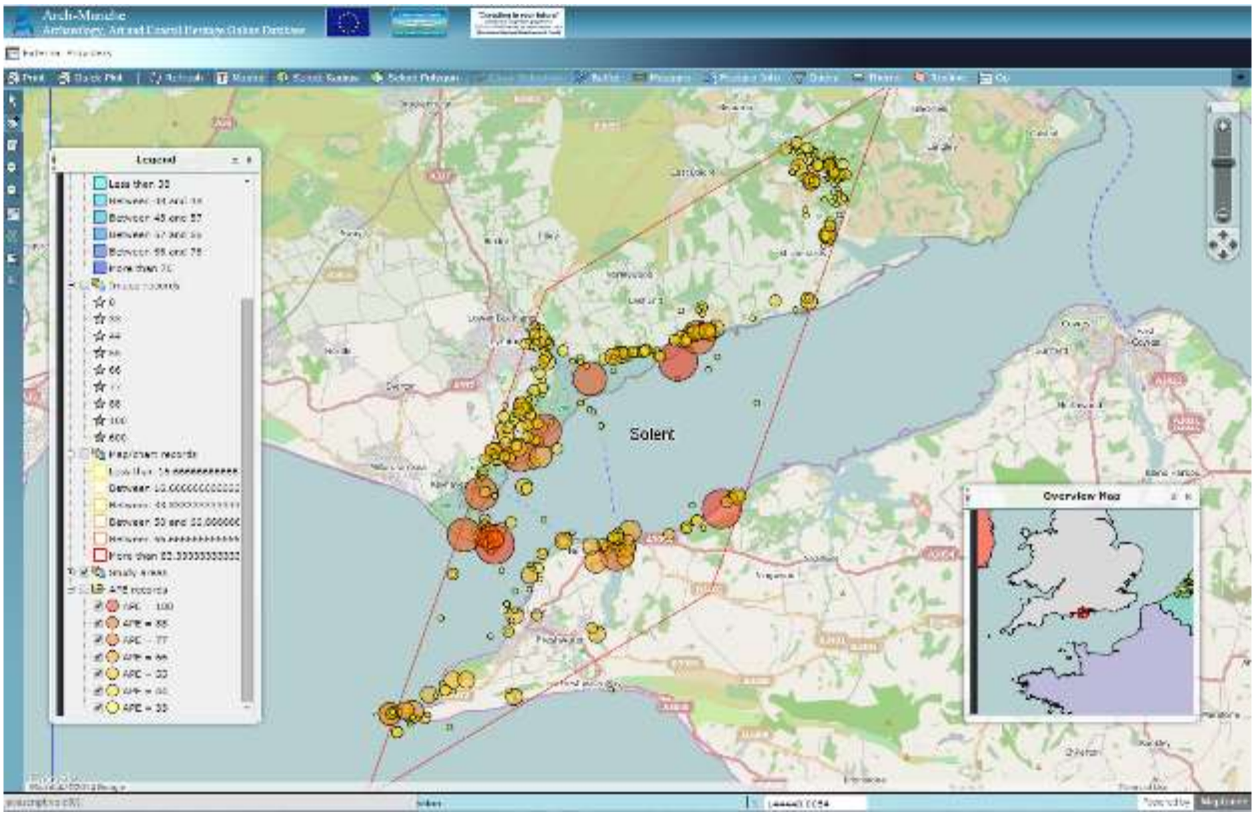


Figure 2.1. View of the Western Solent case study area, the larger red dots have a higher rank

Some difficulties were encountered during the ranking these included:

- Data sets significantly vary in detail between and within the partner countries, some contain a single line description which can be a poor basis for ranking.
- There is a requirement for an experienced archaeologist to undertake the ranking as the process does need a well-rounded background in the historic environment.
- Staff in each partner country carrying out the ranking could occasionally score sites differently depending on subjective interpretation of the criteria.
- It is possible to overlook a site that scores 'low' as a single example yet, taken with others nearby, a higher collective significance might be recognised.

Positive aspects of the ranking included:

- The creation of a database that has broad scope for interrogation and interpretation on a number of themes and issues related to coastal management.
- Enabling the review of large volumes of data against a set of criteria.
- The highlighting of individual sites of high potential.
- Identifying site types that are most capable of providing information on coastal change.

Although the process of ranking is subjective it has led to specific areas and environments where questions concerning the links between past and present coastal behaviour can be positively pursued. The ranking process has helped to identify particular gaps in shoreline knowledge, these can be bridged in each of the study areas as knowledge improves.

This study has revealed that certain types of site and deposit can gain consistent positive scores for their potential to inform on coastal change. Some of these sites can represent single and short-lived episodes. These might include a shipwreck or a prehistoric camp site. Sites of this kind can occur at a particular height, location or time that is pertinent to the understanding of shoreline-change. Other sites can offer a broader range or sequence of chronological and environmental information. They can include biostratigraphical evidence such as pollen records in peat deposits, diatoms in accrued marine sediments and plant macro-fossils in river valley alluvium.

Where short and single-line descriptive texts have been entered into external datasets, it is very easy for some of these qualities to escape assessment. In some instances, old and poorly recorded find-spots may suggest the presence of a greater archaeological or palaeoenvironmental resource, even though no such evidence has yet been documented. This can be the case where a scatter of artefacts has been loosely recorded from a floodplain or from a submerged landscape on the coast.

Overall the ranking process has allowed a large dataset to be reviewed and highlights sites and areas with high potential to inform coastal management.

2.2.3. Art Ranking System

The concept of using historical works of art to support coastal management developed from a visit to Tate Britain in 2007 after examining the painting by William Dyce of '*Pegwell Bay, Kent – Recollections of 5th October 1858'* from the point of view of a geologist and coastal scientist. In particular it appeared that the detailed portrayal of the chalk cliff geology, the wave cut platform on the foreshore, the beach and the coastal defence structures could form a reliable record coastal conditions at this location on that exact date. This raised the question as to how many paintings, watercolours and prints existed for other coastal locations, and were they true representations of the coastline?

In order to test the validity of the concept of using art to provide information on the changing coast it was necessary to develop a ranking system for the various types of artworks, which would allow the development of a list of those artists whose works proved to be consistently accurate in terms of recording coastal change. The objective was to develop a readily available tool for use by those professionals interested in increasing their knowledge of the coast, which would also support existing scientific approaches available for measuring coastal change (McInnes, 2008).

2.2.3.1. The Criteria Explained

In order to assess the reliability and accuracy of the historic artworks the art was assessed against four criteria.

Accuracy of Artistic Style

Varying artistic styles contribute to topographical accuracy to a lesser or greater degree in terms of their portrayal of the coastal environments. Five style sub-categories were considered, namely: *Caricaturist and Genre works, Picturesque Landscapes, Marine and Shipping Subjects, Topographical Artworks including beach and coastal scenery*, and, finally, *Topographical Artworks including beach and coastal scenery with a Pre-Raphaelite influence.*

For the *Caricaturist and Genre* category, including works by artists such as James Gillray (1757-1815), George Cruickshank (1797-1878), John Nixon (c.1750-1818) and Thomas Rowlandson

(1756-1827) and for the *Genre artists*, for example, some of the works of the Newlyn School and Brittany Plein-air artists, their interest usually lay more in human and social subjects rather than physical or historical aspects. These works do not usually contain enough detail to make a significant contribution to understanding of the coastal conditions at particular time; in view of this, such works scored one point out of a total of five in this category.

The second category relates to views of *Picturesque Landscapes* favoured by those artists and illustrators who were producing works in the manner of the Italian landscapes popularised by those returning from the Grand Tour. Often the picturesque views, such as those promoted by William Gilpin and produced by Thomas Walmesley, Francis Jukes and others, comprised aesthetically pleasing, but sometimes exaggerated or adjusted landscapes, with hillsides and cliffs appearing more ‘Alpine’ and precipitous; the desire of the artist was to depict the local scenery in the manner of a classical landscape to satisfy the tastes of their patrons. Whilst the *Picturesque* style is less concerned with topographical accuracy, it can provide at least some indicators of the nature of the landscape at the time. For example, the proximity of development to the coast, the nature of the coastal topography, and the presence of watercourses and other physical features, can inform coastal study in a broad sense. For this reason, the *Picturesque* works scored two points out of the maximum of five points.

Marine and Shipping subjects depicting coastal shipping and craft form a significant component in terms of coastal art. Many yachting, fishing and other shipping scenes include the coastal scenery as a backdrop. Whilst those paintings that are set further away from the coast are less interesting in this context, some works do actually provide a detailed topographical background. Often works produced by naval officers or others who had served on board ship, prove to be particularly accurate. Taking account of the contribution of these paintings a ranking of three points is allocated for this category.

The fourth, and by far the largest category, *Topographical Art including Beach and Coastal Scenery,* comprises coastal landscape paintings, watercolour drawings and prints. This is a rich resource and most of the Channel-Southern North Sea coast is very well illustrated in this respect. In fact there is great interest in the coastal towns and fishing villages located both on the open coast as well as on the tidal creeks, estuaries and harbours. There are, therefore, many works in this category that can inform us of what the coastal landscapes and environments were like at the time they were painted, and, so, such works were awarded four points out of a maximum score of five points.

The final category includes *Topographical Artworks including Beach and Coastal Scenery, which exhibit Pre-Raphaelite detail.* Artists such as William Dyce RA HRSA (1806-1864), John Brett ARA (1830-1902), and Edward William Cooke RA (1811-1880), and followers such as Charles Robertson RWS RPE (1844-1891), Henry Moore RA RWS (1831-1895) and Frederick Williamson RWS (fl.1856-1900) have provided us with precise images of coastal scenery in the mid-to-late nineteenth century. On account of the detail and accuracy of the subjects, with artists seeking to depict nature in a very exact manner, these works form a particularly valuable resource, and were, therefore, awarded the maximum score of five points.

Figure 2.2. Bonchurch, Isle of Wight, UK. Edward William Coooke RA, oil on canvas c1850. Private Collection

Most Advantageous Medium

The second ranking category relates to the most advantageous medium used for illustrating coastal scenery. Six categories were identified – first, *'Copper Plate Engravings'*; second*, 'Oil Paintings';* third*, 'Oil Paintings by Norwich School and Pre-Raphaelite Artists'*; fourth *'Steel Plate Engravings and Aquatints'*; fifth *'Lithographs, Fine Pencil drawings and Watercolour Drawings'*. Finally, sixth, *'Watercolour Drawings by Pre-Raphaelite Artists and their Followers'.*

Although some publishers and artists achieved remarkable success with *copper plate engraving* generally the softness of the copper plates meant that views were not as suitable for recording fine detail. As a result copper plate engravings were awarded a score of one point.

Oil paintings were considered to be rather more valuable as they could provide a greater level of detail and were ranked with a score of two points. Oil paintings by Pre-Raphaelite artists and their followers ranked more highly on account of their precision and the level of detail captured, and such works achieve a score of three points.

Figure 2.3. 'A Beach Scene at Southwold, Suffolk' by Thomas Smythe (1825-1904). Oil on canvas.

Steel Plate engravings and Aquatints were often published individually or as sets; others were contained in topographical books in the pre-Victorian period and through the early-to-mid nineteenth century. The Arch-Manche coast benefits from a wealth of such works, for example the views by Daniell (Daniell & Ayton, 1814) and the Finden Brothers (Finden, 1838). In view of the richness of this resource and the fine detail that could be achieved, combined with the benefits of colouring of some of the views, four points were awarded also for this category.

Lithographs, *Fine Pencil Drawings and Watercolour Drawings* were capable of achieving extremely fine detail. There are excellent examples produced by artists such as Robert Carrick RI (fl.1829-1904) and George Elgar Hicks RBA (1824-1914). The quality of some of the hand-coloured lithographs equates almost to that of watercolour drawings; as a result, lithographs are given a score of five points, the same score as for watercolour drawings. Not only is there an extensive resource of fine watercolour drawings covering most parts of the Channel-Southern North Sea coast, but the detail achieved using this technique is extremely helpful by providing information on cliff and slope geology, the nature of beach conditions, coastal vegetation patterns, as well as the extent of coastal development at the time.

Those watercolours by *Pre-Raphaelite artists and their Followers* score a maximum of six points on account of their often even more detailed appreciation.

Figure 2.4. The coastline at Luccombe, Isle of Wight. A watercolour by the Pre-Raphaelite follower, Frederick Williamson (1878). The cottages below the cliff were destroyed by a landslide in 1910. Private Collection.

The Value of the Subject Matter

This third ranking category was obviously of prime importance to those interested in studying and evaluating coastal change. As a result, a weighting factor of x2 was applied over three categories. First, *General coastal view,* which contributes to an overall appreciation of the coastal geomorphology and character of the landscape scored one point. Second, *More detailed works* providing information on the nature of the beach, the cliff line and hinterland, as well as perhaps information on land usage and environmental conditions, would score two points. Finally, the highest ranking category was for those *Works providing a detailed appreciation* of many aspects of the coast, including the geology, vegetation patterns and coastal development, which scored three points. As a result of the weighting in this category, a maximum of six points could be scored.

Figure 2.5. 'The Old Undercliff Road, Niton, Isle of Wight' by George James Knox. Watercolour, 1866. Image courtesy R.McInnes.

Value of the Time Period

The final ranking category represented the *Value of the time period* in which the artist was working. Three time periods were identified, *1770-1840* (ranking one point); *1840-1880* (ranking two points), and, finally*, 1880-1930 (*ranking three points). The exceptional oil paintings of the Dutch Golden Age merit two points on account of the detail they provide. The rationale behind these scores is that the early works are generally of slightly less interest to coastal scientists than the Victorian landscapes contained in the second category, which illustrate the coastline immediately before the start of, and through much of the Victorian seaside development period. Whilst there may be some information that can be gained from works of the earlier period in terms of depicting the undeveloped and unaltered coast, it is believed that the works covering the period 1840-1880 and, even more so from 1880-1920, where major coastal development changes were taking place, are of greater significance for the coastal engineer and scientist. As a result a maximum of three points was awarded in the category for the time period 1880-1920. Thereafter, artworks tended to lack detail and following the Second World War aerial photography became more widely available.

Figure 2.6. 'The Harbour, Lowestoft, Suffolk' by Alfred Robert Quinton. Watercolour, c.1920. Image courtesy of J. Salmon Limited.

Summary of the Art Ranking System

1. Accuracy of Artistic Style (Maximum 5 Points)	
1.1 Caricaturist/Genre subjects	1
1.2 Picturesque landscapes	2
1.3 Marine/Shipping subjects	3
1.4 Topographical/beach and coastal scenery	4
1.5 Topographical/beach and coastal scenery with Pre-Raphaelite influence	5
2. Most advantageous medium for illustrating coastal change (Maximum 6 points)	
2.1 Copper plate engravings	1
2.2 Oil paintings	2
2.3 Oil paintings by Norwich School and Pre-Raphaelite Artists	3
2.4 Steel Plate Engravings and Aquatints	4
2.5 Lithographs, Fine Pencil and watercolour drawings	5
2.6 Watercolour Drawings by Pre-Raphaelites and Followers	6
3. Value of the subject matter in supporting understanding of long-term coastal change	
(weighting x2 and Maximum score of 6 points)	
3.1 General coastal views which assist overall appreciation of the coastal geomorphology and landscape character of the coastal zone	1
3.2 More detailed view of the beach, cliff, backshore and hinterland including some appreciation of beach profile, cliff geology and structure	2
3.3 Very detailed appreciation of shoreline position, beach profile, geology, geomorphology, coastal environment and coastal defences	3
4. Value of the time period (Maximum of 4 points)	
4.1 1770-1840 (early except Dutch ‘Golden Age’)	1
4.2 Dutch Golden Age (17th century paintings)	2
4.3 1840-1880 (Victorian coastal development period)	3
4.4 1880-1930 (Late Victorian, Edwardian and later coastal development period)	4
Compiling the scores for ranking artists and their works	
1. Accuracy of artistic style Maximum	5
2. Most advantageous medium Maximum	6
3. Value of subject matter Maximum	6
4. Value of the time period Maximum	4
Total maximum score	21

Table 2.12. Summary of the art ranking system

All scores were then normalised to a total score out of 100 in order to enable comparison.

2.2.4. Maps and Charts Ranking

In addition to a range of physical techniques of studying coastal evolution (such as coring and remote sensing), historical maps provide an important source of information. From the late Middle Ages onwards the detail and quality of maps rapidly increased. These maps can be used for coastal research, for instance by georeferencing the maps (comparing the historical map to the present day situation) and digitizing (drawing polygons, lines of points) elements like the evolution of the former shoreline in a GIS (Geographical Information System) like ArcGIS or Quantum GIS.

The quality and detail varies widely between different maps, and simply using them with the assumption that they depict an accurate image of the former (coastal) situation, is likely to induce large mistakes in the coastal reconstruction. Therefore it is important to analyse the quality of a map, before starting the actual interpretation.

When using the term ‘accuracy’ in relation to maps, this refers to the quality of data and the number of errors contained within the map. A high accuracy indicates a more useful map for coastal research, although this usefulness also depends on the specific goals of the research and the specific location of interest. The latter, of course, cannot be measured and defined in an evaluation system and should therefore be assessed by each researcher individually.

Evaluation of the accuracy of historical maps and charts can be achieved in very different ways. It is important to keep in mind the purpose of the study: maps used to study coastal research are subjected to other quality criteria than maps used for ancient road reconstructions. Furthermore it is important to define which elements are taken into account in the accuracy assessment. For this research project we chose a rather classical approach to the elements of map accurateness, freely interpreted after Blakemore and Harley (1982). This includes an evaluation of the topographic, geometric and chronometric accuracy of the maps.

2.2.4.1. Topographic Accuracy

Topographical accuracy refers to the types of depicted elements within a map or chart. What is the smallest depicted element? Which elements are depicted? Are towns simply symbolised by a church symbol or are separate houses drawn? In the Arch-Manche area three main types of coasts are present: estuaries (or tidal basins), cliff coasts, and sand (or dune) coasts. The types of coast represented within a map will define the types of features expected to be mapped. Therefore, separate sub-categories were made within the ranking system for the three above mentioned coastal types.

Figure 2.7. Examples of the depiction of the division of supra-, inter- and sub-tidal areas within estuaries and tidal basins: Left = Well Depicted (high and low marsh clearly defined (source: Algemeen Rijksarchief, Kaarten & Plans II, 8554)). Right = depicted (marsh is separated, but more subjectively (source: Koninklijke Bibliotheek Den Haag, 1049B11_094)).

Figure 2.8. Examples of the depiction of inlets within cliff coasts: left = well depicted, right = depicted (source: commons.wikimedia.org).

Figure 2.9. Examples of depiction of division of dunes and beaches on sandy coasts: left = well depicted (source: Koninklijke Bibliotheek Den Haag, 1049B11_094), right = depicted (source: commons.wikimedia.org).

Estuaries and Tidal Basins: Important estuaries within the Channel – Southern North Sea area include the Scheldt Estuary (Low Countries), the Somme Estuary (Northwest France), the Seine Estuary (heavily transformed under Le Havre´s influence) and the Solent Estuary (Southern England). Within these areas the following criteria for topographical accuracy were assessed to determine whether they were 'well depicted' or 'depicted':

- Divisions depicted between non-tidal, intertidal and subtidal areas
- Tidal channels and inlets depicted

Cliff Coasts: Cliff coasts cover most of the shoreline of Southern England and Northern France (Normandy). The following criteria for topographical accuracy were assessed:

- Division of cliffs and beaches depicted
- Division non-tidal, intertidal and subtidal area depicted
- Inlets (both tidal and river originated) depicted

Dune and Sand Coasts: Sandy coasts are found along the entire coast line of the Low Countries and in Northern France, only intersected by the Scheldt Estuary and some (smaller) river mouths. The following criteria for topographical accuracy were assessed:

- Divisions dunes and beaches depicted
- Division between non-tidal, intertidal and subtidal area
- Topography of dunes depicted

Detail in Non-Coastal Areas: Although there is particular interest in the coastal (intertidal) area, it was useful to note information about topographical detail in the non-coastal area when assessing the maps. The 'non-coastal area' includes everything landward from the water front formed by for instance sea dikes, dunes or cliffs. The ranking system is kept simple in comparison to the coastal areas. Three different categories were used (in addition to 'not depicted'):

- High quality
- Medium quality
- Low quality

2.2.4.2. Geometric Accuracy

Geometric accuracy encompasses both geodetic accuracy (referring to the positioning of a map in a global coordinate system) and planimetric accuracy (referring to distances as depicted by the map versus real distances). Difficulties are imposed by the original coordinate system of the old map as it is not the same as modern coordinate systems; this causes distortions which do not necessarily point to a lack of accuracy. Since these distortions are usually small, and many historical maps do not have information about their coordinate system, the planimetric accuracy assessment was concentrated on to examine the errors due to complexities in the different coordinate systems. The accuracy of the entire map was assessed rather than just the water front zone. Assessing only the latter might create difficulties in finding sufficient suitable Ground Control Points (GCP´s, see below for further info) for analysis.

There are computer programs available to investigate geometric accuracy. Bernhard Jenny describes, in various articles, the methodology used in the program *MapAnalyst* (freely available via http://mapanalyst.org/) in order to define the geometric accuracy of historical maps (Jenny, 2006; Jenny et al 2007; Jenny 2010; Jenny & Hurni 2011). Basically, a present day map (*open street map*) is re-projected and transformed in order to fit on the old map. The more the new map has to be re-projected, the less accurate the old map is. The geometric accuracy is visualised by displacement vectors and distortion grids. The displacement vectors connect the ground control points (GCP´s) in both the old and new map. The longer the line, the bigger the displacement. Alternatively circles can be used (the larger the circle, the greater the displacement). The main visualisation tool is the distortion grid, showing the local distortions in the old map. Where the distances on the old map are smaller than the new map, the grid size will decrease and vice versa. A scaled and rotated (but undistorted) reference grid can be shown for comparison.

Numerical values to compare the geometric accuracy in *MapAnalyst* can be found in the form of the Mean Positional Error (MPE) and the Standard Deviation (SD). Both refer to the average distance from a point in a repositioned historical map (using the GCP´s) and its 'true' position. In most cases the MPE and SD are calculated using a Helmert four-parameter transformation (translation in x and y, scaling and rotating). The MPE is calculated by $\sqrt{(\sum v^2)/(n-2)}$ *(v=distance between each pair of GCP´s, n is number of GCP´s)* and the SD by $\sqrt{(\sum v^2)/(2n-4)}$. Since we use these values as a comparison between different maps it basically does not matter which one is evaluated, as long as the choice is uniform. Since the MPE is calculated in the least complex way we have used this value for the project.

MapAnalyst: Program Interface

The *MapAnalyst* program interface is quite simple (Figure 2.). In the main window both the old and the new map can be shown. Tools are found at the upper end of the display and visualisation tools and output can be found at the bottom of the screen. Open Street Map is set as the default map which projects the world in a Mercator projection but has the disadvantage to exaggerate distances when approaching the poles. The calculations, however, do compensate for this effect and are correct. Alternatively it is possible to import any other map, as long as it has a *World File* (giving all information on the projection system).

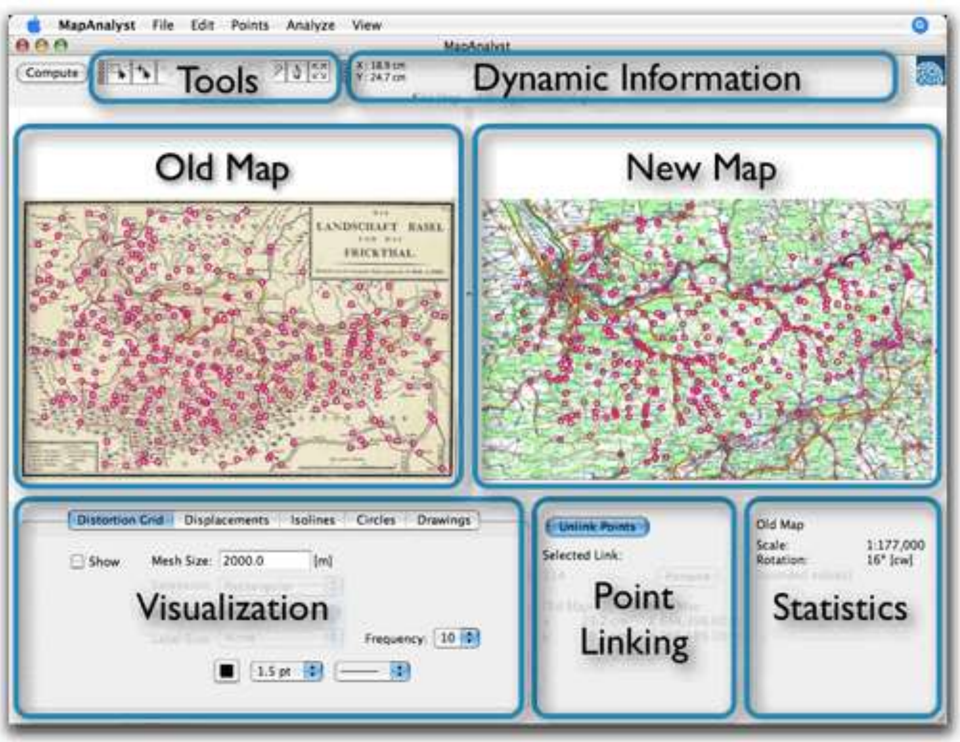


Figure 2.10. Program interface MapAnalyst

2.2.4.3. Chronometric Accuracy

Assessing chronological accuracy is, if it is to be assessed in the most accurate and detailed way, a very time consuming process. For all depicted features a *terminus ante quem* and a *terminus post quem* (giving the date range a certain feature was present in the actual landscape) should be known. These dates should then be compared to the date of manufacturing of the map. In case the map is a copy of an original map, the date depicted should be compared. In this way it is possible to find out if certain parts of the map are either ‘fantastic’ or simply copied from older maps.

Unfortunately, when analysing a large number of maps this process is likely to be too time consuming. Therefore the use of proxies is the only possible solution. The proxies chosen to assess the chronometric accuracy within the Arch-Manche project are:

1. Date of the map. Is the date of the map known? And, in the case of a copy, is the date of the original (and therefore the depicted situation) known? If it is not known, the potential for using the map for (chronological) evaluation of coastal change is limited. It also indicates that it may not be possible to do a full chronometric assessment as there is no date for comparison.

2. The use of terrain measurements. If the use of actual terrain measurements is noted on the map, or several distances are noted, this indicates that an actual land surveyor studied the area which automatically means an increased chance of having chronometrically correct items on the map.

3. Is the map an original or a copy? The chances of a high chronometric accuracy are increased when studying an original map. Certified, authentic copies (or *“Copie Authentique”*) are the next best examples as the quality of the copy is assured. Normal, not certified, copies induce the chance of left-out or added elements, not corresponding with the date depicted by the map. It should be noted that in the case of copies, the date depicted (mostly the date of the original) should be taken into account and not the date of the copy.

An evaluation of these three elements, results in the following ranking (high to low) of the (suspected) chronometric accuracy of historical maps:

Date known	Measurements	Original
Date known	Measurements	Authentic copy
Date known	Measurements	Copy
Date known	Measurements	Unknown
Date known	No measurements	Original
Date known	No measurements	Authentic copy
Date known	No measurements	Copy
Date known	No measurements	Unknown
Date unknown	Measurements	Original
Date unknown	Measurements	Authentic copy
Date unknown	Measurements	Copy
Date unknown	Measurements	Unknown
Date unknown	No measurements	Original
Date unknown	No measurements	Authentic copy
Date unknown	No measurements	Copy
Date unknown	No measurements	Unknown

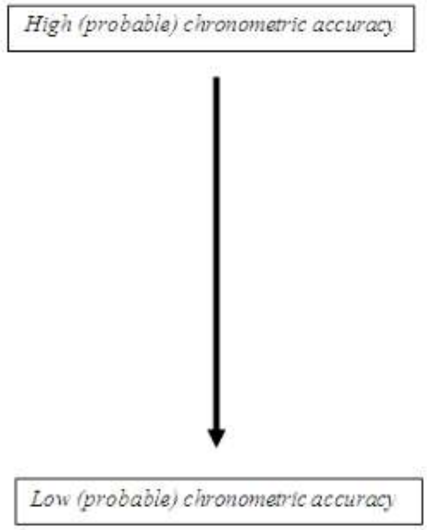


Figure 2.11. Ranking of maps based on chronometric accuracy

2.2.5. Historic Photographs Ranking

Unlike historic maps, charts and artworks it was not necessary to rank historic photographs for reliability and accuracy as they provide and objective view at a point in time. The methodology applied ranked them based on their usefulness in supporting understanding of long term coastal change. Four criteria were used:

1. Purpose of the Photo or Postcard

This was a non-ranking criteria and consisted of the following four options:

- Private.
- Touristic.
- Scientific (geology, geomorphology, archaeology).
- Unknown.

2. Coastal View

The next criteria applied depended on whether the image depicted cultural heritage features. If these were not shown (for example the image was a general landscape view) the following criteria were used:

- General view – no clear detail on the coastal geomorphology (2 points).
- Semi-general view – possible to identify coastal features such as the division between the cliff and beach (4 points).
- Detailed view – possible to clearly see the shoreline position, beach profile, geology etc (6 points).

3. Heritage View

If the image did contain cultural heritage features then the following criteria were used:

- The view provides a general insight on coastal evolution without chronological indications (2 points).
- The view provides an indication on the chronology – identifiable period (4 points).
- The view provides a detailed indication on the chronology – precise chronology (6 points).

4. Quality
The final criteria was based on the current physical condition of the image:
- Poor (1 point).
- Medium (2 points).
- Good (3 points).

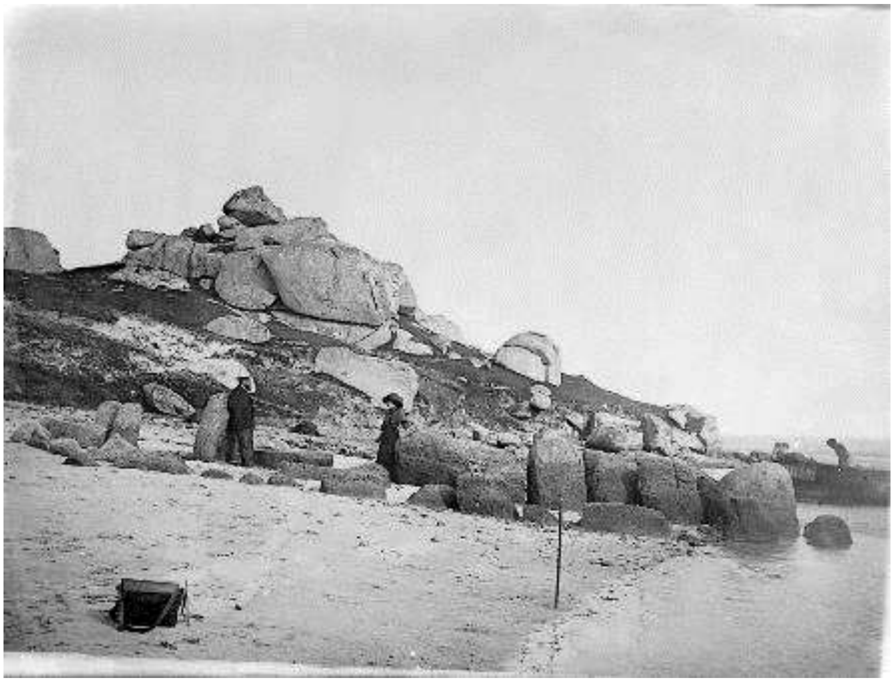


Figure 2.82. The Kernic beach and prehistoric passage grave, Plouescat (Finistère)', ancient photo - (around 1900), author Cdt. Devoir (?) © Labo Archéosciences UMR 6566 CReAAH.

Figure 2.8 is a photo of Kernic beach and a prehistoric passage grave in Plouescat, this image contains cultural heritage and scored 6 points under criteria 3 (Heritage View), the passage grave has been radiocarbon dated to 4300 Cal BP and is now located 3.2m under the current high water line. The current state of the image also scored highly (3 points) as the image has not degraded or been torn so it is still possible to view the detail.

2.3. Fieldwork Approaches
The project partners used a variety of fieldwork techniques to carry out detailed research on significant sites and areas of the coastline looking at the nature, scale and pace of coastal and climatic change as demonstrated through the archaeological, palaeoenvironmental and coastal heritage records as well as artworks. This involved in-depth, inter-disciplinary research including fieldwork with cross-partner staff involvement (two seasons in 2012 and 2013), data gathering, scientific dating and analysis. This section presents the various techniques and approaches used in the project, more detail on the results of the fieldwork can be found in the relevant case study reports (Section 3, the case study reports are numbered from 3A to 3N).

2.3.1. Diving
Diving fieldwork was carried out in the UK on case study area 3D, the Solent and Isle of Wight (Figure 2.). This involved the use of an archaeological dive team to survey known submerged

landscapes and shipwreck sites which have the potential to provide information on coastal change.

The fieldwork comprised survey and sampling of submerged landscapes in the western Solent, evidence held within these sites and deposits provides high resolution data on the development of the Solent as a river, including coastal and climate change and human responses to this. Shipwreck sites across the Solent were also investigated, the sites that were chosen provide valuable information on changing sediment patterns in the area, the monitoring of wreck sites in relation to seabed movement gives us an insight into modern environmental change processes and impacts. The sites investigated have been subject to monitoring in previous years, this provided comparative data in order to understand the rate and level of sediment change in these areas.

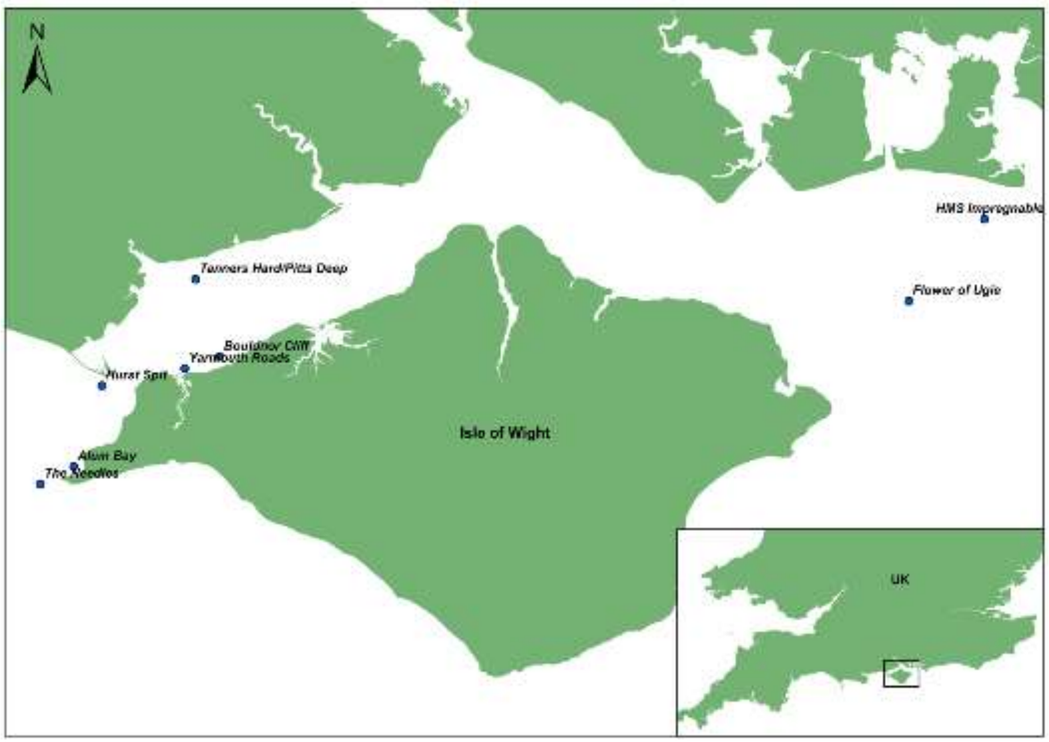


Figure 2.13. Location of dive sites in the Solent, UK

The methods used on the submerged landscape sites included:

Re-establishing previous grids – this allowed site plans to be overlaid in order to monitor changes over time on sites which have been subject to investigation in the past.

Recording and recovering surface finds when under direct threat – these were recorded on the site plans, photographed and recovered for further analysis.

Survey to record rates of erosion - baselines were set up across the sites and tied into previous survey grids, offset measurements were then taken to the edge of the peat drop off at Bouldnor Cliff, and to the foot of the cliff in the north-west Solent.

General site inspections – this involved a review of the seabed to determine whether there have been significant changes since previous diving, and creation of a photographic and video record of the site.

Drift dives – these were carried out in both easterly and westerly directions on both sides of the western Solent, the edge of the peat platforms were followed and inspected with areas of erosion noted. The sites were also inspected for any archaeological evidence which may have eroded from the submerged cliffs.

Sampling – landscape deposits which can provide information on past environments and change over time were recovered using a monolith tin. At the peat deposit west of Hurst Spit where no site plan exists the position was recorded from a fixed buoy on the surface and an accurate depth was taken using a dive computer and from the buoy, recording the exact time of the depth measurement. Samples were then sent for dating and environmental analysis.

The methods used on the shipwreck sites included:

Site inspection – initial diver inspection was carried out to review the area of seabed and determine whether there have been significant changes since previous diving.

Photographic and video record – the sites were photographed and video was taken where possible.

Monitoring – several sites have been subject to ongoing monitoring, established monitoring points were identified and measurements taken to the seabed.

All diving was carried out using a UK Health and Safety Executive (HSE) compliant professional dive team and a licenced dive boat. Volunteers were also able to take part where training and experience was appropriate. Diving activities conformed to the HSE Diving at Work Regulations 1997, and followed the best practice laid out in the Scientific and Archaeological Approved Code of Practice. All potential risks were mitigated through the use of risk assessments.

Figure 2.94. Diver at work on the site of Bouldnor Cliff. Image courtesy of Roland Brookes.

2.3.2. Intertidal Survey

Intertidal survey was carried out in the UK in Langstone Harbour within case study 3D, the Solent and Isle of Wight. Smaller surveys were also carried out on a number of sites around the Solent (Figure 2.10). Sites were chosen which can provide information on past coastal change, as well as more recent change where erosion or extreme weather has exposed archaeological sites and material, and where sites can be used as a proxy to determine the extent of change such as sediment levels.

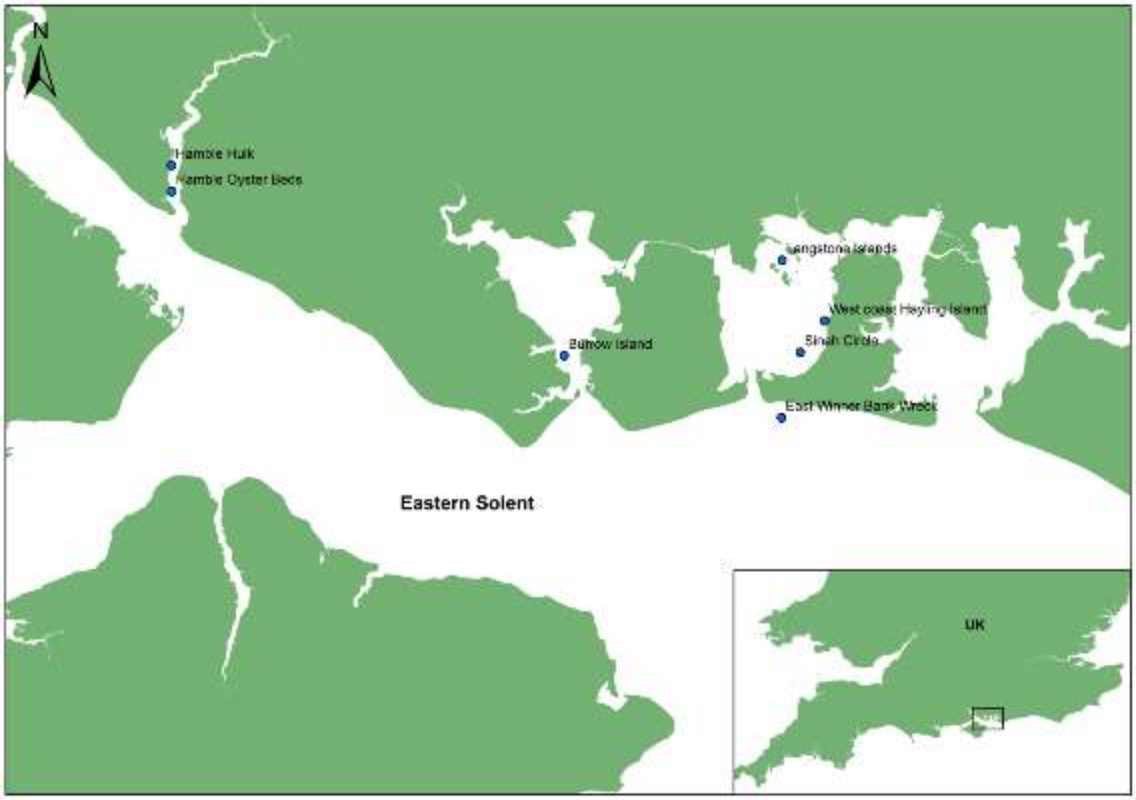


Figure 2.105. Location of intertidal sites in the UK

The following methods were used:

Walkover surveys – these were carried out in order to identify sites, features and finds which may have eroded or been exposed at the fieldwork sites. Positions were taken using a Real Time Kinematic (RTK) GPS along with a photograph, artefacts were recovered if at risk of loss and archaeologically significant.

Controlled Collection – the south east coast of North Binness Island appears to be the site of Roman activity, large amounts of pottery has been revealed on the foreshore. A controlled collection was carried out in this area and the pottery was sent for analysis to the University of Southampton.

Monitoring of previously recorded sites – sites recorded during the 1990's Langstone Harbour Project and survey work in 2002-2004 were revisited to determine whether they were still in-situ or had been eroded. Positions were recorded with the RTK GPS system and photographs taken.

Landscape survey – the RTK GPS system was also used to survey the current edge of two islands in Langstone Harbour, focussing on the base of the small cliff which marks the extent of erosion. The system was also used to survey the oyster beds on the Hamble River, the timber structures along the west coast of Hayling Island and the cliff, and the erosion on Burrow Island.

Photographic survey – this was carried out at all sites. For the East Winner Bank wreck site a camera was attached to a long pole in order to take aerial shots of the site, detailed measurements were also taken of the timbers and the extent of the site exposed by the sand bank.

Sampling – samples were recovered from the timber structures off Hayling Island and sent for Radiocarbon dating.

A Leica 1200 Real-Time Kinematic (RTK) GPS system was used to record the position of sites located during the landscape survey and to carry out a rapid survey of the timber remains found on the west coast of Hayling Island. The RTK system uses the UK Smartnet system to rectify the small basic error that is inherent in all GPS receivers and uses the OSGB36 datum. This allows the Leica 1200 system to operate in the field without a base station and can provide 3D accuracy within the British National Grid to with +/- 15mm. Data collected in the field is then processed through Leica GeoOffice and imported into ArcGIS for further processing, management and analysis. For archiving purposes, all basic data is retained in the form of a simple .txt file to ensure full future access to the original data collected during the survey.

Figure 2.116. The RTK GPS system in use on a timber structure off Hayling Island

2.3.3. Archaeological Excavation

Archaeological excavation was carried out in France at the site of Servel-Lannion (within case study 3I, Tregor and Northern Finistere) and at Quiberon (within case study 3K, Quiberon peninsula and Morbihan) see Figure 2.15. Due to their different environments, the methods used for the excavations were very different on both sites.

Lannion - in the Lannion-Servel area, the Petit Taureau fish-trap is located in the mouth of an estuary, in the intertidal area. Excavation was carried out at low tide using tools and methods applied in terrestrial archaeology, although the excavation was administratively considered as an "underwater excavation", authorized by the DRASSM.

Due to the nature of the site the fieldwork periods were selected to coincide with spring tides, the team generally had 2-4 hours on site per day at various times to fit with the changing tide levels and times. The team was composed of several specialists, students and volunteers, and comprised around 15 people. The surveys were hand drawn in the field but general views were taken along the excavation thanks to a drone. Wood samples were taken during each fieldwork campaign in order to carry out radiocarbon dating, dendrology and dendrochronology.

Quiberon - excavation at the Beg er Vil site in Quiberon involved classic terrestrial archaeological methods; initially a mechanical digger removed the topsoil which was followed by manual excavation. The sampling and sorting of sediments and faunal remains was carried out in parallel with the excavation on the adjacent beach (washing and sieving) and in the field laboratory there were several trainees able to manage the collections. The whole team comprised between 15 and 20 people. In parallel with the excavation and the archaeological data collection (mapping, photos, etc), geomorphological maps of the area were drawn by specialists.

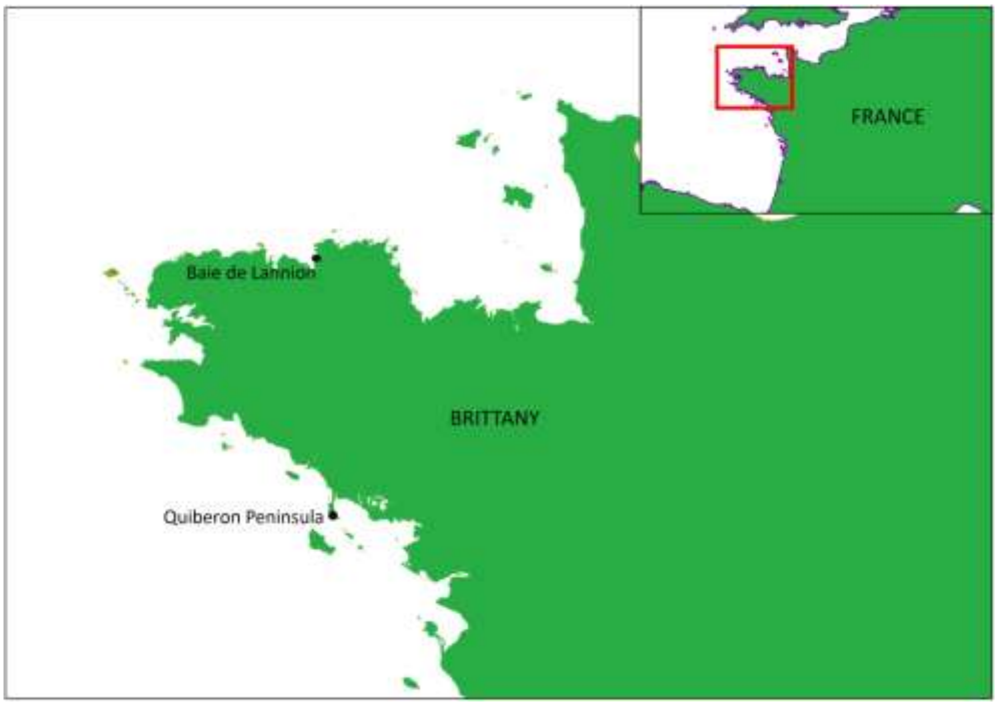


Figure 2.127. Location of Intertidal Excavations in France

2.3.4. Geophysical and Geotechnical

Geophysical and geotechnical fieldwork was carried out in the Belgian case study areas of Raversijde (case study 3L Ostend-Raversijde) and the Scheldt estuary (case study 3M Scheldt polders), as well as Langstone Harbour in the UK (case study 3D, Solent and the Isle of Wight) and off the coast of Quiberon (case study 3K) and St Malo in France (case study 3H, Cote d'emeraude). The various techniques used are described below, further details and results can be found in the relevant case study reports.

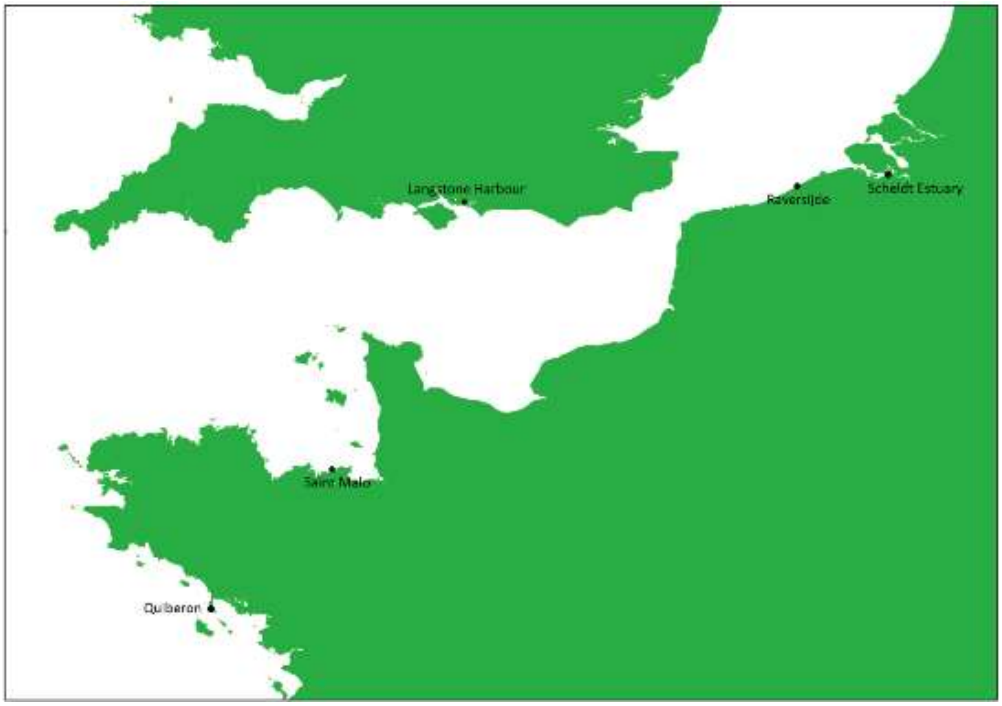


Figure 2.138. Location of geophysical and geotechnical investigations

Cone Penetration testing (CPT) – this method is used to sound the composition of the subsurface and allows for information regarding the geology and hydrology to be obtained as well as the physical and mechanical properties of the subsurface. The method is fast and allows for continuous profiling. The technique involves a cone which is pushed into the ground at a constant rate while continuous measurements are made of the cone resistance and the sleeve friction. The ration of sleeve friction divided by cone resistances, called the friction ratio, is used to classify the soil.

Land Sesimic Investigations - reflection seismic investigations on land involve the use of a controlled seismic source and an array of receivers (geophones). The generated seismic pulse travels through the sediments and will be partly reflected at the interface between two materials with different densities (part will be transmitted through the interface). The reflected waves are recorded at the surface and used to create an image of the subsurface. This image, or model, is not unique (more than one model adequately fits the data, typical for inverse problems) and therefore great care must be taken in data processing and interpretation.

Marine Seismic Investigations - as on land, reflection seismic measurements at sea involve the use of a sound source, towed behind a vessel or mounted to the hull, to generate acoustic waves that travel through the soil. Part of the acoustic signal is reflected from the seafloor but the remainder penetrates the seafloor and is reflected when it encounters boundaries between layers with different elastic properties (Figure 2.14). The recorded reflected acoustic waves result in a continuous record of the sub-seafloor stratigraphy.

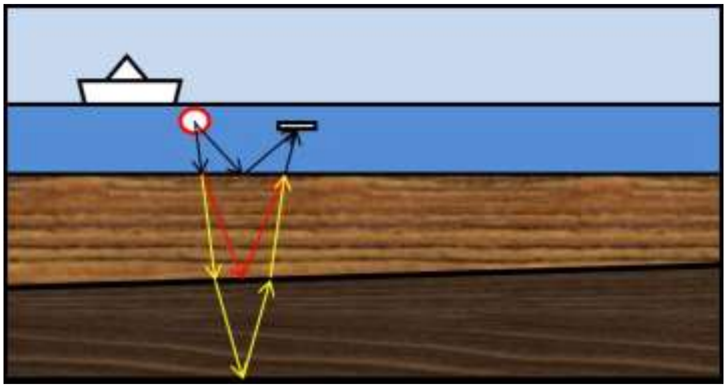


Figure 2.149. Marine seismic reflection principle

Several physical parameters (frequency, output power, pulse length) determine the capability of the chosen technique. High frequencies provide higher resolution, but are limited in amount of penetration below the seafloor whereas lower frequencies provide lower resolutions but better penetration. Increasing output power allows for greater penetration but in the case of a hard seabed or very shallow water this will yield strong multiple reflections (i.e. seafloor echo) and lower signal to noise ratio. Finally, long pulse lengths yield more energy and result in greater penetration but will decrease the resolution. Shorter pulses correspond to broader bandwidth frequency response, thus increasing the resolution.

At both the Belgian case study sites and in the UK case study site of Langstone Harbour a parametric echsounder was used. This source, which is mounted onto a pole attached to the side of the ship or boat emits two signals with a different frequency. The high-frequency signal (100 kHz) allows a very detailed image of the sea floor. The lower-frequency signal (between 6 and 14 kHz) penetrates deeper, resulting in an image of the underlying structure. The fast pulse rate (20-25 pulses per second) resulted in a high lateral coverage. During the measurements the echosounder was attached on a long iron pole fastened to the side of the ship. A motion sensor was used to filter out the wave movement. Positioning was done using a DGPS antenna with an accuracy of ±1 m. In France a sub-bottom profiler (Echoes 1000) was used.

Electromagnetic Survey (EMI) – this was carried out by the department of Soil Management at Ghent University on the site of Raversijde. EMI instruments produce an electromagnetic (EM) field, which varies over time. When electromagnetic fields are induced in the subsurface the resulting field, which depends on specific subsurface properties, can be measured and evaluated (Delefortrie et al., 2014). Zones with a high (measured) conductivity are of specific interest: this may be caused by different things, for instance the presence of metal objects, or shallow peat layers. However, also thick shallow clay layers are known to produce an increase in conductivity, making interpretation a complicated matter. An electromagnetic penetrating profiler was used in the French case study sites.

Auger survey – this was carried out off the west coast of Long Island in Langstone Harbour, with the aim of tracking the buried palaeochannel identified during previous excavations in the area. The survey was carried out using hand augers, both a gouge and dutch head were used. Samples were assessed on site and information logged on an auger log sheet which characterised the colour, consistency, type, size and percentage of inclusions, and soil type. The relative depths of the different soil types were noted when analysing the samples, so as to build a geological/stratigraphical sequence of the sediments. The samples that were taken created a cross formation, with cores AP51-58 and AP6 running south-west to north-east, and cores AP1-5 running north-west to south-east. Samples of peat were recovered for further analysis and dating. The results are detailed in case study report 3L (Ostend-Raversijde). Shallow test cores were also taken at the site of Raversijde, this was to provide ground-truthing for the seismic and electromagnetic data. These cores were taken by a hand-operating coring device called a 'van der Staay suction corer', designed for coring in water-logged sandy sediments.

Side-scan sonar – this was carried out at the French case study sites. The side-scan sonar transmits and receives sound waves. A towfish is towed through the water and transmits fan-shaped acoustic pulses, perpendicular to the direction of travel. The towfish is connected to the vessel by a coaxial electric cable which carries data to the topbox for processing in real time. The acoustic pulse transmitted by the towfish is reflected when it meets a surface, the seabed or any other element present in the ensonified area. Transducers situated on the towfish capture these reflected, or specular waves which travel along the same trajectory as the waves initially transmitted by the device. Travel time is recorded together with intensity. As sound travels at a known velocity through water, the echo, once processed, allows the system to produce an acoustic image of the seabed from which can be determined the lengths, breadths and heights of any objects scanned. An obstacle of sufficient size will intercept part of the transmitted signal and prevent it from being reflected by the seabed. This creates an acoustic shadow which the operator can use to estimate the height of the obstacle. The frequency of the transmitted pulse determines the penetration depth of the wave. Thus, the higher the frequency, the smaller the penetration and vice versa. However higher frequencies provide greater resolutions.

2.3.5. Art Fieldwork Approach

Fieldwork in relation to the assessment of artworks including paintings, watercolours, prints, photographs and old postcards was undertaken at case study sites in England and Brittany, France.

The fieldwork objective was to support the wider Arch-Manche ambitions of establishing:

- What information can the historical images provide to support understanding of long-term coastal change?
- How can the potential of this resource be used most effectively by stakeholders?

Identifying the Artworks for Field Study

The first stage was to identify potential images that might merit more detailed study; this work was undertaken through a review of art data sources in the respective countries. Information about the artworks and photographic images was then entered on the database in order to assess the rank that they achieved in terms of their value in informing us about long-term coastal change. For each image a ranking score was calculated automatically based on the approach described in Section 2.2.3.

Having established, through the art ranking system which of the images were likely to be true representations of the conditions that would have been observed at the time they were painted, and which works achieved the highest scores, it was then possible to consider the locations for field study in more detail. The project partners were anxious to try and ensure that the field study sites represented the full range of geomorphological conditions that exist around the Channel-Southern North Sea coastlines so that art could be used to support evaluation of coastal change across a wide range of environments. The case study sites selected achieved this through inclusion of hard rock clifflines, soft cliffs, coastal landslides, shingle and sandy beaches and spits and saltmarsh and mudflats.

Fieldwork Approach

The ranking system had confirmed that the artworks being studied were by artists who generally achieved a fair degree of accuracy in the images they produced. It was now necessary to test this in the field. Prior to the site visits the location from which the artist depicted the view was established as closely as possible in order that a direct visual comparison could be made in the field.

Each of the case study locations was visited and photographed in varying weather conditions. Inspections were timed, wherever possible, to coincide with Low Water and a walk-over survey was made along the beach and base of the cliff returning along the cliff top. This ensured that thorough comparison could be made between the geomorphological conditions depicted in the artwork and the present day situation. In terms of on-site assessment particular aspects of interest included the extent of coastal erosion since the artwork was produced, evidence of rock falls, landslides and other substantial changes to the coast, changes in the form and nature of the beach (eg: steepness, volume and composition) and changes in the extent of saltmarsh and mudflats as a result of sea level change or human intervention. Furthermore, the nature and extent of coastal defences and development patterns was noted as a number of the interesting geomorphological features had been obscured subsequently as a result of the expansion of coastal towns and villages or by tree and scrub growth.

The main focus for each case study has been the examination of one or two particular artworks, and then to make an assessment of what the image tells us about changes over time from field observation (Figure 2.18). However, for some of the study sites it has been found that several artists painted the view from the same or a similar spot. This helps us to establish a chronology of coastal change through the nineteenth and twentieth centuries. The results for each case study location are described below.

Art fieldwork was undertaken at the following case study locations:

England

- East Anglia
- East Kent Coast
- Hastings, East Sussex
- Solent and Isle of Wight
- West Dorset-East Devon
- West Cornwall

France

- Cote D’Emeraude, Brittany
- North Finistere and Tregor, Brittany
- Quiberon Peninsula and Morbihan
- Cornouailles, Brittany

Nearly two hundred and fifty artworks from across the Channel-Southern North Sea region were ranked. A substantial number of these (39%) were deemed to be of sufficient interest to require more detailed investigation through case studies (56 in England and 42 in Brittany, France).

Figure 2.20. Art field studies involved comparing the current situation to the original artwork, this is Bonchurch shore which was painted by E.W Cooke.

2.4. Data Management

In order to provide common working approaches a database and project GIS were developed, these used open source software to allow joint working and the analysis of project results. This section outlines the methodology for data management.

2.4.1. Context

The Arch-Manche project has placed a high priority and emphasis on effective, efficient and innovative data management that underpins many of the overarching project aims and objectives. As stated in the project proposal, "*Successful data integration and management will be key to the development and delivery of the project. Activity 1 and 2 will be developing datasets on which illustrative, modelling and presentation materials will be based. Presentation materials will be integrated into all levels of reporting, communication and dissemination.*"

A database was created to contain archaeological data, palaeoenvironmental data, maps, charts, photographs and artworks. All of these data sources were integrated into one database that was accessible by all partners and also linked to a project GIS in order to view and analyse the results spatially. This was then developed into a geoportal which could be accessed by the public in order to interrogate the data obtained through the project and to view the 2, 3 and 4 Dimensional models.

2.4.2. Software Rationale

The Arch-Manche project database was developed as the central repository for storing, rationalising and distributing the results of the work undertaken. The key parameters used for the selection of the appropriate system in order to deliver on the aims and objectives for data management and analysis were as follows:

- *Functionality*: the database was required to store various data types and deliver results rapidly enough that the end user need not be conscious of the transactions that were taking place once queries were submitted; the application had to be extensible, with optional features being available if required (for this project the spatial extension functionality was to be key).
- *Licensing and distribution*: the database might have been proprietary, but the output had to be cross-compatible with other non-proprietary systems so that data could be shared between audiences or potential partner projects not necessarily deploying the same proprietary system; open-source software offered the greatest data sharing potential; cost was a factor when comparing like-for-like functionality.
- *Cross-compatibility*: for the reasons cited above, the database was required to run on a variety of hardware and software solutions, not operating system dependent.
- *Accessibility*: a database using a front-end/back-end approach was deemed to enable the greatest flexibility in terms of access, enabling multiple concurrent users and the widest range of options in working with and extracting the project data, therefore a web-based front-end was desired, as opposed to a client running on a single machine.
- *Archiving suitability*: a database system that stores data in ASCII text format is easily archived and managed during and beyond the life of the project, database systems that produce proprietary formats are not appropriate for this reason, or require additional work to make data archive-ready.

Following detailed consideration and assessment PostgreSQL was chosen as the database software. PostgreSQL satisfied all of the criteria, being freely available, open-source, community developed, yet powerful and with the greatest range of spatial extensions currently available. PostgreSQL is described, by its developers, as "the worlds most advanced open-source database" and it is currently deployed in several high profile global organisations and social media platforms. This software is server based, running on all major platforms, including Android, and can be administered and queried from numerous client applications and web-based frontends to display and manipulate the data. SQL dumps are ready to be archived with minimal administration required.

As PostgreSQL satisfied all of the criteria for access, archiving and distribution it can easily interface with other available data sources that have been, are being, or will be developed in the near future. The database can be used to supply spatial data, records for online database portals, images and other content for integration with various other internet based resources.

Despite the rapidly changing technological environment, three years on from the initial selection of PostgreSQL as the Arch-Manche project database platform it remains the leading choice for this type of application.

2.4.3. Database Development

The Arch-Manche project database was developed according to the following principles that were established at the project out-set:

- *Geographic functions:* the database must be a spatially enabled geodatabase and records must be available to a project GIS;

- *Accessibility:* the database and interface should be as accessible as possible and should allow concurrent user working for international partnership development;
- *Ranking:* must contain a ranking system for individual records establishing relative ranking of information from various interrelated disciplines, including art, archaeological, palaeoenvironmental and coastal management data; and
- *Visualisation:* the resulting data should be suitable and accessible for the development of illustrative material, including 3D models, animations and schematic representations, web-GIS and the project website.

2.4.3.1. Geographic Functions

These criteria were used to design a database that provided spatial functionality through the integration of PostGIS, a PostgreSQL extension that enables storage of geographic data and associated geometry as well as suitable coordinate system functions. PostGIS integrates with other available software packages for viewing and analysing the project data, including Quantum GIS (QGIS) and Mapguide open-source. The WGS84 geographic coordinate system, using latitude/longitude and decimal degrees, was defined as the global database coordinate system due to being the most appropriate for marine data distributed across the coast of Western Europe.

2.4.3.2. Accessibility

Database accessibility was maximised through the development of a web-interface front-end that provided data entry functionality for project partners. Access was facilitated using an ordinary internet browser, requiring no special plugins but using a secure login system to ensure security of the data. Functionality to translate feature and boundary coordinates into geographic objects through this interface was built into the database at this time.

Multiple users were able to work on the database concurrently, regardless of geographic location. Occasionally this resulted in record insert or update functions failing, though the user was notified in this eventuality. The primary advantage was the immediate availability of user input to all partners, and the complete avoidance of versioning issues, with the fully updated database being the only copy available. The data store was backed up on a nightly basis to guard against data loss or user error for ‘point–in-time recovery’ (PITR).

2.4.3.3. Ranking

This functionality was implemented through the use of standard SQL ‘trigger’ actions on the database that ‘fire’ when a record is created, updated or deleted, as appropriate. The trigger for each data source was coded individually with sequential SQL statements to calculate a total score which was then normalised to a value with a maximum of 100, thus enabling comparison with other results. On the Arch-Manche database the triggers are set to fire when a record is inserted or updated.

For details of the weighting, normalisation and overall ranking method and rationale, please refer to Section 2.2.

2.4.3.4. Visualisation

The Arch-Manche database was created specifically for the purpose of reusing the resulting data with the minimum of effort. The data is stored on a web-server owned by the Maritime Archaeology Trust, and as such is accessible globally.

The initial visualisation requirement was for project partners to be able to view a spatial representation of records. In the first instance, the data was visualised by connecting to the database through the open-source Quantum GIS package (QGIS) or via ESRI ArcMap. While the records could be visualised and edited in this way, the method was not conducive to partnership work in remote locations due to speed and access conflicts.

Subsequently a web-GIS mapping application was developed to display these results. Mapguide open-source was selected for its extensive functionality, speed and ease of use. The geometry and associated meta-data are pulled directly from the database, meaning that changes to individual records are seen immediately on the map. Together, the database and the web-GIS application formed the basis of the data analysis toolbox for the project.

2.4.3.5. Database Structure

The Arch-Manche database is a relational database designed to provide the maximum potential for query building and ease of obtaining the required information and reports. It is composed of 84 tables of the broad types as shown in Table 2.13.

Table type	Count
Data store (main)	5
Data store (sub)	6
Link tables	5
Lookup tables	66
Spatial tables	2

Table 2.13. Summary of the Arch-Manche database table types

An overview of the schema relationships between these tables is provide in Figure 2.21

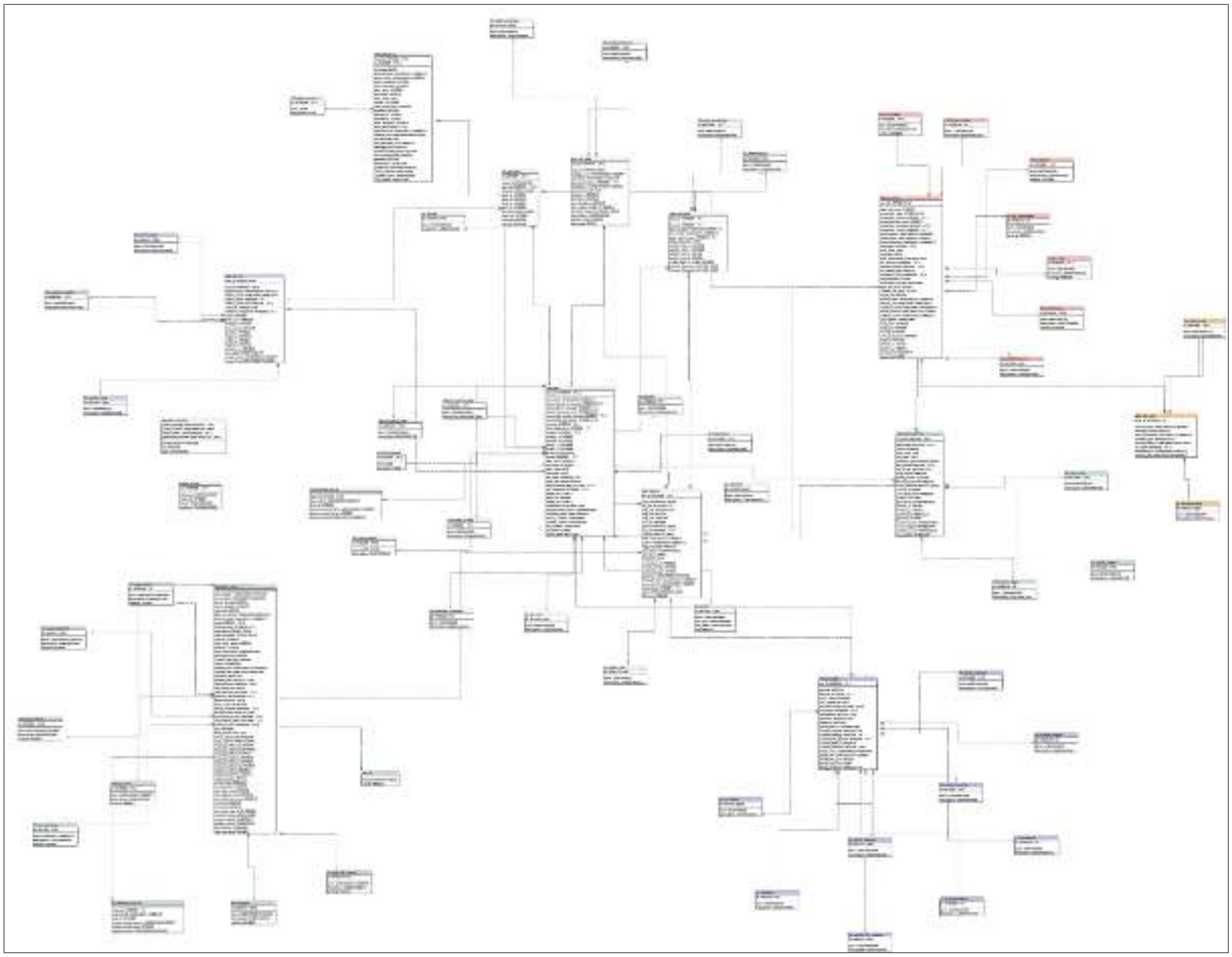


Figure 2.21. The Arch-Manche database schema, showing the five main data table clusters and a sixth group of link tables

Fields are controlled through the use of word-lists, wherever possible, ensuring record consistency. Queries are structured as 'views' on the data and have been developed to provide data for further visualisation.

Form views of each table were built in the web-interface to provide a user-friendly graphical user interface for data entry and individual record searches (Figure 2.15).

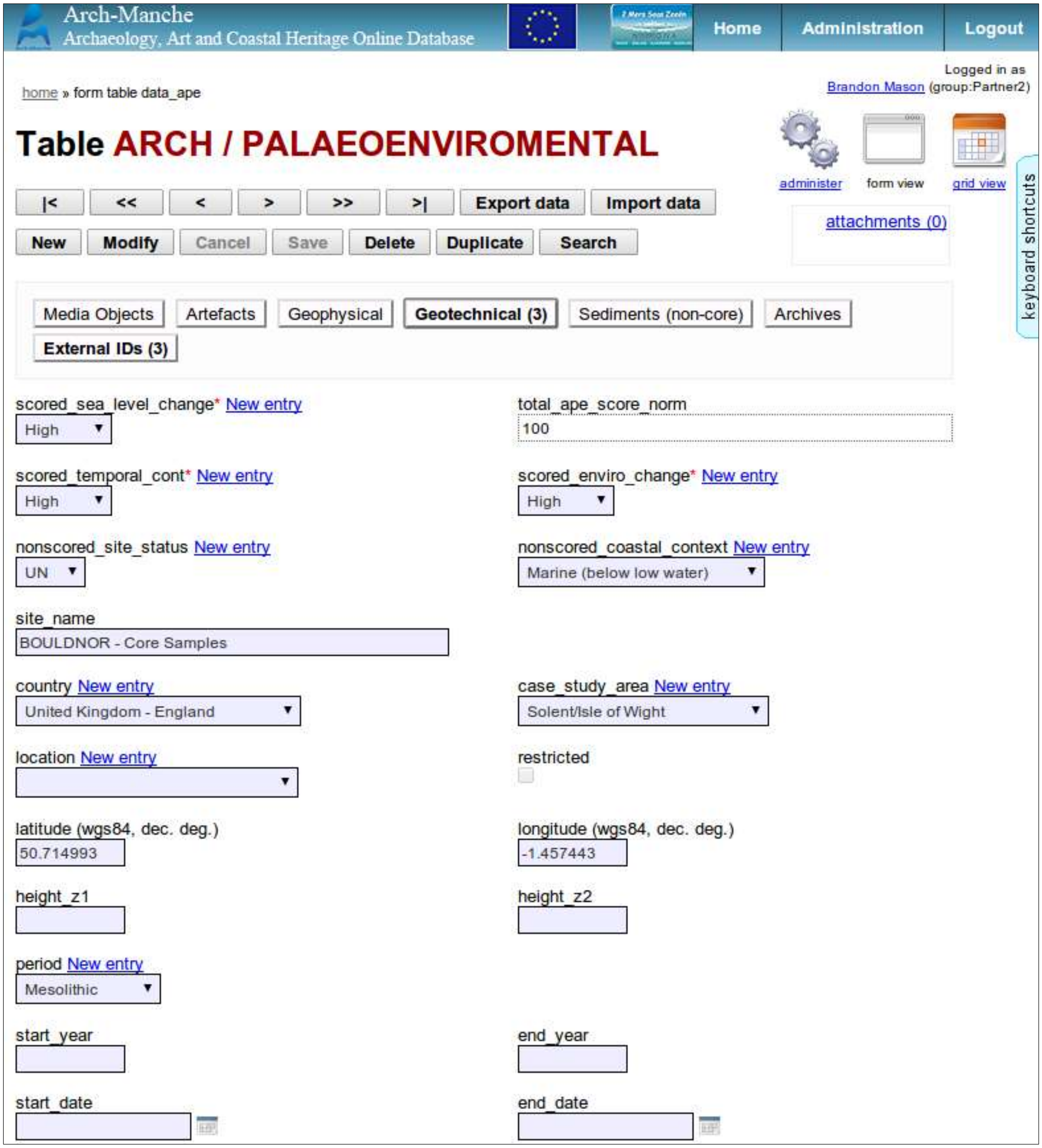


Figure 2.15. Form view of the Arch / Palaeoenvironmental table via the web-interface

2.5. Data Analysis

The Arch-Manche project has developed an online exploration platform for the visualisation and interpretation of the entire project study area (2-Dimensional) and specific partner case study areas (2 and 3-Dimensional). The platform is browser based, requiring no plugins or additional software. It offers the means to explore, understand and engage with the wealth of art, archaeology and heritage common to the partner states in a way not previously accessible to such a broad and diverse audience.

This approach has been achieved through the development of an online geo-portal which provides an easily recognisable Google Maps style plan view interactive map illustrating an immediate appreciation of the range and intense distribution of indicators of coastal change. Each of these points reveals additional information and imagery drawn directly from the underlying database when hovered over with a mouse pointer or touched (for touch enabled devices). The user can also find links and additional information signposting other projects, sites and archives.

Several of these sites are featured as detailed case studies which the explorer has the option to delve into further. Additional navigation controls are available to allow the user to zoom into selected sites and features, pan and tilt the view, revealing full three-dimensional representations of the case study areas.

In this way, the portal caters for basic users (2D interactive) while providing an easy to navigate and even more engaging experience with advanced controls (3D interactive). This is now feasible due to the recent, cutting edge, innovation in visualisation technology, itself not previously developed and deployed in marine archaeology, in tandem with the growing ubiquity of public internet access.

Figure 2.23. The Arch-Manche Geoportal

2.5.1. Case Study Models

Through the project 2, 3 and 4-Dimensional visualisations have been created in order to illustrate the changing landscape over time. These have been created for four case study areas; Langstone Harbour, the Baie de Lannion and two for the Scheldt Polders region.

2.5.1.1. Scheldt Polders

Two models were created for this region, the first was a series of palaeogeographical maps from 9,000 BC to 500 BC. The second was a series of maps from the post-medieval period based on evidence from historical maps.

Holocene Palaeogeographical Landscape Reconstruction

The data obtained from the field studies in this region only provided local information (restricted to Doelpolder-Noord), insufficient for a regional palaeogeographical study. Additional geological information was needed from existing data (sediment cores, archaeological augers, CPT). The vast majority of this data was obtained from the subsurface database of the Flemish Government (Databank Ondergrond Vlaanderen, DOV). The Department of Archaeology of Ghent University provided all the geological information from augers taken during archaeological site surveys in the area.

A major difficulty in the data integration proved to be the high diversity of the type and date of data (some being over 100 years old), the diversity in data resolution and also the diversity of the observers (i.e. geologists, engineers, archaeologists). Consequently the quality of the data varied greatly, as did the interpretation of the geological data. Where possible the raw data and the original descriptions or measurements were studied and reinterpreted taking into account the current geological knowledge of the area. The total data set contained 6423 data points, of which 5783 reach the Pleistocene/Holocene boundary.

The first step in the reconstruction was the creation of an isohypse map of the top-Pleistocene relief using both geostatistical software and geological interpretation. More details on how this was done can be found in the report "Holocene palaeogeographical evolution of the Waaslad Scheldepolders" by Heirman, Missiaen & Vos (2013). In order to allow correct integration with Dutch palaeogeographical maps the NAP level was used instead of TAW. The southwestern part of the Waasland Scheldepolders is located above 0 m NAP (= 2.33 m TAW), while the northeastern part is located below 0 m NAP. The topography of the Pleistocene/Holocene surface fits very well with the Pleistocene/Holocene surface of the southern Netherlands (Vos, 2002, Vos and van Heeringen, 1997).
Full details of the palaeogeographical maps are available in the Scheldt polders case study report (3M).

Post-Medieval Landscape Reconstruction

Based on historical maps, landscape reconstructions for certain time periods (depending on the availability of the maps) can be made. For the Waasland Scheldepolders test-case five time sections were selected (1570, 1625, 1700, 1790 and 1850) that represent major landscape changes. The maps were selected based on their ranking results and an inherent additional criterion: the date of manufacturing should be as close to the chosen time frame as possible, in case of analysis based on multiple maps per time section. This implies a crucial role of qualitative interpretation, as a trade off of the above factors should be made in order to acquire the best possible reconstruction. It also means it is not always possible to use the most accurate map available.

Each time section was based on multiple historical maps, making it necessary to conduct a number of interpolations, in order to "match" the different maps into one continuous reconstruction. For more details regarding the landscape evolution and the choice of maps see the Scheldt polders case study report (3M).

2.5.1.2. Langstone Harbour and the Baie de Lannion

A 4-Dimensional model of the topographical and environmental changes in Langstone Harbour has been created, and a model of the topographical changes in the Baie de Lannion has also been created as part of the project. The models are presented in an interactive format that allows the user to control time and place in 4 dimensions.

The software used is a Cesium WebGL cross-platform to demonstrate the environmental development of Langstone Harbour and the Baie de Lannion. A visual representation is aesthetically pleasing, and provides a very different understanding and appreciation of the information collected and contained therein.

Cesium Web GL is a JavaScript library that has made it possible to create visual representations of the study areas by using online web-maps. The maps interface is similar to Google-, Yahoo-, or Bing maps but does not limit the publication of the obtained data.

The benefits of using Cesium are;

- Availability without any additional software or plugins;
- Open-licensed topographic mapping;
- Simple and user friendly navigation controls;
- Simple layer and time control, giving the user a possibility to change time and place;
- Allows adapted raster imagery and surface models;
- Allows labels and highlights features of interest in a user friendly way; and
- Drastically increased audience reach as webGL technology, 3D computer generated imagery is available to any internet user with a modern web-browser.

Cesium is an open licensed cross-platform virtual globe that can be downloaded and used for free and without licencing issues. The software is developed and supported by an active open-source community, see http://cesiumjs.org/ for more details. The model developed with Cesium can be run on a variety of hardware and software solutions and is not operating system dependent.

Users of the model can view it with the help of any modern web-browser that is connected to the internet. If the user's computer or internet connection is outdated or exceptionally slow increased downloading time might occur. The system was tried on several types of computers, internet connections and phones without encountering any problems.

Model Development

The main objectives when creating the model was to create a:

- User friendly model that allows the user to navigate through space and time;
- Model that visualises the results obtained during Activity 1 and 2;
- Easily accessible model; and
- Model that includes information about areas of interest.

The objectives were achieved through a three stage process:

Stage 1 Summary of Known and New Archaeological Information

Stage one focussed on gathering and summarising the previously known historical and archaeological data as well as the archaeological data obtained during fieldwork. Maps, charts and images where environmental and topographical changes of Langstone Harbour are visible were identified. Based on this data it was decided that the model would focus on re-constructing the Mesolithic, Neolithic, Bronze Age Iron Age, Saxon, post medieval landscapes and compare them to the current environment of Langstone Harbour.

Stage 2 Reconstructing the Landscape

The environment and topography of the past landscapes was recreated by using evidence collected from core samples, pollen and plant analysis and radiocarbon dating together with deposit models previously created for Langstone Harbour.

For each of the of the time slots contour lines representing the topography were created. The contour lines were then exported as raster images with a 1 metre resolution, these files make up the local terrain at the various times in Langstone Harbour.

To accompany the terrain files, high resolution geotiff images for each landscape were created. The images were generated by using segments from current aerial photographs to mosaic a landscape that illustrates the changes that Langstone Harbour has undergone.

Stage 3 Software Development

As described Cesium was deemed to be the satisfactory software for presenting the data. To achieve the aims and objectives of the project Cesium was installed and styled. The software is provided with stylesheets and templates and to adapt the user-end of the model, to add points of interest a combination of html and JavaScript was used.

To be able to import the raster and geotiff into Cesium GDAL software library a software application was developed. The application uses GDAL to read the raster data and converts it to the format required by Cesium. The application was developed by Geodata Institute and is completely independent from the rest of the Langstone Harbour model, it must be run on a Linux server and has been made publicly available through github (https://github.com/). The converted files were imported into Cesium, which then allows the topographic raster data to be overlapped with the geotif to create a 3D model of the landscape. By adding a time element and giving users a way of controlling and choosing what they want to see the 4D model is complete.

Once this process was completed it was also applied to the Baie de Lannion case study area where topographical changes have been modelled.

2.6. Summary

The historical evolution of the coast provides valuable information on past trends which can help develop future coastal climate change scenarios. Present coastal landforms have developed since the last Ice Age, studies of their evolution based on archaeology, palaeoenvironmental and coastal heritage features provides a seamless timescale from the Ice Age to the mid-20th century. Early archaeological evidence demonstrates how people were impacted by coastal change in the past and how populations reacted to some large-scale landscape and climate changes. More recent human activity along the coast can show us how humans have had a direct impact on coastal stability. Some has been positive but much has been counterproductive.

Maps, charts and artistic representations of the coast can all be available for study. Combining information from these data sources within particular coastal frontages enables an in depth understanding of long-term change. An understanding of ongoing changes and the consequent environmental and physical impacts can help inform coastal managers when they are faced with long term strategic decisions.

Sources of data vary within each country with some nations or regions having particular specialist collections, while others do not hold directly comparable data sets. The research process identified key collections which have then been used in support of the Arch-Manche analysis, many of the data sources were ranked using the assessment criteria developed for the project outlined above.

The next section (section 3) of this report includes the individual case study reports from across the partner countries, these outline the results of the ranking and fieldwork, and the subsequent analysis of these results to inform our understanding of long-term coastal change. In order to ensure that a diverse range of coastal situations were assessed across the Channel-Southern North Sea region, fourteen case study areas were selected. These included a variety of coastal frontages which are faced with different challenges in terms of management, physical conditions and available data resources.

3. The Arch-Manche Case Study Sites

In order to ensure that a diverse range of coastal situations were assessed across the Channel-Southern North Sea region, fourteen case study areas were selected within the partner countries. These included a variety of coastal frontages which are faced with different challenges in terms of management, physical conditions and available data resources.

The following areas were subject to detailed ranking of available data sources, fieldwork and analysis to review evidence of coastal change over time. The methodologies used in the ranking, fieldwork and analysis are also explained in Section 2.

Figure 3.1 Location of the fourteen Arch-Manche case study areas and the partner organisations.

UK Case Studies

- 3A – East Anglia
- 3B – Kent
- 3C – Hastings
- 3D – Solent and Isle of Wight
- 3E – West Dorset and East Devon
- 3F – West Cornwall
- 3G – North Cornwall and North Devon

French Case Studies

- 3H – Cote d'Emeraude
- 3I - Trégor - North Finistère
- 3J – Cornouailles

- 3K - Quiberon

Belgian Case Studies

- 3L – Ostend – Raversijde
- 3M – Scheldt polders

Dutch Case Study

- 3N - Netherlands

Past coastal planning regimes have suffered from a poor understanding of the ongoing processes and natural trends that are shaping our coastal zone. Consequently, many coastal settlements are becoming vulnerable as the frequency of coastal erosion, flooding and coastal instability events increase, and the relationship between the land and sea evolves.

This report and in particular the individual case study reports quantify the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

Alongside the case study reports, the data used and the results of the ranking can be viewed through the Arch-Manche portal – www.archmanche-geoportal.eu. This spatial viewer contains the archaeological, palaeoenvironmental, art, photographs and map data used in the project at the case study areas. It also contains the various 2, 3 and 4D models created in some of the case study areas to demonstrate how these sites have changed over time.

CASE STUDY 3A – EAST ANGLIA, UK

Case study area: East Anglia, UK

Main geomorphological types: Soft cliffs, shingle and sandy beaches, shingle spits, creeks, estuaries and saltmarsh.

Main coastal change processes: Coastal erosion, cliff instability, beach change.

Primary resources used: Art, Archaeology.

Summary: The study area comprises extensive clifflines of glacial till which are subject to erosion and instability. Artistic depictions have enabled us to see the rate and scale of this erosion over the last few hundred years. This has been complemented by the extensive archaeological record demonstrating this loss particularly from the Medieval period.

Recommendations: Coastal managers should use these resources when predicting future rates of erosion as they provide hundreds of years' worth of data to assist in the understanding of the rate of change. Further work into historic maps and charts is recommended as this can provide even more detail particularly from the 19th Century.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the technical report on the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

East Anglia is one of six UK case study areas for the Arch-Manche project. This case study report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented along with the results of the art, photographic, and map and chart studies. The analysis of these results and the potential for demonstrating the scale and rate of coastal change are then presented. For further details about the project methodology see Section 2.

Within the East Anglia area the archaeological and palaeoenvironmental resource and the available art resource have been researched, ranked and analysed. The extents of the detailed study areas are shown in *Figure 3A1* below. The area considered for archaeology and palaeoenvironment has been selected to provide a representative range of types of evidence across a range of periods spanning from Palaeolithic through to more recent coastal heritage. The art, photograph and map and chart case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time.

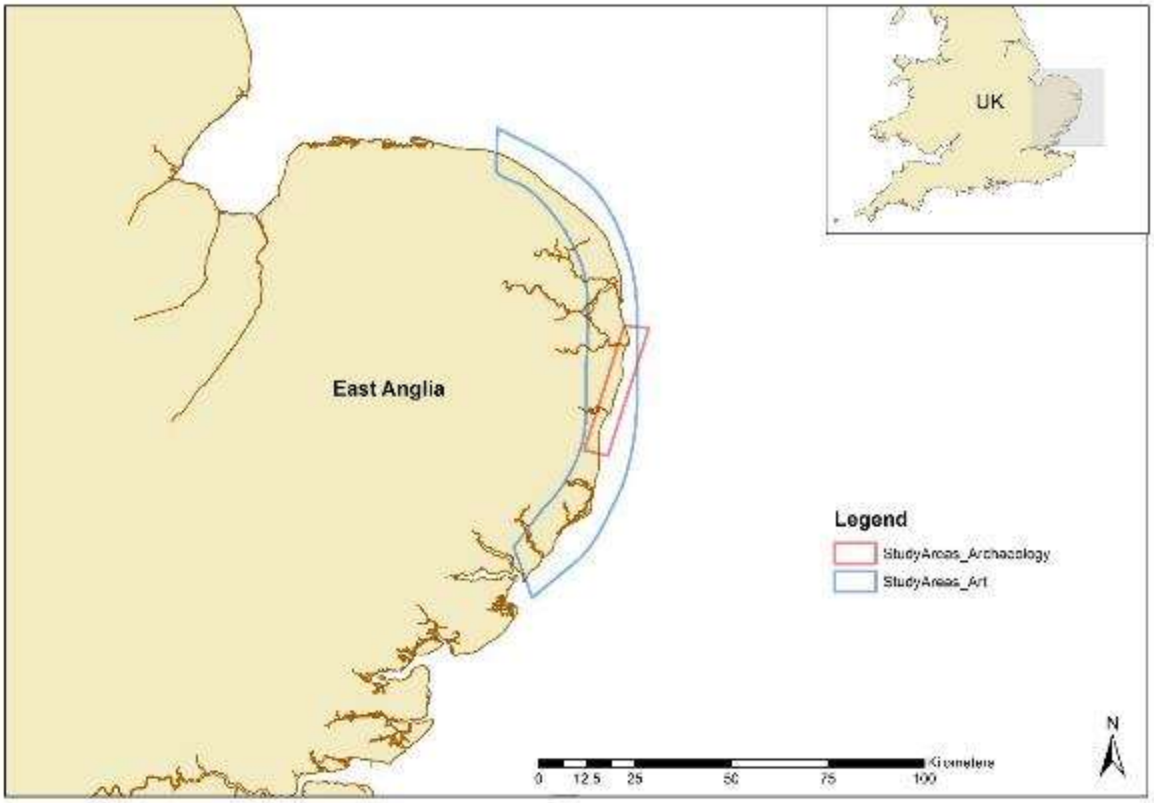


Figure 3A1. Map of the East Anglia Study Areas

3A.1 Introduction to the East Anglia Study Area

The coastline of East Anglia has been subject to urban development progressively over the last 1,000 years. The coastal zone makes a very significant contribution to the economy of the East Anglian region, as well as providing opportunities for relaxation, recreation and enjoyment within an outstanding natural environment. The coastal local authorities have been actively involved in encouraging improved integrated management over the last two decades, and this has led to the production of strategies for the coast in support of the principle of sustainable development. On account of the physical problems arising along this coastline, thorough consideration has been given to existing and potential impacts on people, property and the natural environment. Risk management strategies, known as *Shoreline Management Plans* (SMPs), provide a framework for addressing the hazards of erosion, flooding and coastal instability along this coastal frontage.

There is little doubt that climate change will exert an increasing influence on the lives of East Anglian coastal residents and businesses over the next decades by affecting the pace of coastal erosion, the frequency of sea flooding events and increased landsliding, comprising both first time failures and the reactivation of currently dormant coastal landslides. This will impose increasing pressures on the study area coastline and, as a result, has necessitated changes in the approach to the management of risks. In East Anglia it has been recognised that it is impossible and, indeed, undesirable to defend all parts of this coastline, and the development of shoreline management plans for East Anglia is helping to ensure wise coastal decision-making, which has been based upon a growing understanding of coastal evolution and natural physical processes.

Residents and businesses along the East Anglian coast are becoming increasingly aware of the risks posed by coastal erosion and flooding by the sea. Along this frontage some developments have taken place, historically, in vulnerable coastal locations, and this has increased the risks to both commercial development and residential properties. Along those parts of the Norfolk and Suffolk coasts where development has taken place, efforts have been made over the last few centuries to protect people, property and assets from the impacts of erosion and sea flooding. Traditionally this has been achieved through the construction of sea walls, which still provide vital protection for many of the historic coastal towns and seaside resorts and other key infrastructure, alongside residential properties. However, in some locations construction of defences has, inevitably, had an effect on the natural coastal systems such as longshore drift, causing an adverse impact on coastal frontages down-drift including beaches and salt marshes, and sometimes resulting in increased erosion or instability problems further along the coast.

East Anglian coastal engineers have been at the forefront in helping to advance coastal science in these areas. Research has led to the recognition that, where possible, natural physical processes such as erosion, sediment transport and deposition, should be allowed to continue uninterrupted and that coastal defence can be achieved quite effectively by trying to *work with nature*, for example, by encouraging the build-up of beaches as a very effective form of natural coastal defence. Clearly the situation will vary from one part of the coastline to another, and the most appropriate solution to any coastal defence problem must be considered, taking account of all relevant factors along the whole of the coastal frontage.

In recent centuries and decades the most usual response to protection of property and assets has been the construction of coastal sea walls and flood defences. This has been necessary because East Anglia experiences some of the fastest rates of cliff retreat and most serious flooding problems around the coastline of North-Western Europe. There is a long-term chronology of coastal change, which is evidenced from early maps, sea charts and historical literature accounts. For example, the ancient, lost city of Dunwich on the Suffolk coast was destroyed through progressive marine erosion in the Middle Ages; at this location the coastline has retreated by some 2km since Roman times. Whilst, on parts of the North Norfolk coastline nearly 200 metres of cliff recession has taken place since the late nineteenth century.

Coastal risk problems have often arisen because of a lack of co-ordination in the past between land use planning and development proposals. Parts of the East Anglian coastline developed rapidly, particularly in the Victorian and Edwardian periods when the seaside became popular, and this led to an inheritance of unplanned communities and developments, a number of which were built on eroding cliff tops and in other less sustainable locations. Alongside erosion, coastal flooding is a longstanding problem and historical accounts dating back to Medieval times mention flooding in East Anglia *“houses were destroyed... some 500 people perished”* in 1287 (Brooks, 2007).

During the early medieval period the Middle Peat in the upper valleys of Broadland was extensively excavated to provide fuel (Lambert and Jennings 1960), as shown by borehole data, topographic studies and historical sources. The first phase of peat extraction had ceased by the end of the 14th century, after which the peat pits became flooded and then partly infilled with sediment, forming the present Broads.

The most serious flooding event in East Anglia occurred in 1953, and is regarded as the worst national peacetime disaster to hit the United Kingdom. Exceptional weather conditions, coupled with poor communications, meant that whole communities were given insufficient warning of the advancing threat; the Storm Tide Warning Service was set up after this flood. The government has now put in place a coastal risk management framework, which gives overall responsibility to the Environment Agency, which will work in partnership with the East Anglian coastal local authorities to ensure its successful delivery. It will have to implement policies that address the increasing risks facing the study site frontage whilst also meeting the inevitable financial constraints (Defra, 2007).

It is now widely agreed by those involved in coastal risk management that meeting the challenges of coastal climate change is the most important issue to be faced by decision-makers and the communities they represent. In recent years a significant amount of research and investigation work has taken place in East Anglia in order that appropriate decision-making can be put in place through the planning and political processes. Steadily improving forecasting now being achieved at the sub-regional scale will be a particular value, alongside strategic coastal monitoring programmes, and the investigation of practical solutions involving adaptation to coastal climate change (North Norfolk District Council, 2012). The justification of need for forecasting storm events along the East Anglian coastline, and its efficacy is demonstrated by the response to the most serious storm surge event in the North Sea since the 1950s floods, which occurred in December 2013.

3A.1.1 Geology and Geomorphology

This section outlines the key geological and geomorphological features and processes of the study area. These factors have a significant impact on the on-going changes to the coastline and associated sites, deposits and features preserved related to the archaeological and heritage resource, in addition to being depicted through a range of art sources.

Geological History

The geology of Norfolk and Suffolk dates back to the Cretaceous period and, although masked by more recent glacial deposits, the earliest rocks are approximately 140 million years old. In Norfolk sands and clays were deposited in a shallow tropical sea during the Cretaceous period, particularly in north-west Norfolk, whilst elsewhere expansive spreads of sediments deposited during the Ice Age covered the chalk bedrock, which underlies much of the County. The relatively flat surface created by these deposits together with the immense physical power of the ice sheets, resulted in the wide coastal plain of North Norfolk, which meets the sea as a series of spectacular coastal cliffs in the north-east of the County. The array of surface sediments has given rise to varying soil conditions, land cover and habitats in the coastal zone, a number of which are designated for their environmental significance.

During the Tertiary period, from 65 million years ago, there was a significant fall in sea level, and the area now occupied by the County of Norfolk became land. The incoming of a shallow sea later in the Tertiary and the earliest Quaternary, (approximately two million years ago), resulted in the deposition of shelly sands, known as the Norwich Crag. The subsequent cold and warm climatic phases during the Quaternary period led to deposition of complex sequences of sediments known as the Cromer Forest Bed Series.

Around 450,000 years ago a severe cold phase known as the Anglian Glaciation caused an ice sheet to spread across East Anglia, occupying the whole of Norfolk. As the ice advanced it eroded the ground over which it passed, the eroded material then being deposited at the base of the ice to form sheets of till (Boulder Clay). Associated with the tills are suites of gravel formed at the edge of the ice sheet; these gravels form the impressive Cromer Ridge. These vestiges of former glaciation, with a mix of till, sands and gravels, provide the complexity of soils that characterise the Norfolk coastal zone, and give rise to the great variation in land cover.

By contrast, the geology and geomorphology of Suffolk is relatively simple. Extensive spreads of till, or Boulder Clay, deposited over the last one million years, cover the gently undulating plateau (underlain by chalk) that forms much of the County. The late Tertiary to Quaternary Crag Deposits are marine sandstones, formed when much of Suffolk was below sea level. The variable nature of these sediments gives rise to mixed habitats and landscape types.

Over the last two million years the climate of Suffolk has varied tremendously with periods of temperate climate interrupted by repeated advances and retreats of glaciers and ice sheets. Collectively these periods have become known as the Ice Age, and the action of ice sheets has been instrumental in forming the landscape as we know it today. Deposits from the Ice Age (or Quaternary) are widespread in Suffolk, and comprise a large spread of till (or Boulder Clay) over much of the County, or as glacial gravels in the east. These gravels were deposited around 600,000 years ago.

Over the last 10,000 years the sea has risen by 30m, and is currently rising at an estimated 2mm per year. The relative levels of land and sea during this period have dominated the physical development of the Suffolk coast. Accumulations of shingle, known locally as ‘Nesses’, have developed at Benacre and Thorpeness, while at Aldeburgh the second largest spit in Europe, Orford Ness, commences. Orford Ness has diverted the mouth of the River Alde for a distance of about 20km south from its original outlet of Aldeburgh. Behind Orford Ness are salt marshes, which have developed in the calmer conditions provided by the spit. Along the cliffed part of the coast, erosion has been very active. Dunwich is one of the best known sites in East Anglia to be affected by erosion. It was an important city in the time of King Henry II, and has now almost completely disappeared.

Geomorphological Processes and Human Intervention

The northern extent of the Arch-Manche East Anglian study area is the town of Cromer, where coastal defences protect the weak cliffs composed of glacial tills, sands and laminated clays. To the east is the village of Overstrand, where the cliffs rise to approximately 35m and have been affected significantly by rotational landslide and mudslides. Processes of slope instability are particularly active along this part of the Norfolk coastline, producing failures of the over-steep glacial sea cliffs. The coastline to the east is marked by low crumbling cliffs and high sand dunes, which are particularly vulnerable to attack by storm waves from the North Sea.

In some locations efforts have been made to stabilise sand dunes through the planting of Marram Grass, whilst, elsewhere, such as at Sea Palling, substantial sea defences were undertaken, particularly between Happisburgh and Winterton, following the breach of the sand dunes during the tidal surges of January 1953. The villages along this coastline, particularly Happisburgh, demonstrate the force of the sea and the challenges of coastal risk management. The impracticality of continuing to defend some coastal communities has necessitated new solutions and the Council has been developing innovative approaches, with support from the Department for Environment, Food and Rural Affairs (Defra), towards adaptation to help sustain affected residents and businesses (North Norfolk District Council, 2011).

The coastline to the south consists of wide sandy beaches backed by low cliff lines and includes important resorts such as Great Yarmouth and Gorleston-on-Sea, where the River Yare meanders through a low-lying flood plain, before turning sharply south to create the peninsula on which the town of Great Yarmouth is built. The coastline to the south of Gorleston consists of low-lying crumbling cliffs with sandy beaches, and the ruins of ancient churches such as those at Hopton-on-Sea and Corton. The seaside resort of Lowestoft to the south is divided by a narrow strip of water called Lake Lothing, whilst, to the south, at Pakefield, a sandy, shingle scattered beach lies below low grassy banks. The church of St Margaret and All Saints dates from the fourteenth century and stands close to the cliff edge which has, in the past, been affected by erosion and instability.

South of Lowestoft towards Southwold, the beaches are wide and composed of shingle, broken only by hamlets such as Covehithe where the ruined church of St Andrew is dramatically situated. South of Covehithe, a sand and shingle beach stretches down towards the historic town of Southwold, and a reedy lagoon amongst the sand dunes behind the beach is an important wildlife habitat. The coast between Covehithe and Southwold is backed by an undulating cliff line, and is intersected by a number of stretches of low-lying land backed by saltmarsh (for example, Easton Broad and Easton Marshes). Cliff recession here is very rapid, providing a supply of sand to the beaches at Southwold. Continued coastal retreat threatens the stability of the shingle ridges in the area, which protect the low-lying marshland from inundation by the sea.

The town of Southwold is situated on high ground and is fronted by a relatively narrow, well defended sand and shingle beach. To the south of the town, a wide sand and shingle beach has built up against the north pier of Southwold harbour. Some of this sandy material is transported in suspension by the sea across the mouth of the harbour to the community of Walberswick on the south side, where the beach remains relatively stable. Shingle ridges exist between Walberswick and Dunwich, which are occasionally overtopped by the sea. To the south the higher cliffs of Dunwich and Minsmere are eroding, and also provide a significant source of sediment for the beach. To the south of Minsmere cliffs is the low-lying land of the Minsmere valley, fronted by a shingle ridge. The land then rises at Sizewell, running into the Thorpeness Cliffs, down to Thorpe Ness (Royal Haskoning, 2009).

To the south of Thorpe Ness is the seaside town of Aldeburgh that is located on the promontory of Thorpeness. To the south of the town, a Martello Tower marks the start of Orford beach, and the massive shingle bank that extends south as far as Orford Haven to form Orfordness. This spit reflects the mouth of the river Alde from an approximate west to east alignment, to a roughly north to south alignment. The change in alignment occurs at Slaughden, south of the town of Aldeburgh. Orford Ness is a shingle foreland that shows changes in elevation attributable to changes in sea level rise over the time of its formation. The Ness has been formed over the last 6,000 years and has received sediment supply by longshore drift from the north. The location marks the southern end of the East Anglian study area.

3A.1.2 Summary of the Archaeology and History of the Study Area

The archaeological and palaeoenvironmental study area in East Anglia focusses on the Suffolk coast, extending from Lowestoft in the north to Dunwich in the south. The coastline consists of low-lying wetlands and Broads separating large stretches of cliff which reach up to 17m above sea level. These coastal cliffs have been subject to the fastest recorded recession rates in the UK. The study area also encompasses the estuary of the River Blyth, which is relatively narrow and largely embanked.

The study area was chosen due to the dynamic and rapidly changing nature of this coastline, as well as the presence of important archaeological sites such as Pakefield, with inter-glacial deposits containing some of the earliest evidence of human activity in Northern Europe as well as the well-known medieval town of Dunwich, now lost to the sea.

A report for the Crown Estate in 2010 recognised that ‘this coastline presents one of the greatest future management challenges for the region in particular and the UK as a whole as it undergoes such rapid retreat' (Brooks, 2010:2). The presence of an array of archaeological and palaeoenvironmental features along this stretch of coastline, dating from 700,000 BP help to define the nature, scale and pace of coastal processes and contribute to the management of such a challenging and rapidly changing environment.

The area chosen also corresponds with one of the six areas covered by the Suffolk Coast National Mapping Programme (NMP) as part of the Rapid Coastal Zone Assessment (RCZA) of Suffolk commissioned by English Heritage.

Early Prehistory (Palaeolithic and Mesolithic)
Evidence for the Pleistocene period includes worked flints, butchered animal bones and plant remains now exposed in the cliffs along the Suffolk coast, in particular the area of Pakefield. This Lower Palaeolithic material has been found in-situ within the Cromer Forest-bed Formation and is thought to be the earliest evidence for human activity in northern Europe, dating to c. 700,000 BP (Parfitt et al. 2005; Lee et al. 2006; Wymer and Robins 2006). Excavations were carried out between 2001 and 2005 on the Pakefield site, and finds include a handaxe, several struck flakes, and faunal remains including rhinoceros and bison (Lee et al 2006). Prior to the discovery of in-situ material at Pakefield, the majority of Palaeolithic evidence consisted of sporadic finds of handaxes from the beaches on the Suffolk coast.

Evidence from the Mesolithic Period has mainly been found in plough-soil, where contextual material has been largely destroyed. There is thought to be potential for stratified material in the estuaries, where silts and peats formed over dry land as sea levels rose after the last glacial maximum (Good & Plouviez, 2007:8).

Later Prehistory (Neolithic, Bronze Age and Iron Age)
As with material from the Mesolithic period, evidence from the Neolithic has been largely affected by intensive agriculture and ploughing along the Suffolk coast. This period witnessed the introduction of agriculture and the construction of large monuments. Circular structures and causewayed enclosures have been recorded along with Neolithic artefacts on sites further inland, such as Hadleigh, Barking and Freston and flint scatters of Neolithic and Bronze Age types have been found at Hollesley, overlooking marshland (Medlycott, 2011: 11, Good & Plouviez, 2007:9). However, these fall outside the case study area.

Within the area, assemblages of Neolithic flints have been found, generally in the valleys around Kessingland, Gisleham and Benacre. No preserved settlements have yet been found, but the location of the flint scatters near grazing marshes highlights potential for preserved Neolithic material and environmental data.

Bronze Age barrows are located in the sandy upland areas, which have not been affected by cultivation, although not all have been individually dated due to a lack of archaeological excavation. In Walberswick two round barrows are scheduled, and are thought to date to the Bronze Age. Ring ditches and field systems have also been reported within the area. Excavations further inland on the terraces of the River Waveney have revealed Bronze Age ring ditches, settlement here is thought to have occurred over a long period with environmental evidence having the potential to inform on the changing landscape (Medlycott, 2011: 15).

A lack of dated evidence is also an issue for the Iron Age. Current evidence includes several settlements, which are generally unenclosed, although rectilinear field systems and enclosures have been identified through cropmarks along the coastal zone and are thought to date to the Iron Age. Material from the 1st Century BC to the 1st Century AD reflects a strong continental influence and coins found have allowed for the identification of tribal areas prior to the Roman conquest. A late Iron Age site has been identified in Covehithe, numerous coins suggest that this was in the Iceni tribal area, however, this is now largely lost to erosion (Good & Plouviez, 2007: 9-10).

The National Mapping Programme (Hegarty & Newsome 2005) has identified extensive field systems, broadly dated to the Iron Age/Roman period, although this is based on morphology as opposed to absolute dating. The majority of these sites are further south and outside the study area and so far no large hillforts or defended settlements have been identified.

Roman Period

Following the 43AD conquest and the revolt of Boudica in 60-61AD a second Roman military occupation of East Anglia occurred, this is based on artefact evidence, no early forts have been discovered. Further south, outside of the study area, a shore fort thought to be from the late 3rd Century was identified but destroyed by coastal erosion in the 18th Century, only a few remains can now be seen at extreme low tide (Hegarty & Newsome, 2005:44).

Roman villas are not common in the study area and there is no evidence for formal towns. However, building material has been found along the current shoreline at Gisleham, which may suggest there were several smaller settlements, the date of the site has not been confirmed. In terms of coastal activity, the most common is salt extraction, most known sites are outside the study area, except for some on the Blyth estuary. Walberswick, also on the Blyth estuary, is thought to have functioned as a port, based on scatters of surface finds (Good & Plouviez, 2007: 11).

A report for the National Mapping Programme (Hegarty & Newsome, 2005: 43) recognised the probability that many sites located on the Roman coastline would have been lost, and military sites, roads and urban settlements appear to have been focussed in the west and beyond the study area.

Medieval Period (500AD – 1485AD)

For the early Medieval period there appears to be a marked drop in the visibility of archaeological monuments, although this could be due to low levels of investigation (Good & Plouviez, 2007:11-12). Most evidence from this period is from cemeteries such as the famous boat burial in Sutton Hoo. However, excavations at Bloodmoor Hill, Carlton Colville, revealed a very well-preserved early Anglo-Saxon settlement with associated high status burial and industrial activity (Lucy et al, 2009).

Overlooking the estuary of the River Blyth a possible Anglo-Saxon barrow and ship burial have been identified, although further work is needed to confirm this, the location close to the estuary highlights the potential for waterlogged deposits. Several items from the area around the River Blyth have been recorded including a writing styli and decorated whale bone, historical resources state that Blythburgh is the burial place of King Anna of East Anglia and his son in 654 AD (Good & Plouviez, 2007: 43).

With the known rates of erosion on this coastline, it is likely that any Anglo-Saxon coastal sites have now been lost to the sea. A trawler dragged up a complete dugout near Southwold which has been dated to the middle Saxon period (Good & Plouviez, 2007:13).

Records from the later Medieval period of Suffolk are dominated by the Medieval town of Dunwich now lost to the sea, other examples include Easton Bavents and Sizewell church, all of which were lost by the 19th Century. Dunwich was a thriving port from the 11th Century, mainly due to its fishing industry. However, a storm in 1328 shifted coastal shingle banks, blocking the harbour mouth and consequently shifting trade to nearby Walberswick. The reduced economy meant that the town could no longer invest in sea defences and was quickly affected by coastal erosion, with several kilometres of coastal hinterland being lost (Hegarty & Newsome, 2005:7).

Eight churches and two priories were constructed in the Medieval town of Dunwich, of the two priories, Blackfriars and Greyfriars, only the remains of Greyfriars can still be seen on the cliff edge today, Blackfriars was lost to the sea in the 16th Century (Good & Plouviez, 2007:47). Prior to the growth of the town in the Medieval period it is believed that Dunwich was originally the site of a Roman coastal fort and later Saxon settlement, based on finds of Roman tiles at several religious sites (Sear et al, 2013:15).

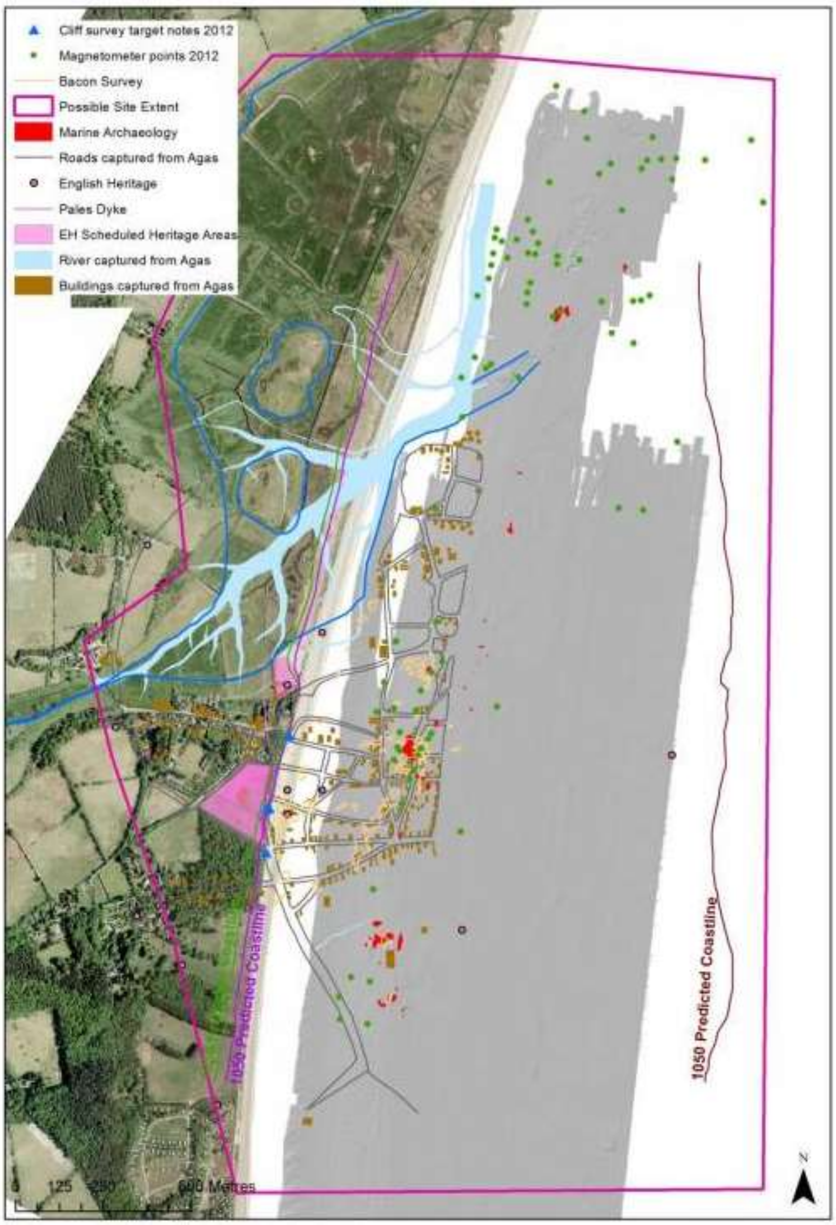


Figure 3A2. Reconstruction of the Dunwich boundary. (Sear et al 2013:Figure53)

Post-Medieval Period (1485AD – 1901AD)

The Post-Medieval period saw significant levels of construction of coastal military defences. The low lying nature of much of this coastline meant that it was seen to be vulnerable to attack, however, many of these defensive sites have now been lost through erosion (Hegarty & Newsome, 2005:14). Most notable are the Martello Towers built during the Napoleonic Wars as part of anti-invasion defences, many of which still survive but are located just outside the study area. The position of the towers was used to georeference historic maps as part of the Crown Estate study into coastal change (Brooks, 2010).

As well as defences from military attack, several modifications to the landscape were carried out in order to reclaim land, and defend the coast against the sea. Much of the Suffolk coast is now made up of drained, embanked and reclaimed land, within the study area this is particularly noticeable around the Blyth estuary.

Within the estuaries several timber quays and oyster beds have been identified, and many Post-Medieval wrecks have been recorded off the Suffolk coast. Most of these are from the late 18th and 19th Centuries. Some earlier shipwreck sites survive, for example, Dunwich Bank, a designated wreck site from an unknown 16th Century vessel, which can provide information on sediment processes off this dynamic coastline.

Coastal towns relied mainly on the fishing industry, although like Medieval Dunwich they were often faced with issues of silting, Walberswick was constantly battling with the silting up of the river and slowly decreased in size, although still remains as a small fishing village. However, several towns along the Suffolk coast flourished in the 19th Century. The building of the harbour and the railway in Lowestoft boosted the fishing industry but also led to the town becoming a popular seaside resort. Southwold, a prosperous port in the Medieval period also attracted visitors with its beaches, however, its importance as a harbour town decreased in favour of Lowestoft, which meant that the towns economy began to rely solely on tourism and a railway line was opened in 1879.

Modern

The majority of sites from the 20th Century comprise WWI and WWII defence systems on the Suffolk coast. These include pillboxes, batteries and anti-tank ditches. Many of these are being affected by the rapid erosion along the Suffolk coastline.

Other sites from this period include mills, often built earlier they have been used and modified in the early 20th Century. One such site is Marsh Mill, Walberswick, in use until 1940, and although damaged by fire and target practice during the war, the remains can still be seen today.

The major coastal town of Lowestoft continued to be important for trade until the start of WWI but had declined completely by the 1960's. Southwold continued to attract visitors as a seaside resort and the famous pier was constructed in 1900. The pier was severely damaged by a storm in 1934 and was also damaged during WWII, but was later refurbished and Southwold continues to thrive as a seaside resort.

3A.1.3 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for the Project

Archaeological and palaeoenvironmental data has been obtained from the NRHE, UKHO and the Suffolk HER, further information about the data collected for the project is available in Section 2.1.

Several key projects have been carried out in East Anglia over the last twenty years which have been consulted. The majority of this work has been a result of the English Heritage Rapid Coastal Zone Assessment (RCZA) process. English Heritage recognised that there was a lack of understanding of the archaeology in the coastal zone and that the historic environment needed to be integrated into coastal management schemes, as a result a series of RCZA's were commissioned along the English coast. Alongside this, Suffolk Council also recognised the need to record coastal archaeology before it was lost to erosion. These programmes resulted in several reports including, *The Archaeology of the Suffolk Coast* (Good & Plouviez, 2007) and *The Archaeology of the Suffolk Coast and Intertidal Zone* (Hegarty & Newsome, 2005). The programmes included the study of aerial photography, an assessment of historic maps and documentary evidence, as well as a field survey of the intertidal zone, sites were then added or updated in the Suffolk HER. These reports have provided a general overview of the archaeology and history of the Suffolk coast, and the current management situations.

Alongside this, work has been carried out on the regional research framework for East Anglia, this appeared initially in two parts, a resource assessment (Glazebrook, 1997) and a research agenda and strategy (Brown and Glazebrook, 2000). This work was then reviewed and a revised framework was published looking at key projects since 2000 and assessing progress made on research topics identified in the previous reports (Medlycott, 2011). This provided an overview of the main archaeological projects as well as highlighting gaps in understanding and potential for further research.

The Suffolk Shoreline Management Plan was also consulted, the most recent being the SMP7 from 2010. This report identifies risks along the coast and preferred management policies.

Alongside these broader programmes several more specific research projects were consulted, on the key archaeological and palaeoenvironmental sites from the case study area; Pakefield and Dunwich. Simon Parfitt and Chris Stringer have worked on the archaeological deposits on land at Pakefield (Parfitt et al, 2005), demonstrating that the site contains the earliest evidence for human occupation in Europe. Further work by Wessex Archaeology (2008) through the Aggregate Levy Sustainability Fund aimed to assess the potential survival of similar deposits offshore.

A large collaborative projected funded by English Heritage was carried out on the historic town of Dunwich (Sear et al, 2013), this project included the use of marine geophysical survey techniques and diver surveys, alongside historical documentary and geospatial evidence, as well as land based archaeological evidence. This allowed the team to produce a map of the changing coastline and the current extent of the site (*Figure 3A2*).

3A.1.4 Art History of the Study Area

This section presents the background to artistic representations within the area including key schools and individual artists. This provides the background to the broader consideration of individual artworks within the study area.

Introduction

The art study area extends for a distance of 130km from Cromer in North Norfolk, eastwards and then southwards to Orford Ness in Suffolk. The site was selected on account of its varied geomorphological conditions, which include eroding clay and sandstone cliffs, coastal landslides, and low-lying land, which is prone to flooding by the sea. The location also has an outstanding art heritage resource.

The counties of Norfolk and Suffolk have a particularly rich art heritage comprising landscape paintings, watercolour drawings and prints, together with a large number of extensively illustrated topographical books. These works of art, which have been produced since the late eighteenth century, may be used by coastal scientists to provide supporting information to our understanding of long-term coastal change. Extending back long before the days of photography, images of the East Anglian coast depict physical and environmental changes over the last two hundred years as well as describing social change on the coast (McInnes & Stubbings, 2010). As well as depicting coastal erosion, flood events and natural change, works of art can illustrate progressive coastal development, as well as changes in landscape and agricultural practices. This additional information is particularly valuable in terms of supporting coastal monitoring programmes such as that of the East Anglian Coastal Group working in partnership with the Environment Agency (East Anglian Coastal Group, 2013). Through art it may be possible to take advantage of the wisdom of hindsight and examine the coastline before significant development took place, when natural coastal processes were free to operate in an unconstrained way. This approach for the East Anglian coastal study sites, therefore, aimed to:

- Demonstrate the role that historical works of art (oil paintings, watercolours and prints) can provide in terms of supporting understanding of long-term coastal change;
- Assist understanding of the chronology of coastal change in East Anglia; and
- Provide examples of those artists' works which form reliable records of coastal conditions at the time they were painted.

Literature Review

The coastline of East Anglia benefits from a rich landscape art heritage. This has been noted in a number of key reference works relating in particular to the Norwich School of Artists, art colonies that flourished along this interesting coastline, as well as the works of individual landscape painters residing or visiting the location (Rajnai, 1976; Hemingway, 1979; Walpole, 1997; Scott, 2002; Collins, 2005; Newton, 2005; Ellis (ed), 2005; Ellis (Ed), 2006; Munn, 2006; Walpole, 2009).

The coastline was explored from the late eighteenth century and numerous fine topographical books were published, often illustrated with engravings, aquatints or lithographs (Beatniffe, 1808; Parkin, 1788; Armstrong, 1791; Bell, 1807; Dixon, 1811; Britton & Brayley, 1812; Stark, 1828-1834; Lound & Ninham, 1831; Turner, 1838; Ewing, 1842).

Some artists and writers collaborated and undertook tours of the coastline of the British Isles, producing elaborate illustrated books, for example *'A Voyage Round Great Britain'* by William Daniell and Richard Ayton (Daniell & Ayton, 1814). Commencing in 1814, the voyage took ten years to complete, and the eastern coast of England was painted on the return journey in 1822. Daniell's delicate aquatints accompanied by Ayton's text, together provide us with an intriguing account of this part of the British coastline, including descriptions of coastal erosion events during the early nineteenth century. In 1838 the Finden Brothers published their *'Ports, Harbours, Watering Places and Picturesque Scenery of Great Britain'* (Finden & Finden, 1838), which includes steel engraved views of the East Anglian coast, together with the detailed accompanying descriptive account.

The East Anglian Art Resource

In addition to illustrated books, there is a wealth of paintings and watercolour drawings that form by far the largest number of illustrations of the study area coastline. In particular, East Anglia benefits from a rich resource of landscape painting, which dates back to the start of the nineteenth Century. East Anglia is regarded by some as the 'cradle of English landscape painting' with celebrated artists from the Norwich School, together with Suffolk artists such as John Constable and Thomas Gainsborough exemplifying the art of landscape painting in this country. Although the latter two great artists rarely painted the coastline of East Anglia, there are, fortunately, a wealth of other painters who chose to illustrate the coastal scenery in sufficient detail.

The culture centre for the arts in East Anglia was the city of Norwich, which benefitted from the foundation of the Norwich Society of Artists in 1803, which held its first annual exhibition two years later in 1805, and continued exhibiting almost without interruption until 1833. The School of Artists was led by a number of outstanding artistic families and individuals including the Crome family, the family of John Stark, the Cotman's, John Thirtle, George Vincent and Robert Ladbrooke.

The most prominent figure in the Norwich School was John Crome (1768-1821) who met a fellow artist, Robert Ladbrooke, during the course of his artistic apprenticeship. With patronage from wealth families from within the County, Crome flourished as an artist and, whilst most of his views are of the city of Norwich and surrounding countryside, he also, painted the coastline, especially the activities of fishermen on the shore at Great Yarmouth beach and elsewhere. Robert Ladbrooke (1769-1842) also painted views of the coastline, particularly at Great Yarmouth. Another member of the same family, John Burney Crome (1794-1842), produced a dramatic painting entitled *'Great Gale at Yarmouth on Ash Wednesday 1836'*, which illustrated the devastating effects of the storm on the sea front properties in that year.

Other important artists of the Norwich School included James Stark (1794-1859) who, together with George Vincent, continued as the mainstays of the Norwich School after John Crome died. George Vincent (1796-c.1835) was, alongside Stark, one of the most important second tier artists of the Norwich School. He first exhibited at the Norwich Society in 1811, again favouring views of the coast such as *'The Fish Auction, Yarmouth'* (1827), which, along with his other works, provided not only an interesting social account but also details of the beach levels and coastal conditions existing at the time.

With John Crome, John Sell Cotman (1782-1842) is acknowledged by most as the leading artist of the Norwich School. Although painting widely in England, Cotman's East Anglian works tend to focus on architectural landscapes of the countryside rather than the coastal scenes. His sons, Miles Edmund Cotman (1810-1858) and John Joseph Cotman (1814-1878) were also prolific painters of the Norfolk landscape and the Broads.

Although the Norwich School flourished in Norfolk there was no similar formal school of artists working in Suffolk during the eighteenth and nineteenth Centuries, rather a number of distinguished landscape painters who were particularly well known, such as John Constable RA (1776-1837) and Thomas Gainsborough RA (1727-1788). Whilst Constable is well known for his magnificent landscapes of the Suffolk/Essex border, and other distinguished works of London and parts of the English coast, there are a few paintings that can assist in understanding coastal change in East Anglia. John Moore (1820-1902) painted coastal and shipping scenes, as well as accurate views of coastal towns such as *'Cromer-Sunrise'*, which clearly indicates the proximity of the town, the cliffs and the coastline in detail.

During the reign of Queen Victoria, and coinciding with the increasing interest in the seaside, sea bathing and natural earth sciences such as geology, many more artists turned to the coastline for inspiration and subject matter. Locations seriously affected by coastal erosion, such as the historic lost city of Dunwich in Suffolk, were painted by J. M. W. Turner as early as

1824. A succession of artists continued to paint the popular subjects of Dunwich, Southwold and Walberswick right through the nineteenth century and into the twentieth century. Well-known marine painters visited the Suffolk and Norfolk coasts including Edwina Hayes (1804-1904), Edwin Ellis (1841-1895), Charles Thorneley (1858-1898), William Anderson (1856-1893), Clarkson Stanfield (1828-1878) and George Stanfield Walters (1838-1924). All painted views along the coastline, many of which were set against the backdrop of the shore and the cliffs. Whilst such works do not necessarily provide the same detailed appreciation of the coast as some of the other artists, their works can give some appreciation of coastal geology, geomorphology and form, which is helpful in a general context.

Topographic artists continue to paint the Suffolk and Norfolk coasts, particularly the cliffed coastlines, ports, harbours and estuaries as well as the resorts. Henry Moore (1831-1895) painted *'Crossing the Bar, Walberswick Sands'* in 1857, whilst Walter Crane (1845-1915) painted a detailed watercolour of *'Eastcliff, Southwold'* in 1886. This illustrates the row of fisherman's huts that used to line the base of the cliffs before they were all washed away in the storms of 1905 (Munn, 2006).

An artist more associated with the Newlyn School of Cornwall, Walter Langley (1852-1922) visited Walberswick in 1891, and produced a number of views of the village as well as of nearby Southwold. Edwin Edwards (1823-1879) was an etcher and engraver who also worked in oils and exhibited views of Southwold and Walberswick at the Royal Academy in 1868 and 1878 respectively. His view of *'Southwold'* (c.1875) clearly shows beach levels, the development of the beach, the nature of the slopes and the cliff top development. Other leading artists who portrayed the coastline in considerable detail included Myles Birket Foster (1825-1899) who painted a view of Cromer as well as several scenes of Walberswick in the 1890s, whilst Charles Robertson (1844-1891), a follower of the Pre-Raphaelite School of Artists, painted a view of Southwold harbour with Walberswick and its windmill in the distance with the title of *'On the East Coast'* in about 1883.

During the late nineteenth and early twentieth centuries increasing numbers of colour plate book illustrations appeared in order to cater for the growing number of coastal visitors. This time period also saw the introduction of colour picture postcards produced by famous companies such as Raphael Tuck and J. & F. Salmon of Sevenoaks in Kent. Book publishers, including A. & C. Black and Salmon's, commissioned a range of artists to paint attractive views usually in watercolour, that could be used as book illustrations. A. & C. Black published their *'Norfolk'* and *'Suffolk'* volumes in 1821 and 1829 respectively; the Suffolk volume was illustrated with 40 plates by Alfred Heaton Cooper.

The keen interest in paintings of coastal scenery in this part of East Anglia continued through the early twentieth Century until the Second World War and beyond, with artists including Sir John Arnesby Brown (1866-1925) exhibiting views of the Suffolk coast, particularly from 1833.

It can be seen from this short overview of East Anglian coastal art that art and related media represent a substantial resource that can be interrogated to support understanding of coastal change. Clearly, works of art need to be proved to be of sufficient accuracy and, in order to address this requirement, a ranking system was refined as part of this project and is described in Section 2.2.

3A.1.5 Art Resources Consulted for the Project

In order to establish the art resource available for this study it was necessary to review the topographical paintings, drawings and prints held by the principal national, region and local collections covering the Norfolk and Suffolk coastal frontages. To achieve this objective, on-line reviews were carried out of the collections held at the national level within key museums and art galleries including the Tate Britain, the Victoria and Albert Museum, the National Maritime Museum, the British Museum, the National Gallery and the Witt Library at the Courtauld Institute in London.

In addition it was necessary to establish if there were relevant artworks contained in museums and art galleries in East Anglia, including the Norwich Castle Museum and Art Gallery, the Great Yarmouth Museum's collection, King's Lynn Museum, Sheringham Museum, Aldeburgh Museum, Dunwich Museum, Colchester and Ipswich Borough Council museums and galleries, Lowestoft and East Suffolk Maritime Museum, Waveney District Council collection and, finally, the Southwold Sailor's Reading Room. The research has also drawn on findings from the study of the East Anglian Coastline sponsored by The Crown Estate (McInnes & Stubbings, 2010).

As part of the research it was necessary to contact museum and gallery curators and search available publications, as well as undertaking research on the Internet, taking advantage of new facilities such as the Public Catalogue's Foundation volumes and BBC Your Paintings.

Additionally an assessment has been made of art from the study area contained in important publications and, in particular, catalogues of exhibitions at principal London galleries and also in East Anglia itself. The literature sources relating to works exhibited are comprehensive and comprise reviews of the artists and their works (eg. Graves, 1901), together with catalogues and dictionaries published by the museums themselves and interested publishers (e.g. the Antique Collectors' Club). The published works of this kind do, therefore, represent a considerable resource of assistance to this study (Wood, 1978; Russell, 1979; Archibald, 1980; Lambourne & Hamilton, 1980; Mallalieu, 1984; MacKenzie, 1987; Ellis (ed), 2005; Ellis (ed), 2006).

In East Anglia itself the Norwich Castle Museum and art gallery holds a collection of approximately 1,200 oil paintings, 10,000 watercolour drawings, as well as over 8,500 prints. In particular the gallery holds an outstanding collection of the Norwich School of Artists. The breadth of the collection illustrates how the city of Norwich became the centre of a flourishing school of artists, the spirit of which continues today. These artists include Henry Bright, Frederick George Cotman, John Sell Cotman, Miles Edmund Cotman, John Crome, Thomas Lound, George Vincent, Alfred Stannard, Joseph Stannard and Joseph Stark.

The Norfolk Museums and Archaeology Service and the Borough Council own works held in Great Yarmouth Museum's collection, and include important marine painters such as William Joy, as well as coastal and topographical painters including Robert Ladbrooke and John Moore of Ipswich. On the north coast, the Sheringham Museum contains a number of oil paintings which illustrate the eroding coast of Norfolk including the view of Sidestrand church and Eccles church tower on the beach following coastal erosion taking place. The Aldeburgh Museum at the southern end of our study area frontage includes accurate depictions of the low-lying Suffolk coastline by the important artist John Moore of Ipswich. A small museum in the village of Dunwich contains oil paintings by Edward J. Lingwood depicting coastal erosion affecting the All Saints church.

One of the finest collections in East Anglia is held by Ipswich Borough Council museums and galleries, and includes over 900 oil paintings, 7,000 watercolours and 7,000 prints. Established in 1847 the collection also includes important works by the masters of English landscape painting, John Constable and Thomas Gainsborough, and members of the 'Suffolk School'.

Artists who depicted the coast in their collection include Walter Daniel Batley, Henry Davy, John Moore of Ipswich, Bertram Priestman and Henry Robert Robertson.

3A.2 Current Environmental Impacts/Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the East Anglian coastline and reviews the current coastal management issues and approaches.

3A.2.1 Review of Key Contributors to Coastal Change

It has been explained that the East Anglian study area coastline is affected by a range of physical processes, particularly coastal erosion, sea flooding and coastal instability. The soft rock geology, comprising silts, sands and clays and gravels, offer little resistance to the aggressive marine erosion, whilst the low-lying frontages are particularly prone to flooding as a result of surges in the North Sea. As well as this the coastline has been affected by relative sea level change, the alteration in the location of sediment sources and sinks, as well as the impacts of anthropogenic management (Brooks, 2010).

Coastal erosion over the centuries is evidenced through the losses of a number of communities including Shipden seaward of the town of Cromer, Wimpwell which used to lie off Happisburgh, Waxham Parva formerly situated off Waxham, the village of Ness off Winterton, and Newton Cross which formerly existed seaward of Hopton. Many of the existing coastal villages were originally also much larger in extent.

On the Norfolk coast the ruins of Eccles church existed on the beach for many years, whilst in Suffolk, the historic city of Dunwich, as well as other coastal communities, now lie beneath the sea. Records of erosion and flooding events, sometimes with disastrous loss of life, are recorded through time in journals such as the Anglo-Saxon Chronicles (Unknown Authors up to 1154) and a pamphlet describing the serious flooding affecting coastal communities such as Great Yarmouth in 1557 (White, 1607).

During the early 19th century Great Yarmouth experienced the highest recorded tides, resulting in extensive damage, with the same storm event also affecting Gorleston and the cliff line of Cromer. During the twentieth century coastal defences have been attacked by a succession of severe gales and storms, such as the event in 1938 when cliff instability at Sidestrand saw 20,000 tonnes of the cliff face collapse along a frontage of 120 yards (Brooks, 2007). The most serious storm event to affect the east coast of England was the flooding event of January 1953, and is regarded as one of the biggest environmental disasters to have occurred in the United Kingdom. Over 300 people lost their lives, and 24,000 properties were flooded, with a further 40,000 people being evacuated from their homes. The same storm also had impacts elsewhere around the Channel – Southern North Sea coastlines. In 1994 major coastal slope instability occurred on the cliffs at Overstrand to the south of Cromer. This led to cliff top retreat of some 20 metres, and necessitated major cliff stabilisation works.

A 2010 report for The Crown Estate presented the major factors affecting the East Anglian coastline, this report recognised that there is a combination of sea level change, variations in wave, tidal and surge conditions, changes in the location of sediment sources and sinks, influences from nearshore bathymetry as well as anthropogenic management (Brooks, 2010).

3A.2.2 Summary of Current Coastal Management Approach

Coastal risk management is a responsibility of coastal local authorities in partnership with the Environment Agency, which has an over-arching supervisory role. The East Anglian Coastal Group fulfills a coordinating role in bringing together coast protection authorities and other key agencies along the East Anglian frontage. Coastal risk management policy is being addressed through the preparation of forward-looking shoreline plans, which provide a basis for policies for this length of coast and set the framework for managing the risks along the coastline for the future. In particular, the shoreline management plans set out the risks from flooding and erosion to people in the developed, historic and natural environment within the shoreline management plan area. The plan also identifies opportunities to maintain and improve the environment by managing the risks from flooding and coastal erosion, looking ahead over the next century.

The East Anglian plans identify the consequences of putting the preferred policies into place and set out procedures for monitoring how effective these policies are. Importantly the plans discourage inappropriate development in areas where flood and erosion risks are high, and ensure that international and national nature conservation legislation and biodiversity objectives are met. The study area frontage falls within the jurisdiction of two shoreline management plans; SMP6 Kelling Hard (to the west of Cromer) to Lowestoft and SMP7 Lowestoft to Felixstowe. The lead authority for SMP6 is North Norfolk District Council and for SMP7 Suffolk Coastal District Council.

Coastal change in East Anglia has been monitored in a comprehensive way since 1987. This has comprised a range of activities including survey and monitoring activity such as topographical surveys, bathymetric surveys, aerial photography, wave monitoring and data analysis. More recently, the Strategic Regional Coastal Monitoring Programme has been rolled out around the whole of the English coastline, with financial support from the Environment Agency and Defra. Large-scale coastal monitoring, such as that existing for East Anglia, now provides a systematic approach to the collection, management and analysis of data for strategic and operational management of coastal erosion and flood risk. The monitoring programme is risk-based and integrates the requirements of the coast protection operating (authorities) with coastal defence responsibilities at both strategic and operational levels, technical and financial benefits are evident at a range of temporal and spatial scales.

Through the shoreline management planning process the need for upgrading of coastal defences can be identified and a number of major projects have been undertaken along the Suffolk and Norfolk coasts, such as at Cromer, Thorpeness and other locations. Coastal risk management falls within the overall framework of integrated coastal zone management, which has been actively developed along the study area coastline.

3A.3 Archaeological and Palaeoenvironmental Ranking

This section outlines the results of the archaeological and palaeoenvironmental ranking from the East Anglia study area, followed by a discussion of the results. The ranking methodology applied is detailed in Section 2.2.

3A.3.1 Results of the Archaeological and Palaeoenvironmental Ranking

Within the East Anglia study area data was obtained from the local Historic Environment Record (HER), the National Record of the Historic Environment (NRHE), the United Kingdom Hydrographic Office (UKHO) and the English Heritage Peat Database. It should be noted that where the data obtained from the HER was limited, and where sites ranked highly, further research was then required in order to understand the full nature and extent of the site. Each dataset went through a process of cleaning, in order to prevent the duplication of sites. A total of 783 sites and records were assessed.

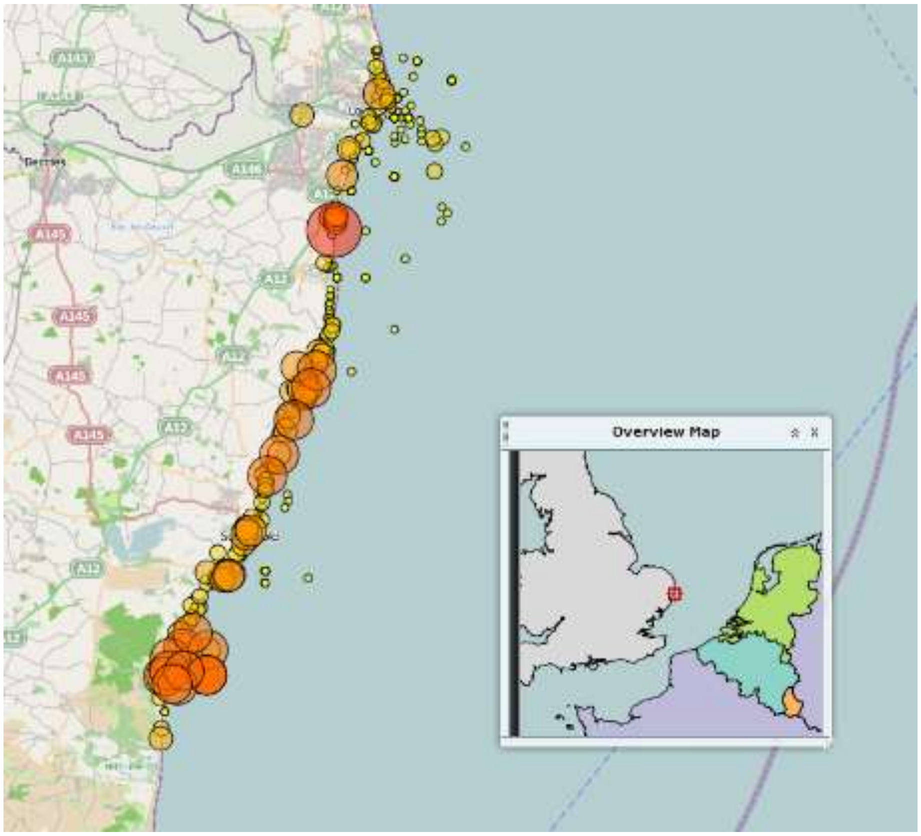


Figure 3A3. Map showing the distribution of all archaeological and palaeoenvironmental sites within the East Anglia study area

The highest ranked sites are listed in the table below, the total score has been normalised to give each site a score out of 100.

APE uid	Site Name	Site Type	Period	Score – Sea Level	Score – Environ mental	Score – Temporal Continuity	Total Score	Coastal Context
1581	PAKEFIELD - Forest deposits	Buried Landsurface	Lower Palaeolithic	Medium	High	High	88	Intertidal
706	BENACRE BROAD - Core sample	Submerged Landsurface	Prehistoric	High	Medium	Medium	77	Marine
710	EASTON BROAD - Peat	Submerged Landsurface	Prehistoric	High	Medium	Medium	77	Intertidal
1790	EASTON BAVENTS - Deserted Medieval Village	Submerged Landsurface	Medieval	Medium	High	Medium	77	Marine
1734	DUNWICH - Greyfriars Friary	Monument	Medieval	Medium	High	Medium	77	Above HW
1771	COVEHITHE – Well	Monument	Medieval	Medium	High	Medium	77	Marine
1779	DUNWICH – Chapel of St Francis	Monument	Medieval	Medium	High	Medium	77	Above HW
1787	DUNWICH - Dommoc See	Monument	Medieval	Medium	High	Medium	77	Marine
1738	DUNWICH - St	Monument	Medieval	Medium	High	Medium	77	Marine

	Antony's Monastery							
1811	DUNWICH - All Saints Church	Monument	Medieval	Medium	High	Medium	77	Marine
1789	DUNWICH - Quay and Harbour	Monument	Medieval	Medium	High	Medium	77	Marine
1788	DUNWICH – Castle	Monument	Medieval	Medium	High	Medium	77	Marine
2329	DUNWICH – Hospital of the Holy Trinity	Monument	Medieval	Medium	High	Medium	77	Above HW
1808	DUNWICH - Sea walls and river cut	Monument	Medieval	Medium	High	Medium	77	Marine
2426	DUNWICH - Church St Peters	Monument	Medieval	Medium	High	Medium	77	Marine
1784	DUNWICH - Church St Nicholas	Monument	Medieval	Medium	High	Medium	77	Marine
2427	DUNWICH - St Katherine's Chapel	Monument	Medieval	Medium	High	Medium	77	Marine
2428	DUNWICH – Blackfriars	Monument	Medieval	Medium	High	Medium	77	Marine
2429	DUNWICH - Knights Templar	Monument	Medieval	Medium	High	Medium	77	Marine
709	COVEHITHE BROAD - Peat	Buried Landsurface	Prehistoric	High	Medium	Medium	77	Marine
2324	DUNWICH – Seabank	Monument	Medieval	Medium	Medium	Medium	66	Above HW
1530	SOUTHWOLD – Well	Monument	Post Medieval	Medium	Medium	Medium	66	Above HW
1551	SOUTHWOLD - Earthworks	Monument	Post Medieval	Medium	Medium	Medium	66	Above HW
1570	LOWESTOFT – Town	Monument	Medieval	Medium	Medium	Medium	66	Above HW
1710	COVEHITHE – Pit		Unknown	Medium	Medium	Medium	66	Above HW
1718	SOUTHWOLD - Find spot		Neolithic?	Medium	Medium	Medium	66	Intertidal
1793	DUNWICH – Kiln	Monument	Medieval	Medium	Medium	Medium	66	Intertidal
1714	WALBERSWICK – Peat	Buried Landsurface	Prehistoric	Medium	Medium	Medium	66	Intertidal
1563	PAKEFIELD – Church	Monument	Medieval	Medium	Medium	Medium	66	Above HW
1578	BENACRE - Linear lines in peat	Monument		Medium	Medium	Medium	66	Above HW

Table 3A1. Results of the highest ranking archaeological and palaeoenvironmental sites within the East Anglia study

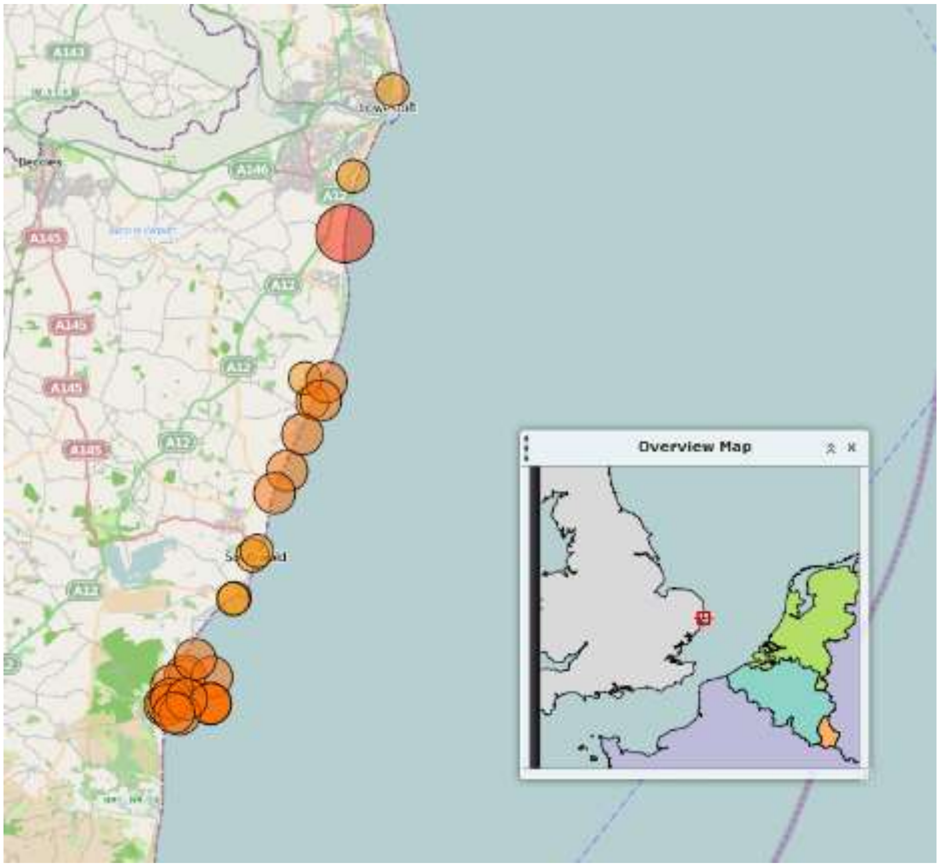


Figure 3A4. Map showing distribution of highest ranking archaeological and palaeoenvironmental sites within the East Anglia study area

Rank for sea level change

	High	Medium	Low
Number of sites	3	118	676

Rank for environmental change

	High	Medium	Low
Number of sites	17	16	740

Rank for temporal continuity

	High	Medium	Low
Number of sites	1	104	678

Table 3A2. Results of the three archaeological and palaeoenvironmental ranking categories

3A.3.2 Discussion of the Ranking Results

The table of highest ranking sites is dominated by medieval monuments, mainly from the town of Dunwich but also the medieval village of Easton Bavents. The Suffolk coast is witnessing some of the most rapid rates of coastal recession in the world, it is due to this that so many sites have now been destroyed or exist as ruins on the seabed. This is also reflected through the large number of sites ranking high for environmental change, the medieval monuments were not simply inundated by a rising sea-level, but lost due to a rapid recession of the coastline caused by a combination of wave action, storm surges and sediment dynamics eroding and undercutting the soft cliffs which make up the majority of this coast.

Alongside the medieval monuments other top ranking sites include buried or submerged prehistoric material, including the Lower Palaeolithic site of Pakefield where material is being eroded along the cliff. The site at Pakefield however, is the only site containing in-situ and dated archaeological material. Other sites such as Covehithe, Benacre Broad and Easton Broad do have high potential to provide further information about the changing landscape, but there is currently little analysed material.

This data can provide information, which will enable the development of modelling coastal change. The medieval town of Dunwich is well known and has been subject to large-scale research most recently through a joint project between English Heritage, GeoData, the National Oceanography Centre and Wessex Archaeology (Sear et al, 2013). The project involved the assessment of archaeological material, as well as historic maps, charts, paintings and sketches in order to determine the position of the coastline at various times since 1587. So the potential of this data is already well known. The ranking has however, highlighted the potential for prehistoric material to provide an understanding and modelling of coastal change over a longer time period. Peat deposits have been noted at low tide at Benacre Broad and Covehithe Broad. Apart from Pakefield, the Suffolk coast contains little dated and in-situ archaeological material from the Palaeolithic to the Neolithic. Such sites may have been lost due to rapid erosion of this coastline, however, records of peat deposits identified at low tide demonstrate the potential for further prehistoric material to provide an understanding of coastal change in the longer term.

Wessex Archaeology (2008) recognised the potential for further material to survive offshore at Pakefield due to the nature and location of the Lower Palaeolithic material found at the base of the cliff, a geophysical survey and vibrocoring was carried out. Sediments matching those at the base of the cliff were noted and highlight potential for further submerged archaeological material which have not been destroyed by erosion or glacial processes.

Other sites which ranked lower but still have the potential to provide information on coastal change include WWI and WWII gun emplacements, anti-tank blocks, pill boxes and air raid shelters, these are found all along the coast from Lowestoft to Southwold and can provide information on the rate of coastal change over the last 100 years. Many wreck sites were also assessed, although the majority are modern (1901-Present), around twenty medieval and post medieval wrecks were ranked. Located just south of the study area, the 16th Century protected wreck site Dunwich Bank, discovered in 1993, has been subjected to ongoing monitoring and may offer some potential to assess the history of seabed processes since the date of wrecking.

It should be noted that not all monuments that were investigated as part of the 2012 Dunwich project (Sear et al, 2013) are contained within the HER or NRHE, however all medieval monuments in this area attained the same ranking score so provide a reflection of site types and their potential value.

3A.4 Ranking Artistic Depictions

The focus on artistic depictions of the East Anglia study area has been on historic paintings, however, several historic photographs, maps and charts were also assessed in order to highlight the potential of this resource. The results of the ranking for each of these is presented below followed by a discussion.

3A.4.1 Historic Photograph Ranking

As part of Activity Two a ranking system was developed for historic photographs, the development of the system and proposed methodology is set out in Section 2.2. The ranking system has been applied to a selection of historic photographs within this case study area.

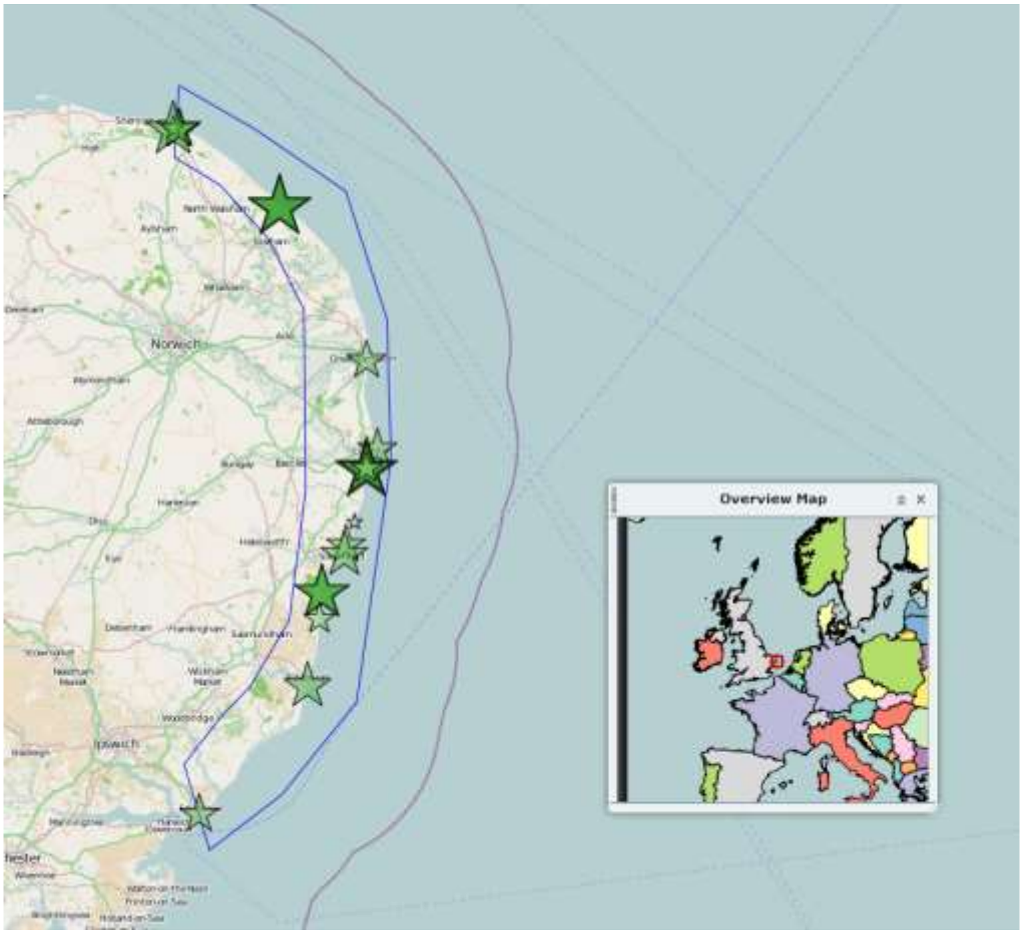


Figure 3A5. Location of historic photos in the East Anglia case study area

A total of 28 historic photos were assessed as part of the project, images were primarily chosen from locations along the East Anglian coastline where historic paintings and archaeological sites were also known. The photographs were collected and then ranked. Hundreds of historic images exist for this stretch of coastline, it should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic photos to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums and galleries, as well as private collections has the potential to provide many more.

The table below outlines the results of the ranking, note that photographs were ranked as either a heritage view or a non-heritage view.

Img_ uid	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
1178	Happisburgh Beach	1965	High		Good	100
1181	Lowestoft from Pakefield	1890		High	Good	100
1187	Well shaft, Happisburgh	1947	High		Good	100

1169	Dunwich All Saints Church	1904	High		Fair	88
1166	Dunwich Church	1914	High		Fair	88
1176	Golden beach Happisburgh	1955		High	Fair	88
1185	Pakefield	1906		High	Fair	88
1168	Dunwich Beach	1960	Medium		Good	77
1167	Dunwich Beach	1955	Medium		Good	77
1175	Southwold from the pier	1919	Medium		Good	77
1172	Felixstowe Pier	1906	Medium		Good	77
1174	Southwold from the Old Lighthouse	1890	Medium		Good	77
1180	Lowestoft	1955	Medium		Good	77
1182	Martello Tower at Felixstowe		Medium		Good	77
1184	Pakefield	1903		High	Poor	77
1161	Cromer Beach	1901	Medium		Fair	66
1162	Cromer Beach	1954	Medium		Fair	66
1163	Cromer Pier	1901	Medium		Fair	66
1170	Easton Bavents	1936	Medium		Fair	66
1171	Felixstowe beach from the pier	1920	Medium		Fair	66
1173	Felixstowe Pier	1919	Medium		Fair	66
1177	Great Yarmouth	1928	Medium		Fair	66
1165	Lowestoft	1928	Medium		Fair	66
1183	Minismere near Dunwich	1960		Low	Good	55
1186	Slaughden Quay	1894	Medium		Poor	55
1164	Cromer Rock Garden	1960	Low		Fair	44
1160	Covehithe Cliffs			Low	Poor	33

Table 3A3. Results of the historic photograph ranking

The majority of photos assessed were of heritage views, containing features which can be identified today, the oldest photo assessed was taken in 1890.

3A.4.2 Maps and Charts Ranking

A ranking system was developed for maps and charts, the development of the system and methodology is set out in Section 2.2. Several historical maps exist of the East Anglian coastline, with some going back over 400 years. Two maps were assessed as part of the project. It should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic maps and charts to provide information on coastal change in this area. A brief search of resources available online was carried out, although further research online, in museums, libraries and galleries, as well as private collections has the potential to provide many more. This could also be combined with the study of historic maps and charts as part of the larger Dunwich project (Sear et al 2013), where searches were carried out at the National Archives, National Maritime Museum, the Admiralty Library and the British Library. The focus of this project was on the town of Dunwich, but the majority of maps consulted depict the whole of the Suffolk coastline. The maps were assessed and digitised to create map regressions of the coastline, this was later combined with all other data sources.

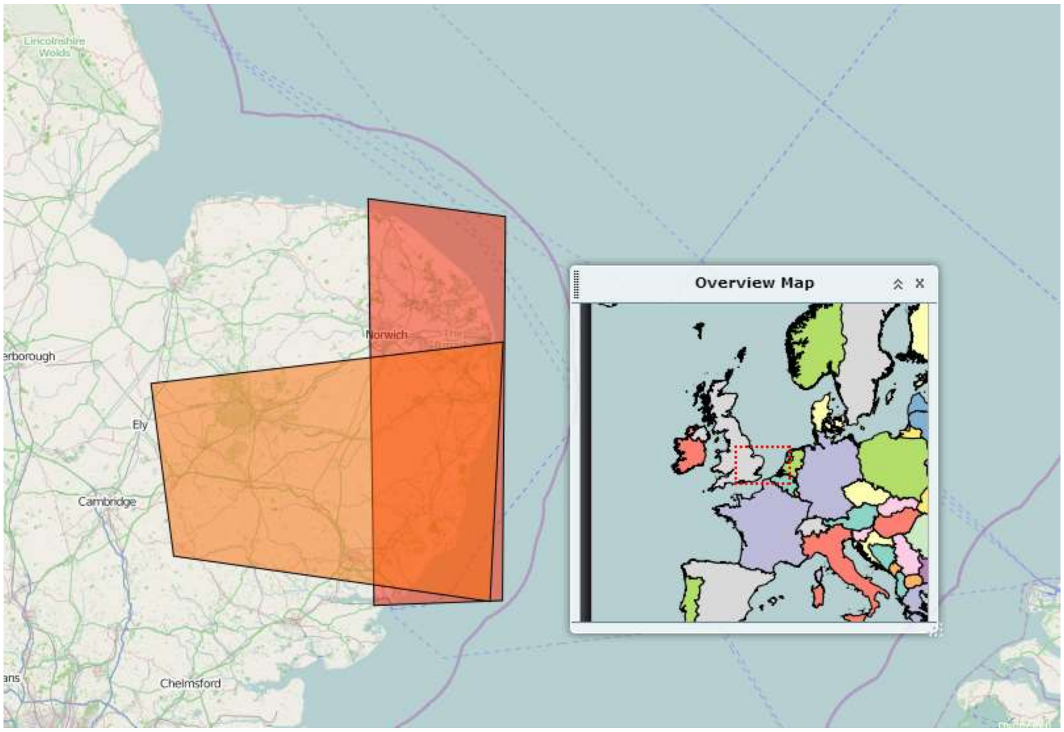


Figure 3A6. Location of the two maps assessed along the East Anglian coastline.

MAP_ uid	Title	Year	Score Chronometric Accuracy	Score Topographic Accuracy	Score Detail in non-coastal area	Score Geometrical Accuracy	Total Map Score
141	OS map 1st edition	1880-1890	60	100	100	66.66	81.66
120	Hodskinson's map Suffolk	1783	60	63.88	66.66	50	81.66

Table 3A4. Results of the map ranking

3A.4.3 Art Ranking

The research has identified 248 exhibiting artists who painted on the coastline of East Anglia between 1880-1940. The names of these artists have been obtained from an examination of the main art dictionaries and listings of the principal exhibitions such as the Royal Academy (RA) as well as from auction house records. However many of these artists painted genre subjects, shipping and fishing scenes or buildings, which provide only marginal information relating to coastal conditions whilst for others only a painting title was available rather than image.

The development of the ranking system has been described in Section 2.2. The highest ranking artworks, usually gaining 60-70 points are detailed watercolour drawings, lithographs and steel engravings from the mid to late Victorian period. These are followed by oil paintings from the early and mid-nineteenth century that were painted by artists or followers of the Norwich School who, although painting in oils rather than watercolour, were, nevertheless, able to capture a significant amount of coastal detail.

Artists tended to paint attractive or dramatic coastal locations as well as meeting specific demands of their patrons. On the East Anglian coast they were drawn to the coastal towns and villages either on account of their locations or because of the interest in the activities of fishermen and their craft working along the shoreline. The result has been that many of the sites of key geomorphological and coastal risk management interest have been painted by artists particularly during the nineteenth century. Within the higher ranking artworks there are examples, which include locations affected by coastal landsliding, marine erosion, flooding and beach change. Where a particular location has been painted by a limited number of artists or perhaps just one artist that work has been included to illustrate a particular feature or issue.

These differing coastal landforms and processes and their impacts on coastal residents, assets and infrastructure could not have been easily matched to the most informative works of art without the provision of the ranking system. The ranking system has identified ten case study locations and at each at least one artwork has been examined in more detail below as follows:

Case Study Number	Location	Artist	Date	Score type	Score period	Score style	Score enviro	Total Score
1	Cromer Beach, Norfolk	John Varley	1802	Water-colour	Early	Topog.	Detailed View	74
2	Cromer Cliffs and Beach	John Moore	1850	Oil	Mid	Topog.	Detailed View	66
3	Great Yarmouth Beach	Rock & Co	1850	Steel Plate	Mid	Topog.	General View	55
4	Gorleston-on-Sea	Joseph Lambert	1822	Copper Plate	Early	Topog.	General View	44*
5	Pakefield Beach and Cliffs	Alfred Stannard	1882	Oik	Late	Topog.	General View	55
6	Southwold Cliffs, Suffolk	Helen Clarke	1889	Water-colour	Late	Topog.	Detailed View	74
7	Southwold Beach	J.B Crome	1838	Lithog.	Early	Marine/shipping	Detailed View	66
8	Southwold Harbour	William Daniell	1822	Aqua-tint	Early	Topog.	Detailed View	66
9	Slaughden Quay	John Moore	1883	Oil	Late	Topog.	Detailed View	74
10	Orford Ness	William Daniell	1822	Aqua-tint	Early	Topog.	Detailed View	62

*Table 3A5. Top art ranking results. (*This image, although lower scoring, provides the only known view of the Lowestoft cliffline prior to its substantial alteration; hence it was selected.)*

A more detailed explanation of each site and the interpretation of the individual artworks is provided below. The assigning of scores to each artwork suggests names of those artists who have depicted different aspects of the East Anglian coast across the timeline 1770-1920. These artists include John Varley (1778-1842), William Daniell (1769-1837), Henry Davy (1793-1865), John Moore of Ipswich (1820-1902), Thomas Smythe (1825-1906), Helen Clarke (Flourished 1880-1890) and Alfred Heaton Cooper (1864-1934). These artists can be relied upon in terms of the accuracy of their depictions of the East Anglian coastline.

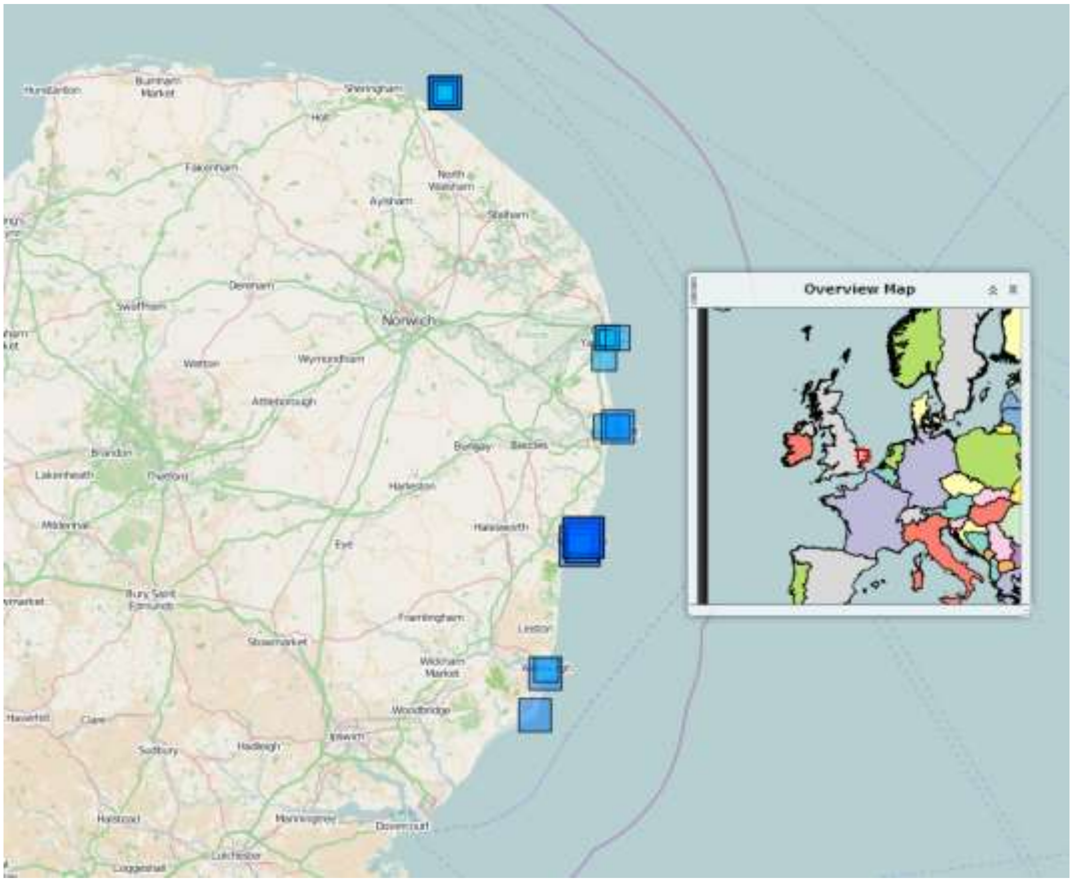


Figure 3A7. Location of the artistic depictions

3A.4.4 Discussion of Ranking Results

Through the East Anglian case studies the value of various artworks has been tested at sites of differing geomorphology. The combined approaches of desk-based research, museum and gallery searches and field visits have confirmed the added value of art from the period 1770-1940 to support other coastal surveying and monitoring technologies (e.g. Space-borne, air-borne, ship-borne and terrestrial). It is important to remember that artists in the late Georgian and Victorian eras worked for very demanding, wealthy clients who often sought exact views of the coastal landscape to remind them of their visit. Before the days of photography precise images were, therefore, a prerequisite in most cases. The examination of the works of many East Anglian artists testifies to their considerable artistic skills in capturing accurately the coastal topography.

Some of the artworks examined in these case studies show significant coastal change over time as well as telling the story of human intervention on the coast. Other artworks show very little change over the last two hundred years and this information is of equal interest to the coastal scientist. Importantly also the artworks illustrate in many cases the nature of the natural undeveloped coastline and suggest what conditions might be experienced if coastal defences were not maintained in the future. This is particularly significant as along certain coastal frontages it will not be possible to continue to defend the coast as has been the case in the past for physical or environmental reasons.

The East Anglian study focused on the use of historic paintings, however a selection of historic maps and photographs were also consulted to review the potential of these data sources.

Because of the dynamic nature of this coastline historic photographs can be a valuable resource with many historic photos containing depictions of the cliff with recognisable heritage features nearby, including churches, wells and houses. These can be compared to the modern situation and from this an accurate idea of the rate of erosion since the date of the photograph can be gained. Historic maps and charts have been used successfully in the Dunwich project (Sear et al, 2013), these can provide an indication of the cliff retreat, however, it is often difficult to make out more detail regarding the current shoreline, beach elevation etc.

Two maps were assessed, Hodskinson's map of Suffolk from 1783 and the 1st Edition Ordnance Survey Maps of the East Anglia coastline. Hodskinson's map from 1783 gives a good impression of the county as a whole, but the detail in the coastal zone is lacking. Although it can tell us about the settlement patterns, details of the parks, gardens and houses, it is unclear where the high or low water mark is, the extent of beaches and marshland, and inlets and estuaries are also lacking in detail. The OS map provided more detailed information and dates from the 1880's. According to a study by Oliver, R (1996) it is from this period that mapping surveys became accurate enough to be used in the study of coastal change. A more comprehensive study for The Crown Estate has been carried out to assess the use of historical maps to assess coastal change in Suffolk (Brooks, 2010), such data can be combined with the artistic depictions, photographs and archaeological material gathered as part of this project in order to gain a more comprehensive understanding of the long and short term changes along this dynamic coastline.

3A.5 Art Field and Research Studies

No archaeological or palaeoenvironmental fieldwork was carried out for the East Anglia case study area, this section outlines the field studies undertaken as part of the art study.

3A.5.1 Key Research Questions to be Addressed from Artistic Depictions

Having established, through the art ranking system that the images are likely to be true representations of the conditions that would be seen at the time they were painted, the research questions to be answered through examination of the artworks at the case study sites were:

- What information can the historical images provide to support understanding of long-term coastal change?
- How can the potential of this resource be used most effectively by the end-user?

In order to identify the most suitable artworks that could be studied in more detail at the field study sites a national search was undertaken involving an extensive review of landscape paintings, watercolours and prints held in public and some private collections. Following ranking of over forty artworks ten examples have been the subject of more detailed analysis involving site visits.

Along the East Anglia study area coastline there are a range of physical conditions to be found including eroding cliffs, cliff instability problems, beach change and flooding of low-lying land by the sea. In order to reflect these varying conditions art images have been selected from across the East Anglian study site. Sites A1 and A2 at Cromer consider eroding, unstable cliffs and the nature of the beach. Sites A3 to A6 examine cliff behaviour and beach change at Great Yarmouth, Gorleston-on-Sea and Pakefield. Sites A7 and A8 investigate cliff erosion and beach levels at Southwold. Site A9 assesses issues relating to low-lying land at Slaughden near Aldeburgh and, finally, Site A10 assesses coastal change at Orford Ness. Each site considers the potential of the artwork to be used as a qualitative or quantitative tool to support understanding of long-term coastal change and coastal management more widely.

3A.5.2 Approach to Information Gathering and Fieldwork for Assessing Coastal Artworks

Where it has been practical to gain access and relevant to the study, present day photographs were taken in the field to try, as far as possible, to match the views painted by the 18th, 19th and early 20th Century artists. It also provided the opportunity to assess the conditions of the cliffline and beach and changes that may have taken place over time. In terms of work in this field each of the locations has been visited and photographed in varying weather conditions. Inspections were timed to coincide with Low Water and a walk-over survey was made along the beach and base of the cliff returning along the cliff top. This ensured that thorough comparison could be made between the geomorphological conditions depicted in the artwork and the present day situation.

3A.5.3 Art Field Data Gathering Results

The selected sites in the East Anglian case study area were chosen to reflect a range of geomorphological types. Site inspections have confirmed that the locations selected do provide a good representation of coastal geomorphology against which the value of historical artworks can be tested.

This fieldwork element has been largely visual in terms of identifying the location of the paintings and making judgements, on site, of the role that art can fulfil as a qualitative or quantitative tool to support coastal risk management. The field inspections allowed a more accurate appraisal to be made of current physical conditions rather than relying upon written accounts and reports particularly as storm events can cause significant alterations over relatively short time periods.

The main focus for each case study has been the examination of one particular artwork and to make an assessment of what it tells us about changes over time from field observation. However, for some of the study sites it has been found that several artists painted the view from the same or a similar spot. This helps us to establish a chronology of coastal change through the nineteenth and twentieth centuries. The results for each case study location are described below. The art case studies are numbered from A1 to A10.

A1. Cromer Beach, Norfolk

Location

'*Cromer Beach'*, looking from the south northwards towards the pier and the town in 1802, from a watercolour drawing by John Varley (*Figure 3A8*).

Why was the study site selected?

The town of Cromer is located close to the top of unconsolidated soft cliffs, which range in height between 20 and 50m. In places the cliffs contain large boulders of chalk (erratics), which are a result of previous glaciations. The cliff line is currently protected by a concrete seawall, which is vital to prevent coastal erosion and further instability causing problems for valuable cliff top properties and infrastructure. If the current policy of maintaining the coastal defences is continued, the cliffs would be held in their current position, however, there is likely to be some narrowing and lowering of the beach as a result of the impacts of storm waves reflecting off the hard structure. A large amount of work is necessary to maintain the condition of the seawalls and prevent outflanking of the walls, due to the cutting back of the cliffs to the east and the west of the frontage. The aim for the frontage is to continue to maintain the coastal defences in the long term. However, this will result in the loss of beach along the frontage and have adverse impacts in terms of sediment transport, geology and geomorphological processes, as well as the natural landscape and the seascape. Any information to improve understanding of long-term coastal change at Cromer is, therefore, particularly valuable.

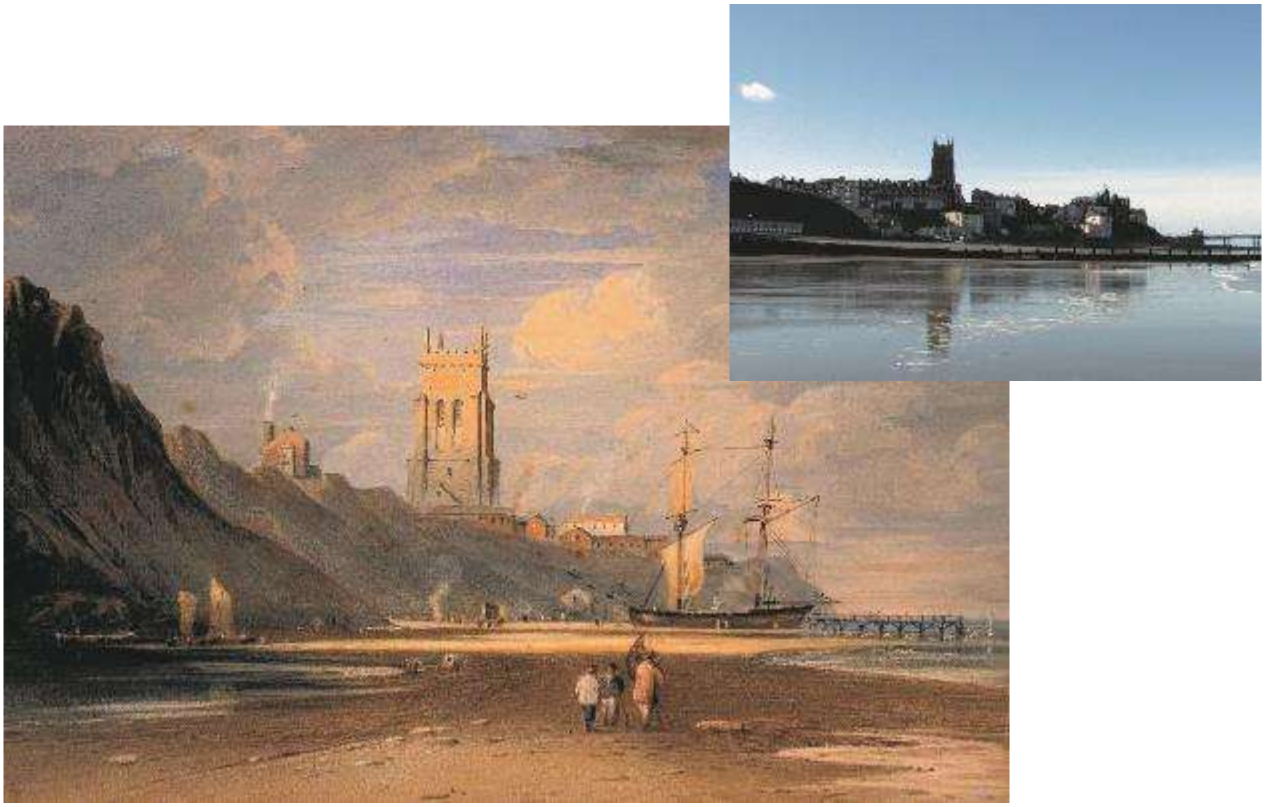


Figure 3A8. 'Cromer Beach' by John Varley, watercolour 1802. Courtesy: Norwich Castle Museum.

Geomorphological setting

The cliff line along this section of the North Norfolk coast comprises 20-50m high loosely consolidated cliffs and slopes. The glacial till cliffs rest on a chalk outcrop, which can be found at the base of the cliff itself. The beach is predominantly sandy with a thin layer of shingle at the base of the cliff. Prior to coastal defences being constructed, sediments from the eroding cliffs were carried eastwards and southwards around the North Norfolk coastline, in the direction of Suffolk. A wide sandy beach exists at present, although this is prone to lowering as a result of both rising sea levels and scour against the existing seawall.

Key coastal risk management issues for the frontage

The key issue is how to maintain adequate protection in the long-term for the town of Cromer. This is achieved through the maintenance of the coastal defences themselves and of a healthy beach, which can form a valuable form of coastal defence.

How the artwork can inform coastal risk management

The watercolour by Varley is of interest because it provides detail of the condition of the beach at the beginning of the nineteenth century as well as the state of the cliff line. The beach is composed of sand and appears to be in a healthy state with a slight crest towards the centre of the beach, witnessed by the pool of water trapped at the back of the beach in the left foreground of the watercolour. The cliffs can be seen in their natural state before coastal defences were constructed and the proximity of the development to the cliff top is clearly visible. The level of the beach against the piles of Cromer pier can be seen to the right.

Over the intervening period a seawall was provided along the foot of the cliffs to prevent erosion at their toe and groynes have been constructed to control beach levels. It is interesting to note that the artist, Varley, returned to Cromer and painted a view from the similar spot in 1830, which showed little apparent change to the cliff line or the beach. The weak cliffs along this part of the North Norfolk coast reach heights of up to 70m but the seawall prevents coastal erosion. Where the cliffs are undefended the rate of retreat experienced would be of the order of 2-2.5 metres a year. The construction of the sea wall during the Victorian period would have the effect of reducing the sediment supply to the beach as erosion could no longer take place. This would have the effect of reducing sediment inputs with implications for Cromer beach and beaches to the south. Despite this the beach at Cromer appears in a healthy condition. There has been some accretion on the upper part of the beach but also some steepening (Environment Agency, 2013).

The watercolour by Varley shows us what conditions might be expected to look like along the Cromer town frontage if the sea wall and groynes were not maintained in the future. There would be significant erosion and reactivation of the instability problems in the cliffs with consequent risks to people, property and assets.

Where can the original artwork be viewed?
Norwich Castle Museum and Art Gallery.

Cromer Beach - Ranking score achieved: 74

A2. Cromer Cliffs and Beach, Norfolk

Location
‘Cromer Sunrise’ and ‘Cromer Sunset’ – A pair of oil paintings by John Moore of Ipswich, c.1850 (*Figure 3A9* and *Figure 3A10*). Whereas the previous case study site at Cromer was observed from beach level, this pair of views illustrate the conditions along this frontage taken from the cliff top to the west and the east of the town.

Why was the study site selected?
This site was selected because it illustrates how historical landscape paintings of the coastline can provide information on cliff processes as well as beach conditions.

Geomorphological setting
The cliffs of Cromer are composed of unconsolidated glacial tills, which are seated on a foundation of chalk; this outcrops at the base of the cliffs. The beach is predominantly sandy but with some extent of shingle, particularly at the base of the cliffs.

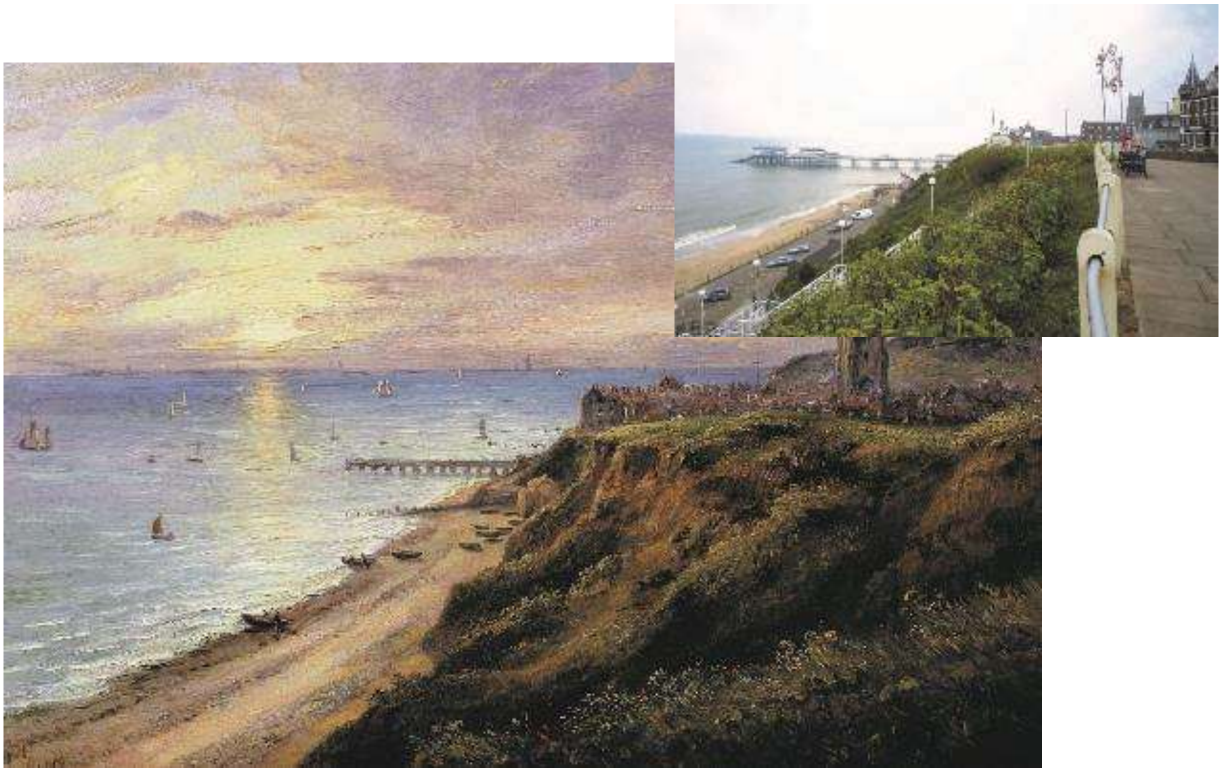


Figure 3A9. 'Cromer' by John Moore of Ipswich, c.1850, oil on canvas. Photography courtesy of Mandell's Gallery, Norwich. Private Collection.

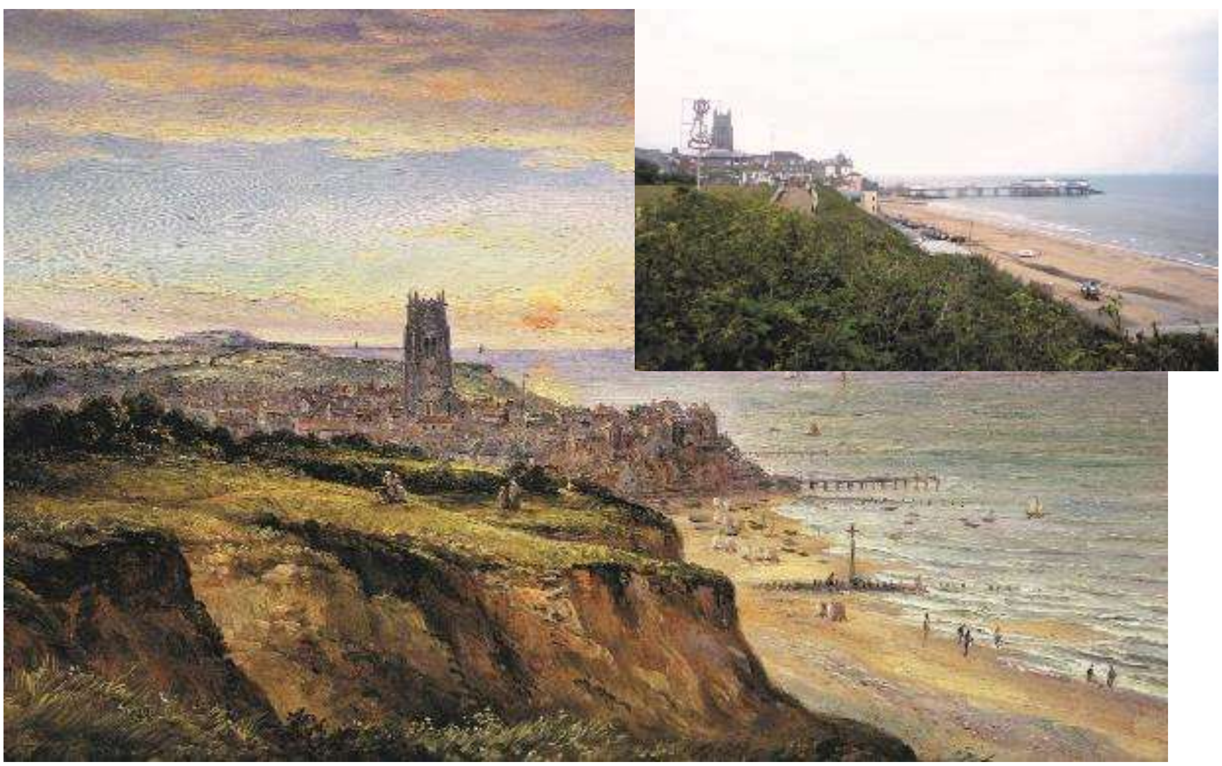


Figure 3A10. 'Cromer' by John Moore of Ipswich, c.1850, oil on canvas. Photography courtesy of Mandell's Gallery, Norwich. Private collection.

Key coastal risk management issues for the frontage

The key issue is how to maintain adequate protection in the long-term for the town of Cromer. Essential to this is the maintenance of the coastal defences themselves and a healthy beach, which can form a valuable additional form of natural coastal defence.

Observations on the artwork

For this case study there are two paintings viewing the town of Cromer from the west and from the east. In the case of the cliffs, the natural processes of cliff erosion and weathering can be clearly seen. Large sections of the 30 – 35m high cliff can be seen spalling away by a process known as mass wasting, particularly in the painting from the west. The indentations in the face of the cliff shown in the two paintings suggest that cliff conditions are influenced strongly by the local geology and groundwater conditions. The back scars of small slides and slips can be seen at the top of the cliff adjacent to the grassy land in the front of the church. These processes will have been speeded up through a lack of toe support, which is resulting in removal of support for the cliff line above by marine erosion. The artworks also illustrate how the steep clay cliffs are attempting to re-grade naturally to a more stable angle of repose by the processes of slope failure. The accumulation of slope debris at the foot of the sea cliffs is, however, being quickly removed by coastal erosion and as a result the cliff face is unable to achieve equilibrium, and therefore, remains actively unstable.

Historical evidence suggests that the rate of cliff retreat at this time could have been of the order of 1.5m-2m a year based on erosion rates of undefended frontages to the east. This gives an indication of the potential risks if the coastal defence policy of '*Hold the Line*' was discontinued.

Also of interest is the depiction of the beach, which shows the extent of the sand and shingle ridges running along the beach parallel with the cliff line. The careful painting of the groynes and the pier also give an indication as the extent of the beach and the way the sediment is being retained by the groyne, particularly in the view from the east, at that particular time. This pair of paintings can, therefore, provide useful indications of conditions prior to coastal defences being constructed. The present day views illustrate how the cliff face has become almost completely vegetated over the intervening period, largely as a result of protection at the toe by nineteenth century or earlier sea wall construction. Along part of the town coastal frontage a large car park has been constructed, which has had the effect of advancing the coastal defence line seawards, and this provides additional support for the previously unstable cliff line.

How can the artwork inform coastal risk management?

The artwork describes very clearly the conditions that were being experienced along the frontage before areas were defended. It suggests what conditions might be experienced in terms of the re-activation of cliff instability problems if coastal defences are not maintained or are removed at some time in the future. This would lead to significant toe erosion of the cliff line and instability problems, which would impact upon people, property and assets in the town.

Where can the original artworks be viewed?

Private collection.

Cromer Cliffs and Beach - Ranking score achieved: 66

A3. Great Yarmouth Beach and Jetty

Location

'Great Yarmouth Beach and Jetty, Norfolk' views by Rock & Co (
Figure *3A11*) and by Edward William Cooke (Figure 3A12). Great Yarmouth is a large and popular seaside resort, located at the mouth of Breydon water, lying between the town of Caister-on-Sea to the north, and Gorleston-on-Sea to the south on the east coast of Norfolk.

Why was the study site selected?

This site was selected on account of the contrast with the high cliff frontage to the north (Case Studies A1 and A2 – see above), and Great Yarmouth is located on a low-lying frontage with a wide sandy beach.

Geomorphological setting

The town of Great Yarmouth is located within a coastal policy unit that is generally characterised as a dune coastline. However, during the nineteenth century and onwards, substantial development has taken place for tourism purposes alongside the historical importance of the town as a port and fishing settlement. The town has a linear structure developing on a piece of land, which is separated from the hinterland by a river emerging from the Breydon Water immediately to the west. The original flow from Breydon might have been directly into the sea but sediment transport from north to south has led to the creation of a long spit, forcing the river to take a southerly course to emerge nearer to Gorleston-on-Sea. Great Yarmouth frontage is characterised by a very wide sandy beach.

Figure 3A11. 'Yarmouth Jetty, Norfolk'. Rock & Co., 1850

Figure 3A12. 'Yarmouth' by Edward William Cooke, RA, 1838, steel engraving

Key coastal risk management issues for the frontage

A low concrete wall and promenade extends along the whole of the Great Yarmouth seafront and the structure has a remaining life of approximately 50 years. The frontage also has a field of timber groynes, which have a residual life of up to 20 years. Over the next decades, the beach at the southern end of the frontage is likely to narrow and steepen, and improvements may be required to the defences in order to maintain their integrity. Rising sea levels will have an impact on the frontage, particularly at the southern end, posing increased risks of flooding. The issue of risk was highlighted by the December 2013 storm surge.

Observations on the artwork

There are a large number of views taken of Great Yarmouth beach on account of the location of the fishing village on the shore adjacent to the pier. It is possible to note beach levels against the timber pier structure and make comparisons through the numerous artworks that exist of this particular location. The view by Rock & Co. Engravers, dated 21st June 1850 (Figure 3A11), shows the timber fishing jetty and beach levels at the time. This compares with the present day view, which shows the healthy condition of the beach. An even earlier view of Yarmouth Beach by Edward William Cooke RA, published 1838 (Figure 3A12), also shows the relatively low beach levels against the timbers of the jetty.

How can the artwork inform coastal risk management?

A critical issue for coastal managers is maintaining the quality and volume of beaches along low-lying frontages, which may otherwise be prone to flooding. Therefore, monitoring of beach levels over time is particularly important. Whilst for the last 20 years in particular, sand monitoring systems have existed around much of the coastline of England, there are very few cases where longer term records exist. As a result, historical images, which indicate beach levels, extending back into the 19th century, can be particularly valuable for comparative purposes. An examination of these engravings seems to suggest that beach levels have increased over time. This is also inferred through recent beach monitoring (Environment Agency, 2013), which states that moderate to massive accretion has occurred along the Great Yarmouth frontage although there has also been some beach steepening.

Where can the original artwork be viewed?
This engraving and similar views appear in many nineteenth century topographical books. Examples can be seen at Norfolk County Museum or on the Internet.

Great Yarmouth Beach and Jetty - Ranking score achieved: 55

A4. Gorleston-on-Sea Beach and Cliffs

Location
'Gorleston-on-Sea Beach and cliffs, Suffolk' by Joseph Lambert, 1822 (
Figure *3A13*). Gorleston is a seaside town almost contiguous with Great Yarmouth, but lying at its southern end at the mouth of the Great Yarmouth harbour.

Why was the study site selected?
In contrast to the site at Great Yarmouth to the north, which is very low-lying and has had a history of flooding problems over time, Gorleston is fronted by low, now heavily defended, cliffs, and offers a comparative approach in terms of coastal defence policy.

Geomorphological setting
Along this frontage there are unconsolidated cliffs, which range in height of between 10-15m; the whole frontage is now heavily defended. There is a narrow sandy foreshore but a wider flat backshore at the northern end, which narrows considerably towards the south.

Key coastal risk management issues for the frontage
The seawall and the harbour arm at the entrance to the port both have an estimated residual life of about 20 years, although the life of the groynes may be only up to ten years.

Figure 3A13. 'Gorleston, Suffolk'. Joseph Lambert, 1822. Copper plate engraving.

Observations on the artwork

This early copper plate engraving c.1822 shows the coastal village of Gorleston with only rudimentary defences at the foot of the slope on the beach fronting certain properties. The natural form of the cliffs can be seen in the foreground. A narrow beach exists between the cliff line and the sea. The interest in the early view is in the marked contrast with the present situation where the whole of the coastal slope is now heavily defended with a seawall and substantial slope re-grading and grassing in a series of terraces and paths with the properties redeveloped and now set well back from the cliff line.

The site is interesting as it illustrates the dramatic change as a result of development along this coastline, particularly in the twentieth century. It is interesting to note that, despite the defences being put in place, an extensive wide sandy beach exists along the frontage. A series of monitoring surveys undertaken since the 1990s attest to the steady accretion of the frontage amounting to an increase of approximately 100m since 1996 (Environment Agency, 2011). This has been accompanied by some beach steepening.

How can the artwork inform coastal risk management?

The engraving from 1822 illustrates the risks that existed to coastal properties at the time and the necessity for subsequent coastal protection measures. Although probably engraved at High Water the view suggests that significant changes to the beach morphology have taken place over the last two hundred years. It also illustrates how risks have been reduced over time through the necessary improvements to coastal defences.

Where can the original artwork be viewed?
This is an example of one of many nineteenth century engravings that are found in topographical guide books for the area. Such views can be seen in the reference library in the Norwich city reference library.

Gorleston-on-Sea Beach & Cliffs - Ranking score achieved: 44

A5. Pakefield Cliffs and Beach

Location
'Pakefield Cliffs and Beach, Suffolk' by Alfred Stannard, 1882 (*Figure 3A14*). Pakefield is, in effect, a southern extension of the town of Lowestoft located to the north. The town is famous for St Margaret's and All Saints Church, which is located immediately adjacent to the beach at the top of a low cliff.

Why was the study site selected?
This site was selected on account of the coastal geomorphology, which comprises a low cliff line, backing a wide shingle and sand beach. It is a location, which has, in the past, been affected by significant erosion and cliff instability problems leading to the loss of cliff top properties (*Figure 3A15*).

Geomorphological setting
Pakefield is characterised by a sandy beach with scattered shingle deposits located below low grassy banks and cliffs. Over the last century the cliffs and slopes have become increasingly vegetated in market contrast to the situation in the late nineteenth century.

Key coastal risk management issues for the location
It is necessary to continue to maintain the stable backshore and cliff line in order to protect the historic church and cliff top assets existing along the frontage. In the past the cliffs at Pakefield have been the subject of severe coastal erosion, with a number of properties being destroyed as a result of the retreat and rotational landsliding.

Figure 3A14. 'Pakefield' by Alfred Stannard, 1882, oil on canvas. Photograph courtesy of Mandell's Gallery, Norwich

Figure 3A15. Coastal instability at Pakefield, early twentieth century

Observations on the artwork
The painting by Alfred Stannard shows a busy scene with a fish market on the beach below the church. The beach appears wide and sandy, which lacks the vegetation cover that exists today. Although the painting by Alfred Stannard is not particularly detailed, it does suggest that since this date the beach has been accreting and, therefore, makes an interesting comparison with the present day coastal environment.

How can the artwork inform coastal risk management?
This painting informs us of the changing beach conditions at Pakefield since the 1880s. In particular the beach appears more extensive today and the backshore and coastal cliffs appear to be extensively vegetated. This appears to be supported by evidence from coastal surveys since the 1990s, which show significant rates of accretion at the northern (Lowestoft) end although there has been some erosion at the southern end (Environment Agency, 2011).

Where can the original artwork be viewed?
Private collection.

Pakefield Cliffs and Beach - Ranking score achieved: 55

A6. Southwold Cliffs

Location
'Southwold cliffs, Suffolk' by Helen Clarke, 1899 (Figure 3A16). Southwold is situated on the open Suffolk coast. The town is almost an island as, on its north side, it is cut off from the hinterland by Buss creek, and on the south by the river Blyth. Southwold is an important historic coastal town containing many listed buildings, as well as being a popular seaside resort.

Why was the study site selected?
Southwold and the village of Walberswick to the south have been favourite locations for artists since the early 19th century. As a result, there is a rich art heritage, which can illustrate the changing cliff and beach conditions over time. The many artworks painted at Southwold can, therefore, illustrate the Arch-Manche concept particularly well.

Geomorphological setting
Southwold is situated on the open coast and is almost separated from its hinterland by Buss Creek to the north, and the river Blyth to the south. To the north of Southwold a small community at Easton Bavents is located along an undefended cliff frontage, whilst the town of Southwold itself is defended by a concrete sea wall with an extensive natural beach to the south. The boundary is the mouth of the Blyth Estuary with its estuary mouth being channelised with hard defences (see case study A7 below).

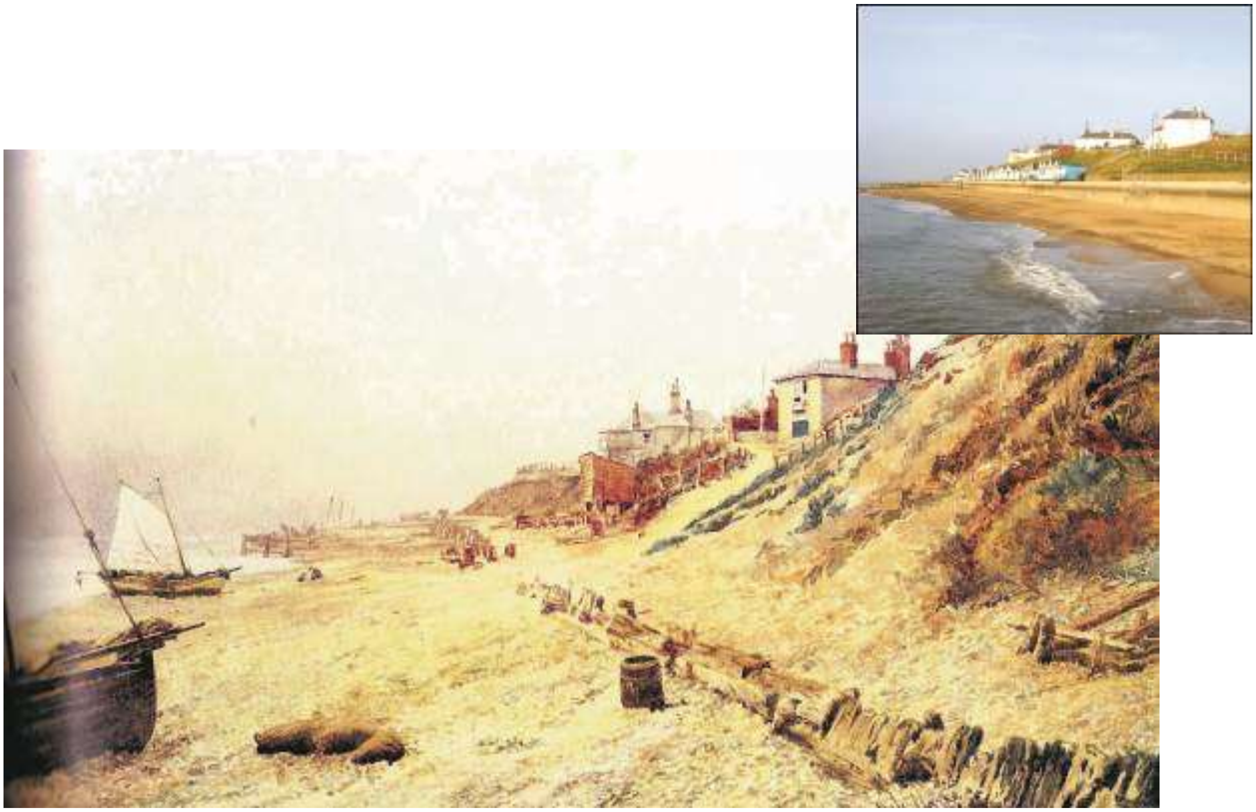


Figure 3A16. 'Southwold' by Helen Clarke, 1899, watercolour. Photograph courtesy of Derek Newman Fine Art. Private collection.

Key coastal risk management issues for the location

To continue to manage the existing coastal defences, looking ahead over the next 100 years, including 'holding the defence line' along the town frontage.

Observations on the artwork

This view by Helen Clarke was painted in about 1899, and provides a detailed illustration of the conditions on the cliff line and the beach at that time. Rudimentary coastal defences line the foot of the cliff and the beach appears to be of shingle; although the more vegetated cliffs appear relatively stable in the foreground they are more susceptible to active erosion beyond. Some further coastal defences and a groyne can be seen projecting into the sea in the middle distance. The situation in 1899 can be compared with the present day view below, which shows a new concrete sea wall and re-grading and stabilisation of the coastal slope. The beach appears lower in the present day view, which may perhaps be a result of wave reflection from the hard structure causing some scour, or other factors including a reduction in the supply of sediment feeding from the north, as well as rising sea levels.

The watercolour by Helen Clarke suggests that the defences would provide little protection against the force of the North Sea and the fact that the defences in the middle distance and beyond appear some way seaward of the cliff would suggest that waves have been breaking through the timber breastwork and eroding the cliff behind.

How can the artwork inform coastal risk management?

The watercolour shows the form of the beach, which appears more stable and steeper than in the present day photograph. The vegetation on the cliff in the foreground suggests that waves are not undermining the cliff at this location compared with further along the coast. The picture illustrates how the coast might look if defences were not maintained.

Where can the original artwork be viewed?
Private collection.

Southwold Cliffs - Ranking score achieved: 74

A7. Southwold Beach, Suffolk

Location
'The Wreck of the Princess Augusta*'* by J. B. Crome, 1838 (Figure 3A17). This view shows the beach frontage immediately to the south of the town of Southwold, which can be seen in the distance.

Why was the study site selected?
This detailed lithograph illustrates conditions on an extensive open beach facing the North Sea, which is backed by a concrete sea wall. It contrasts with the narrower beach to be found abutting the town to the north.

Geomorphological setting
The site comprises a very extensive sand and fine shingle beach to the south of the town of Southwold, and to the north of the harbour. At the back of the beach the cliffs rise gently towards the grassy slopes of Gun Hill.

Key coastal risk management issues for the location
To maintain the quality of the beach and the existing coastal defences to protect the town, looking ahead for the next 100 years.

Figure 3A17. 'Wreck of the Princess Augusta on Southwold Beach' by J. B. Ladbrooke, 1838, lithograph

Figure 3A18. 'The beach at Southwold' by Thomas Smythe', c.1860, oil on canvas. Private collection. This view is taken from the same location as Figure 3A17

Observations on the artwork

This view is of interest because it illustrates both beach conditions and also the occasion of the wreck of the '*Princess Augusta*' on Southwold beach in October 1838. In the foreground, the wreck has taken place in a shallow bay but, overall, in the middle distance and beyond, the very extensive beach, leading toward the town of Southwold, can be seen. The southern edge of the town with some buildings and the church is visible. Beach conditions appear healthy at the time, although the whole frontage is quite low lying.

How can the artwork inform coastal risk management?

This 19th century lithograph provides us with an interesting depiction of the shipwreck set against the coastline at Southwold. It provides only a general view of the beach but together with other artworks of the location it demonstrates healthy beach conditions at the time.

Where can the original artwork be viewed?

Southwold sailor's reading room or on website.

Southwold Beach - Ranking score achieved: 66

A8. Southwold Harbour

Location

'Southwold Harbour' by William Daniell, 1822 (*Figure 3A19*). Southwold harbour lies at the mouth of the River Blyth to the south of the town of Southwold, and separates Southwold from the village of Walberswick to the south.

Why was the study site selected?

The site was chosen because it allows comparison of the present day with an early 19th century image of the harbour infrastructure, with the town of Southwold beyond.

Geomorphological setting

It has been explained that the town of Southwold to the north is situated on rising ground between the Buss Creek and the River Blyth. To the south of the Blyth and Southwold harbour the land is low lying comprising saltmarsh, dunes and low cliffs leading towards the historic medieval town of Dunwich.

Key coastal risk management issues for the location

Maintenance and management of the harbour and harbour mouth for the future, and to ensure that properties in the vicinity of Southwold and Walberswick receive a sufficient standard of protection from the risk of flooding.

Figure 3A19. 'Southwold Harbour' by William Daniell, RA, 1822, aquatint

Observations on the artwork

This detailed aquatint engraving by William Daniell shows the view looking across the mouth of Southwold harbour towards Southwold in the distance. The extensive low lying land beyond the harbour arms, comprising a beach backed by fields, is also the location of the previous case study. This view shows the form of construction of the harbour, as well as the conditions for craft entering the harbour during rough weather.

How can the artwork inform coastal risk management?

The artwork shows the nature of construction of the original mouth of the river. This has since been replaced with a reinforced concrete structure that can be seen in the present day view. Where historical coastal defences, such as sea walls and harbour walls are being replaced, it can be useful to understand how the original structures were erected and the materials used. This knowledge can sometimes help to reduce the costs of investigations.

Where can the original artwork be viewed?

This aquatint is one of 308 views of the British coast contained in *'A Voyage Round Great Britain'* by William Daniell and Richard Ayton (Daniell & Ayton, 1814). The images are represented in the Arch-Manche database.

Southwold Harbour - Ranking score achieved: 66

A9. Slaughden Quay

Location

'Slaughden Quay' near Aldeburgh, Suffolk by John Moore of Ipswich, 1883 (*Figure 3A20*). Slaughden is a small community located on the Suffolk coast to the south of the seaside town of Aldeburgh on the River Alde.

Why was the study site selected?

The site is typical of the low lying saltmarshes and mudflats to be found on the southern part of the Suffolk coastline. This work by John Moore of Ipswich illustrates the coastal geomorphology and environment of the area. Such artworks provide the opportunity to consider not just the physical changes that have taken place over time but also environmental changes.

Geomorphological setting

Slaughden Quay is located on the River Alde and is situated on a massive shingle spit, which extends for some 16km south of Aldeburgh to Orfordness and Orford Beach. The shingle spit is separated from the hinterland by the River Alde, which flows eastwards, through Snape, before broadening into a wider estuary and narrowing again and turning sharply south as a result of longshore drift.

Figure 3A20. 'Slaughden Quay' by John Moore of Ipswich, 1883, oil. Photograph courtesy of Colchester and Ipswich Museums

Key coastal risk management issues for the location
There are complex issues associated with a potential breach by the sea through the estuary to the south of the Slaughden Martello tower in the medium to long term. These issues are being explored in more detail following the completion of the Suffolk Coast Shoreline Management Plan (Suffolk Coastal District Council, 2010). The long-term coastal risk management strategy for this frontage, looking ahead for the next 100 years, is 'no active intervention'.

Observations on the artwork
This quite detailed oil painting shows a tranquil scene at Slaughden Quay by John Moore of Ipswich, painted in 1883. The painting illustrates, in a general way, the nature of conditions at this site, which appear to have remained relatively unchanged.

How can the artwork inform coastal risk management?
Artworks do not just have to illustrate significant coastal change, be it coastal erosion, instability or indeed accretion. If they illustrate that conditions have remained relatively unchanged over time this is equally important information that can contribute to our understanding of long-term coastal change. This would appear to be the case in this particular work.

Where can the original artwork be viewed?
Ipswich and Colchester Museums, BBC Your Paintings.

Slaughden Quay - Ranking score achieved: 74

A10. Orford Ness, Suffolk.

Location
'Orford Ness, Suffolk' by William Daniell RA, 1822 (Figure 3A21). Orford Ness is a very extensive cuspate foreland shingle spit located in southern Suffolk, extending south from the seaside resort of Aldeburgh for a distance of 16km. It is separated from the hinterland by the River Alde, which has been forced to flow southwards parallel with the coast, as a result of the historical longshore drift and build-up of the Ness itself.

Why was the study site selected?
This is one of the most important geomorphological features of its kind in Great Britain and is a location where there is a coastal policy of '*No active intervention'.* Orford Ness is Europe's largest vegetated shingle spit covering an area of 900ha and includes a range of internationally designated habitats.

Geomorphological setting
The site is located on a major shingle spit, which has the potential to breach between the shore and the estuary as a result of its exposed location, and particularly in the face of rising sea levels and a potential increase in the frequency of storm events. The Alde/Ore estuary runs behind this massive shingle ridge to emerge at the coast at North Weir Point to the south. The spit was formed almost entirely by waves through the process of longshore drift. The main influence has been storm waves throwing shingle over the top of the beach crest, where it is protected from the more usual wave action. Over the last two hundred years historical evidence suggests that the spit has extended southwards at between 64-183 metres per year. Over the years this leads to the formation of stable shingle ridges of finer material and swathes of coarse shingle, which may then be colonised by vegetation.

Figure 3A21. 'Orford Ness Lighthouse, Suffolk' by William Daniel, RA, 1822, aquatint. Private Collection

Key coastal risk management issues for the frontage
The need to manage access to Orford Ness and to gain a more detailed appreciation of physical processes taking place in this area.

Observations on the artwork
This aquatint engraving by William Daniell shows the 'Orford Ness Lighthouse' in 1822 with its neighbour, the 'Low Light', about 1.5km beyond. Daniell's view shows a low shingle and sandy beach, with steps leading up to the entrance to the lighthouse. Comparison can be made with beach levels against the lighthouse structure compared with today. It appears that beach levels have changed little at the lighthouse since 1822.

How can the artwork inform coastal risk management?
The view of Orford Ness shows the nature of the shingle spit at this point in the year 1822. The view is finely depicted and allows comparison of long-term beach change to be made. The fact that there appears to be no significant change over such a long period is important in terms of understanding the evolution of the spit.

Where can the original artwork be viewed?
Available to be viewed via the Arch-Manche portal. Original aquatints can be obtained relatively easily via Internet searches.

Orford Ness - Ranking score achieved: 62

3A.6 Analysis

The East Anglia study has combined the use of archaeological and palaeoenvironmental data, paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve our understanding of coastal change in the long and short term. The coastlines of the study area are constantly evolving, analysis of the past enables us to assess progressive changes and alterations to the coast and by understanding past coastal change it is possible to predict future changes and potential impacts more accurately.

The study area contains some of the oldest evidence of human occupation in Europe, now eroding from the modern cliffs, as well as evidence of more recent towns and villages now lying in ruins on the seabed. Much of the more recent erosion has also been captured in historic paintings and photos, and a variety of maps and charts have helped to record the rate and scale of this change over the last few hundred years. This section examines the most informative and reliable data gathered from this study area for contributing to understanding of the scale and pace of coastal change.

3A.6.1 Archaeology and Heritage Features

As described earlier the archaeological assessment focussed on the Suffolk coast from Lowestoft to Dunwich. The highest ranking sites were prehistoric buried and submerged landsurfaces which have the potential to provide information on past environments and sea-level change. The discovery of in-situ material at Pakefield pushed back the accepted dates for evidence of human occupation in Britain from around 400,000 years ago to 700,000 years ago. The discovery of mammal bones and other environmental material has allowed for the reconstruction of the climatic conditions which show similarities to the Mediterranean climates of southern Europe today and the assessment of plants and insects indicates the presence of marshy areas fringing a slow-flowing meandering river (Parfitt et al, 2006).

Work to identify whether the deposits from the cliffs at Pakefield continue offshore has been successful, proving that these early sediments, now submerged, have not been completely destroyed by glacial processes or marine erosion (Wessex, 2008:20). The in-situ material at Pakefield is therefore a reliable example of how archaeological and palaeoenvironmental data can be used to show how this area has changed in the long term both in terms of environmental change and relative sea-level change.

Submerged deposits further south at Benacre Broad, Covehithe and Easton Bavents can also inform environmental change and relative sea level change. These deposits contain peat which has the potential to provide datable environmental evidence and the location of this deposit relative to the current coastline can also provide information on relative sea-level change in the longer term. Further research is required to understand the full extent and current condition of these deposits.

Other high ranking material was from the medieval town of Dunwich, extensive work has already been carried out within a collaborative project funded by English Heritage (Sear et al 2013). The project combined archaeological and geophysical data with historic maps, charts, photos and documentary evidence. The project has been able to demonstrate the location of the coastline over the last few hundred years based on a combination of all these datasets and can therefore be used as a tool to assist with management of this coast in the future.

Dunwich and Pakefield are not the only sites which can be used to inform coastal change. Further work to establish the coastline at various periods all along the Suffolk coast was carried out by The Crown Estate (Brooks, 2010) looking at not only the coastline position but also the associated nearshore bathymetry, a detailed historical investigation of the coastline retreat was carried out using historic data including maps and charts, however, no attention was given to the value of archaeological material in improving our understanding of coastal change. The Arch-Manche project has highlighted that many sites and deposits exist in the coastal, intertidal and marine zone of Suffolk which could add to our understanding of the coastline position, for example in the area of Covehithe (see Figure 3A22).

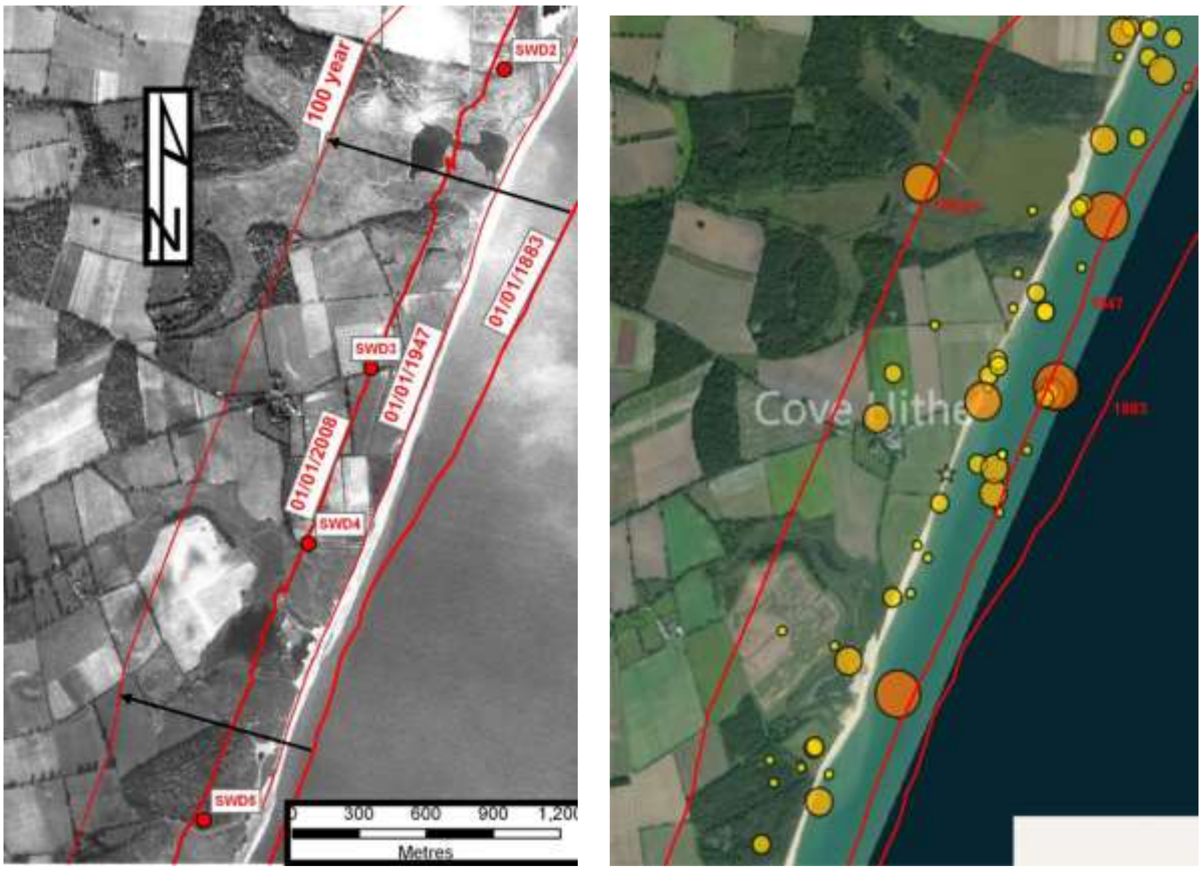


Figure 3A22. Covehithe. The image on the left (© Crown Estate, Brooks, 2010) shows the coastline near Covehithe in 1947, past shorelines are derived from historic maps, as well as a prediction of the shoreline in 100 years. The image on the right shows the same area today, with the historic and projected coastlines overlaid. The circles represent archaeological and palaeoenvironmental material assessed during the project, the larger darker circles have scored higher, and include peat deposits and a medieval well lost to the sea

Although much work has been carried out on reconstructing the coastline from the medieval period, further work is required to understand the rate and scale of coastal change from the Palaeolithic, Pakefield contains a wealth of information and deposits are known to survive offshore. Records of peat deposits exposed at low tide in other areas of the Suffolk coast can also provide further information to improve our understanding of coastal change in the longer term. The Arch-Manche project has demonstrated that along the stretch of coast in Suffolk a wealth of archaeological material is available to improve our understanding of coastal change not just in the last few hundred years but in the last few hundred thousand years.

It is also interesting to note that a number of the archaeological sites which have significant potential for holding data to inform on coastal change are themselves likely to be lost through continuing erosion of the coast. This highlights the need to gather data from those high and medium scored sites to capitalise on this information before it is lost.

3A.6.2 Artistic Depictions

Following the research and location of a large number of artistic images of the study area coastline it was possible to rank their relative importance in terms of their value in informing on long-term coastal change. The art case study area was extensive in East Anglia because of the range of geomorphological types exposed around its coast. These included estuaries, creeks, river mouths, shingle spits, saltmarshes and mudflats. Because of the volume of artworks produced it has been possible to illustrate change over time through ten case study examples reflecting the range of physical features.

The ranking system directed research to the higher ranking case study locations usually where detailed artworks were available, painted, often, in watercolour, or printed as aquatint or steel plate engravings. Where a particular site offered interesting potential for study of coastal change the highest ranking image available was selected for study.

At the project outset the main focus was on a qualitative assessment of the artworks. However, after a review of the works by some artists it is clear that they may also allow quantitative assessments to be made, particularly where structures such as sea walls, groynes or buildings exist and where, for example, beach levels are clearly indicated or where actual cliff retreat can be measured against a structure.

In terms of the case study examples for soft cliffs artworks display these particularly clearly, for example, in the watercolour drawing of Cromer by John Varley (*Figure 3A8*) and in the views of the town by John Moore of Ipswich (*Figure 3A9*, *Figure 3A10*). Here the geomorphological processes of mass wasting and slumping, taking place on an undefended cliff, are clearly visible. The paintings tell us what conditions might occur if the coastal risk management policy changed from *Hold the Line* to *No Active Intervention*. These views of Cromer also illustrate in some detail the beach conditions that existed through the nineteenth century. The beach remained healthy no doubt because of the ready supply of sediments from the naturally eroding cliffs. There appears to be some evidence of flattening of the beach since Victorian and Edwardian times probably as a result of wave reflection from the hard defences at the foot of the cliffs and as a result of sea level rise.

At Great Yarmouth the extensive sandy beach has provided an effective form of coastal protection for the frontage for centuries. The beach is reliant on the continuously eroding cliffs to the north to supply a feed of suitable beach material. There are many artworks of Yarmouth beach because a focus for artists right through the nineteenth century was the fishing community that worked from a location close to Yarmouth Jetty (pier) on the main beach. Most paintings illustrated the activities of fishermen with the jetty as a backdrop and it is, therefore, possible to view beach levels against the timbers of the jetty and examine fluctuations over time. Although the structure has been removed recently (2012) art records do provide evidence of the healthy nature of Yarmouth beach extending back to the early 1800s.

The low cliffs at Gorleston and Pakefield were also popular subjects for artists. At Gorleston there has been extensive coastal protection measures constructed since mid-Victorian times but before that engravings show the vulnerability of coastal properties and the need for defences to be provided. At Pakefield the retreat of the soft cliffs led to extensive damage to properties and infrastructure along part of the frontage in the period up to the 1980s. Most artworks here focus on the fishing activities on the shore below the historic church of St Margaret's and All Saints, which is situated close to the cliff top. However, here the paintings show how the foreshore and cliffs have become increasing vegetated and thus more stable.

The town of Southwold to the south is, alongside Cromer, perhaps the most painted location along the Suffolk coast. The relatively prosperous town, with its steady flow of summer visitors, included many clients who wished to purchase art. This, together with the establishment of a flourishing art school at Walberswick immediately opposite Southwold on the south side of the mouth of the River Blyth ensured a rich resource of paintings, watercolours and prints. For Southwold it has been possible to compare changes along the cliffline below the town of Southwold and to demonstrate the valuable protection role that the sea wall plays, whilst along the beach to the south there are several views, which allow comparison of the shape and volume of the beach. The crested shape of the beach, a natural feature, is clearly visible in several paintings and watercolours, a feature still present today. Such artworks are important in showing that there has been relatively little change in the beach over the last 150 years; this is useful information for coastal engineers.

At Walberwick there are numerous views of the mouth of the River Blyth; perhaps the first being that by William Daniell in 1822 (*Figure 3A19*). It is possible to observe through successive artworks the history of construction of river defences over time. Such information is helpful to designers wishing to replace older structures.

At Slaughden Quay, to the south of Aldeburgh, we can observe the open low lying coast of creeks, estuaries and saltmarsh, a highly important environmental habitat. Such frontages are likely to be increasingly affected by sea level rise with resulting changes to the habitat and species. We can use artworks of natural environments such as this to contribute to the record of the changing environment and in some cases identification of particular plant and shrub species is possible.

At Orford Ness William Daniell also produced a fine aquatint engraving showing both the old and the new lighthouse. The level of the beach in 1822 can be directly compared against the foundations of the lighthouse itself; such works, where physical structures exist in the coastal zone, do allow a quantitative assessment to be made of conditions at that particular locality including an estimate in the level of the beach at the time.

In terms of the most helpful artworks for comparing coastal change the watercolours of John Varley, the oils by John Moore of Ipswich and the engravings by William Daniell and others stand out. Some of the highest ranking artworks of the East Anglian coastline can be viewed easily in the important art collections in the county museums and art galleries of Norfolk and Suffolk, in particular Norwich Castle Museum & Study Centre (eg: Varley) and Ipswich & Colchester Museums (eg: John Moore). All oil paintings can be view on the BBC Your Paintings website whilst the relatively rare and expensive aquatint engravings by William Daniell and others can be inspected easily on the Internet after searching the artists' name and title of the image.

Although not a comprehensive study, several historic photographs and maps were also assessed. First edition Ordnance Survey Maps from the 1880's provide a lot of detail on the coastline, including the high water mark, the location of beaches, dunes and spits. With recognisable heritage features such as lighthouses, these can be compared to maps from earlier and later periods. The historic OS maps are available digitally and have been georeferenced, allowing for the direct comparison with modern maps to compare change over time. Historic photos also often provide detailed information on the coastline, although only relevant for around the last 150 years these can still show the position of the coastline in comparison to known heritage features, many of which survive showing the East Anglian coastline.

3A.6.3 Combined Resources

As demonstrated above, East Anglia contains a wealth of information which can improve our understanding of coastal change, ranging from prehistoric archaeology to 19th Century paintings. Combining this broad range of data it is possible to understand coastal change in both the long and short term. Several areas along the East Anglian coastline contain all types of data; archaeology, art, photographs and historic maps.

Southwold was an important harbour in the Medieval period, and although its importance later declined in favour of Lowestoft, the harbour remained in use at a smaller scale and the town has thrived as a seaside resort. Historic paintings and maps demonstrate how the entrance to the harbour has changed over the last two hundred years (Figure 3A23).

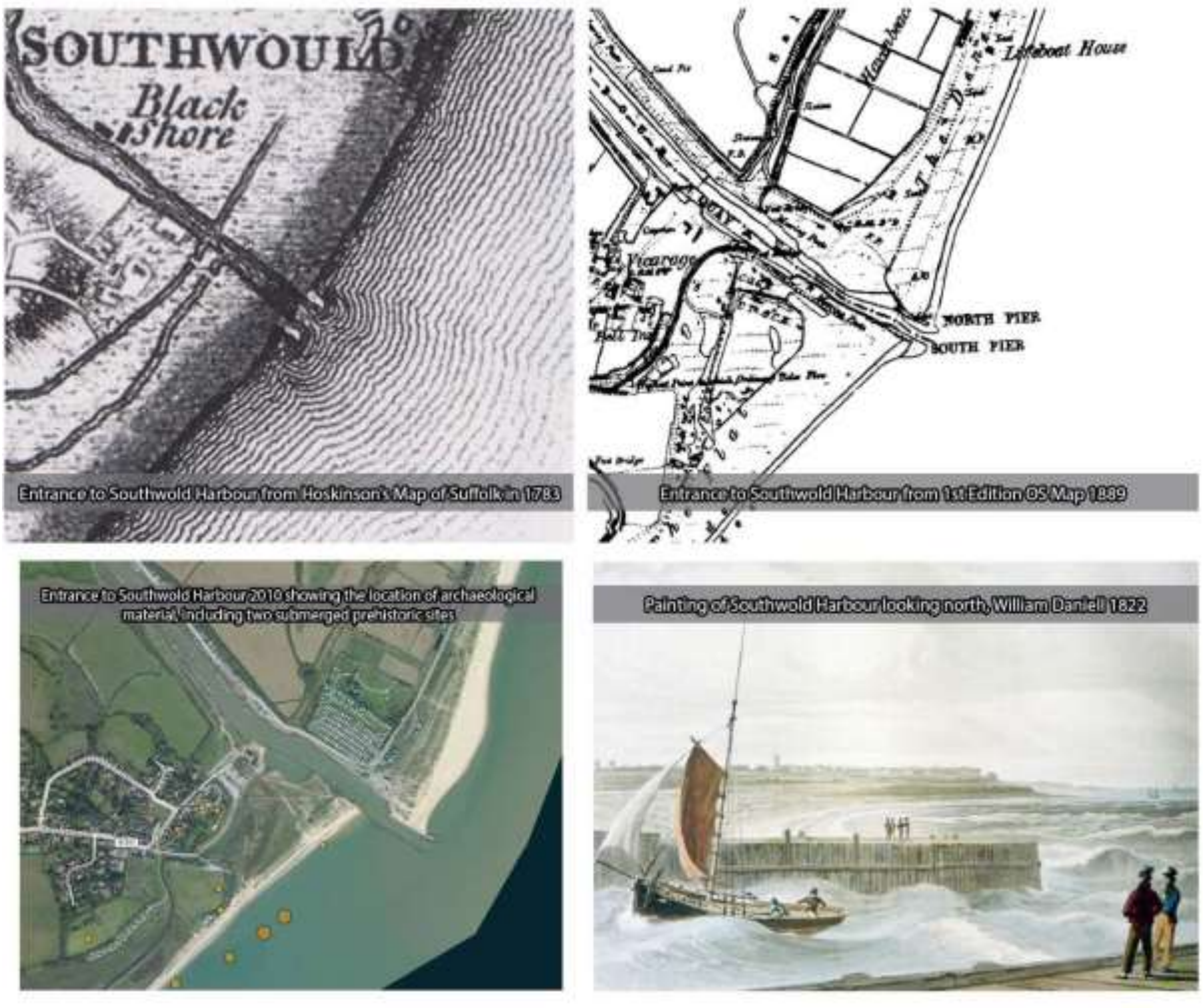


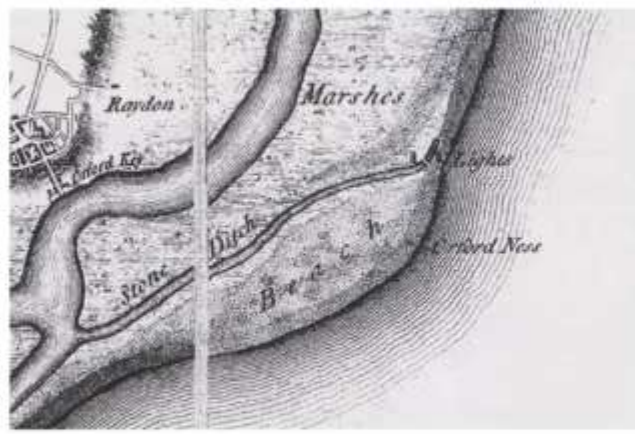
Figure 3A23. The use of historic maps and paintings showing heritage features can help understand coastal change at the entrance to Southwold Harbour. The location of archaeological sites is also shown on the bottom left image, this includes peat and possible Neolithic material exposed at low tide.

The timber entrance to Southwold Harbour has now been replaced with concrete and there appears to be a level of sediment accumulation at the entrance to the harbour since the map of

1783, this was known to be one of the reasons behind the decline of the harbour as sediment build up affected shipping. However, the map from 1783 may not be accurate enough to confirm this.

The area of Orford Ness is another good example of combining art, maps and heritage features to understand coastal change. Two timber light towers were constructed at Orford Ness in 1637, known as the High and Low lights, affected by coastal erosion they were replaced by brick towers in 1720 and 1792, but by 1887 the lower light was lost to the sea. The higher light can still be seen today, however, in June 2013 the lighthouse was decommissioned due to the threat of erosion, the following maps and paintings depict the lighthouses and coastline at various periods (Figure 3A24).

Orford Ness on 1st Edition OS Map from the 1880's. Both lights are shown



Hodskinson's map of Suffolk 1783 shows two 'lights' at Orford Ness

Current location of the higher Lighthouse, Google Earth 2013. Photo copyright Stuart Warrington.

Aquatint engraving of Orford Ness (high) lighthouse by William Daniell in 1822, the low lighthouse is shown in the distance

Figure 3A24. The lighthouses at Orford Ness depicted in 1783, 1822, 1880 and 2013. Such features are often depicted in historic maps and paintings and are good reference points when illustrating coastal change

The following image (*Figure 3A25*) shows a 1st edition OS map of Happisburgh, the high water line is marked on the map and the red line shows the current high water mark (2013), an early 20th century photo of the old coastguard station has also been found, the coastguard station was relocated in 2011 as erosion made access unsafe. Although outside of the archaeology study area for the project, Happisburgh also contains some of the oldest evidence of human occupation in northern Europe, similar to that described earlier in Pakefield. This site contains evidence suggesting a much different environment to that seen today, consisting of a large river with a flood plain on the edge of a forest.

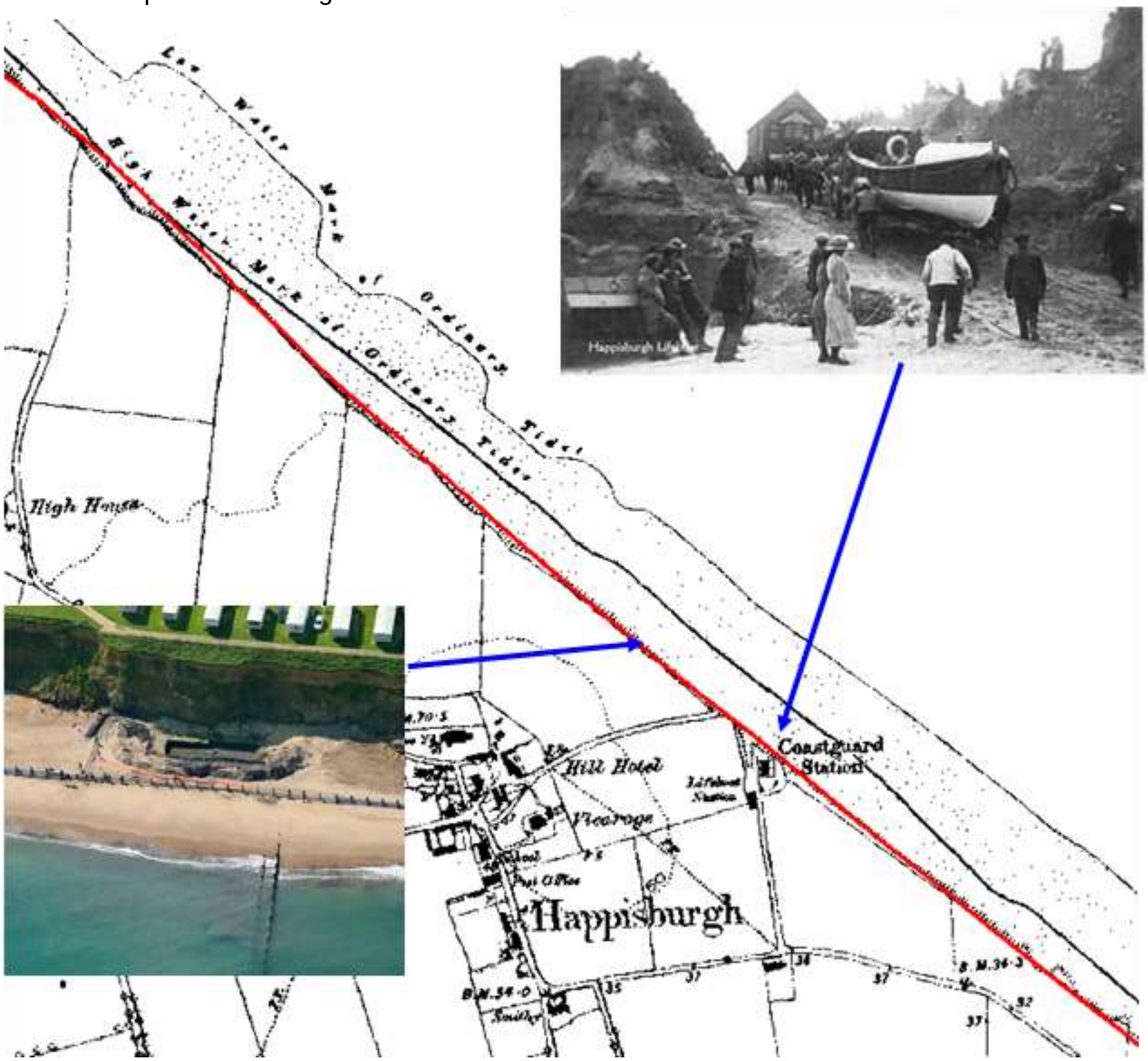


Figure 3A25. 1st Edition OS Map showing the high water mark at Happisburgh, compared to the high water mark in 2013 (red line). The photo in the top corner shows the old coastguard station, re-located in 2011 further inland due to coastal erosion. The photo in the bottom left is of the Happisburgh excavation courtesy of Mike Page

3A.7 Conclusions and Recommendations

The East Anglian Case Study area was chosen due to its dynamic coastline of varying geomorphological types with areas witnessing some of the fastest rates of erosion in the world. Although the focus of this study has been on archaeological evidence and artworks, the study has also demonstrated that there is a wide range of other resources which can be combined to provide even more detail on both long and short term changes, including historic photos, maps and charts. The following section will outline some of the conclusions and recommendations from this study to inform coastal management in this area.

The archaeological and palaeoenvironmental study focused on the Suffolk coast from Lowestoft to Dunwich. This area contains a wealth of information from 700,000 year old prehistoric sites to WWII defence systems. Although the area of Dunwich has been subject to detailed research in order to map the medieval coastline (Sear et al, 2013), the Arch-Manche project highlights the potential of other sites all along the coast which can tell us about the environment and coastline over the long and short term. Records of exposed peat deposits at low tide and archaeological material exposed along the eroding cliff lines have the potential to provide information on past environments. Further research would be required in order to obtain datable material and environmental evidence in order to reconstruct the prehistoric environment and map changes over time in more detail. With this it could then be possible to create 2, 3 and even 4-dimensional evolution models showing the changing landscape over time.

The art case studies in East Anglia clearly demonstrate the dynamic nature of the coastline and the impacts of coastal erosion, instability and flooding over the last 200 years. This region benefits from a rich resource of paintings, drawings and prints, which illustrate coastal conditions over the time period 1770-1940. A large number of artworks were ranked for accuracy and this helped determine which artworks and case study locations should be assessed in more detail also reflecting a suitable range of geomorphological conditions.

Only a small portion of historic maps and photos were assessed from the East Anglia study area. A larger study would be required in order to assess maps and charts from a larger time period, as well as further historic photos and postcards. Other resources could also provide detailed information, for example coastal pilot books, these publications contained detailed perspectives of the coast to be used in navigation and could provide accurate information on the East Anglian coast.

Each of the resources listed above can provide detailed information about past environments and the position of the coastline, through combining these resources it is possible to provide more accurate information not just from one time period but over a longer term, this can inform the rate, scale and pace of coastal change along the East Anglian coastline. The data can not only provide quantitative information on coastline position, but can also provide qualitative information that can assist in illustrating coastal changes to a large audience. While detailed coastal monitoring data is only available in East Anglia for the last few decades, the data assessed above can help fill the large ‘data gap’ for the earlier periods from the Palaeolithic to the 20th Century.

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3A.8 Case Study References

Archibald, E. H. H., 1980. '*Dictionary of sea painters*'. Antiques Collector's Club. Woodbridge.

Armstrong, M. J., 1791. *'An essay on the contour of the coast of Norfolk but more particularly of the Marum-Banks and Sea-Breaches so loudly and justly complained of'*. Norwich.

Beatniffe, R., 1808. *'The Norfolk Tour, or Travellers pocket companion'*. Private Press.

Bell, E., 1807. *'Antiquities of Norfolk'*. Private Press.

Britton & Brayley. 1812. *'A Topographical and Historical Description of the County of Norfolk'*. London

Brooks, P., 2007. '*The Norfolk Almanac of Disasters'*. Breedon Book Publishing Company. Chippenham. United Kingdom.

Brooks, SM. 2010. *Coastal changes in historic times – linking offshore bathymetry changes and cliff recession in Suffolk* . The Crown Estate

Brown, N. and Glazebrook, J. (eds). 2000. *Research and Archaeology: a Framework for the Eastern Counties. 2. Research agenda and strategy*. East Anglian Archaeology Occasional Paper No.8.

Collins, I., 2005. *'Making waves – Artists in Southwold'*. Black Dog Books, Norwich.

Daniell, W. & Ayton, R., 1814. *'A Voyage Round Great Britain'*. Private Press. London.

Defra, 2007. '*Environment Agency Strategic Overview for Flood and Coastal Erosion Risk Management*'. Crown Copyright.

Dixon, R., 1811. *'Sketches illustrative of picturesque scenery in Norfolk'*. Norwich

East Anglia Coastal Group, 2013. 'Coastal Monitoring'. From EACG website: www.eacg.org.uk

Ellis, A. (Ed.), 2005. *'Oil paintings in public ownership in Suffolk'*. The Public Catalogue Foundation.

Ellis, A. (Ed.), 2006. *'Oil paintings in public ownership in Norfolk'*. The Public Catalogue Foundation.

Environment Agency. 2011. *'Coastal Trends Report – Suffolk'*. RP022/S/2011

Environment Agency, 2013. *'Coastal Trends report for North-East Norfolk and North Suffolk'*. RP033/N/2013.

Ewing, W., 1842. *'The Norfolk topographer's manual'*. Revised from the original by Samuel Woodward.

Finden, E. & Finden, W., 1838. *'Views of the Ports, Harbours and Watering Places of Great Britain'*. Virtue & Co. London.

Glazebrook, J (ed). 1997. *Research and Archaeology: a Framework for the Eastern Counties, 1. Resource assessment*. East Anglian Archaeology Occassional Paper No.3.

Good, C & Plouviez, J. 2007. Archaeological Service Report; The Archaeology of the Suffolk Coast. Suffolk County Council.

Graves, A., 1901. 'A dictionary of artists who have exhibited works at the principal London exhibitions from 1760-1893'. Kingsmead Press. Bath.

Hegarty, C & Newsome, S. 2005. The Archaeology of the Suffolk Coast and Inter-tidal Zone; A report for the National Mapping Programme.

Hemingway, A., 1979. *'The Norwich School of Painters'*. Phaidon Press. Oxford.

Lambert, J.N. and Jennings, J.N. 1960. *The Making of the Broads*. Memoirs of the Royal Geographical Society **3**.

Lambourne, L. & Hamilton, A. J., 1980. 'British watercolours in the Victoria and Albert Museum'. Crown copyright. London.

Lee, JR. Rose, J. Candy, I. Barendregt, RW. 2006. Sea-level changes, river activity, soil development and glaciation around the western margins of the southern North Sea Basin during the Early and early Middle Pleistocene: evidence from Pakefield, Suffolk, UK. *Quaternary Studies* 21(ii), 155-217

Lound, T. & Ninham, H., 1831. *'Etchings of views in Norfolk'*.

Lucy, S. Tipper, J. Dickens, A. 2009. *The Anglo-Saxon Settlement and Cemetery ay Bloodmoor Hill, Carlton Colville, Suffolk.* East Anglian Archaeology 131.

MacKenzie, I. 1987. 'British prints'. Antique Collector's Club. Woodbridge.

Mallalieu, H., 1984. 'The dictionary of British watercolourists up to 1920'. Antique Collector's Club. Woodbridge.

McInnes, R. & Stubbings, H., 2010. '*Art as a tool to Support Understanding of Coastal Change in East Anglia'.* The Crown Estate. ISBN:978-1-906410-10-0.

Medlycott, M (ed). 2011. Research and Archaeology Revisited :a revised framework for the East of England. East Anglian Archaeology Occassional Paper No. 24 ALGAO East of England.

Munn, G., 2006. *'Southwold – An earthly paradise'*. Antique Collector's Club. Woodbridge.

Newton, I., 2005. *'Painting on the edge – British coastal art colonies'* (1880-1930). Sansom & Co. Bristol.

North Norfolk District Council, 2011. *'Coastal Pathfinder Project'.* Supported by Defra.

North Norfolk District Council, 2012. *'The North Norfolk Defra Coastal Pathfinder project.*

Oliver, R., 1996. Taking to the water: some examples of OS mapping of the coast. Sheetlines 45, 9-27.

Parfitt, S.A. et al. 2005. The earliest record of human activity in northern Europe. *Nature* 438, 1008-1012.

Parfitt, S.A. Pitts, M. Stuart, T. Stringer, C. Preece, R. 2006. *700,000 years old: found in Suffolk.* British Archaeology: Online http://www.archaeologyuk.org/ba/ba86/feat1.shtml

Parkin, Rev. C., 1799. *'A new and complete history of Norfolk'*. Norwich.

Rajnai, M., 1976. '*The Norwich Society of Artists'*. Norwich Museums Service for the Paul Mellon Centre.

Royal Haskoning, 2009. '*Lowestoft to Felixstowe SMP2'.* Lead Authority: Suffolk Coastal District Council.

Russell, R., 1979. 'Guide to British topographical prints'. David and Charles. Newton Abbot.

Sear, D. Murdock, A. LeBas, T. Baggaley, P. Gubbins, G. 2013. *5883 Dunwich, Suffolk: Mapping and assessing the inundated Medieval town*.

Scott, R., 2002. *'Artists at Walberswick'*. Art Dictionaries Ltd. Bristol.

Stark, J., 1828/34. *'Scenery of the rivers of Norfolk'*. Norwich.

Suffolk Coastal District Council. 2010. *'First Review of Shoreline Management Plan'*. SMP7. Lowestoft Ness to Felixstowe Landguard Point.

Turner, D., 1838. *'Etchings of views in Norfolk'* by the late J. Crome. Norwich.

Unknown Authors, up to 1154. '*The Anglo-Saxon Chronicles'.* British Library and elsewhere

Walpole, J., 1997. *'Art and artists of the Norwich School'*. Antique Collector's Club. Woodbridge.

Walpole, J., 2009. *'Suffolk artists of the eighteenth and nineteenth centuries'*. Antique Collector's Club. Woodbridge.

Wessex Archaeology, 2008. Seabed Prehistory: Gauging the Effects of Marine Aggregate Dredging Final Report/ Vol VII Happisburgh and Pakefield Exposures Ref: 57422.37.

White, E., 1607. '*A True Report of Certain Wonderfull Overflowings of Waters, now lately in Summerset-shire, Norfolk and Other Places In England*'. Norfolk Heritage Centre.

Wood, C., 1978. 'The dictionary of Victorian painters'. (2nd Edition). Antique Collector's Club. Woodbridge.

Wymer, J. and Robins, P. 2006. Happisburgh and Pakefield. *Current Archaeology* 201, 458-67.

CASE STUDY 3B – KENT, UK

Case Study Area: Kent, UK

Main geomorphological types: Soft cliffs, shingle and sandy beaches.

Main coastal change processes: Coastal erosion, cliff instability, flooding and breaching.

Primary resources used: Art, Archaeology.

Summary: The study site includes the weak sandstone and chalk cliffs of the Isle of Thanet at Reculver and Pegwell Bay to the north, and barrier beaches at Deal and Walmer on the east coast. To the south there are unstable weaker cliffs at Folkestone. Art resources have been used to see the rate and scale of change over the past 200-300 years, and the archaeological resource has been used to look further back at change since the last Ice Age.

Recommendations: Coastal managers should use these resources when predicting future rates of coastal change as they provide hundreds of years' worth of data to assist in the understanding of the rate and scale of change. Further work into historic maps and charts as well as photographs is recommended as this can provide even more detail particularly from the 19th Century.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the technical report on the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

Kent is one of six UK case study areas for the Arch-Manche project. This report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented along with the results of the art study. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then ourlined. Further detail of the project methodology is available in Section 2.

Within the Kent area the archaeological and palaeoenvironmental resource and the available art resource have been researched, ranked and analysed. The extents of the detailed study areas are shown in Figure 3B1 below. The area considered for archaeology and palaeoenvironment has been selected to provide a representative range of types of evidence across time spanning from the Palaeolithic through to more modern coastal heritage. The art, photograph and map case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time.

Figure 3B1. Map of the Kent study areas, the archaeological area is shown in red and the art area in blue.

3B.1 Introduction to the Kent Study Area

The archaeological study area of Kent runs along the eastern coast of the county, from Margate in the north, to Dover in the south. It incorporates the major settlements of Broadstairs, Ramsgate and Deal, and the most easterly point of the county at North Foreland. In the north, the study area covers the historic Isle of Thanet, which is characterised by steep low level cliffs and small sandy bays. Settlements continue up to the seafront in Margate. South of Ramsgate, the River Stour enters Pegwell Bay is a generally lower lying siltier basin area from which a narrow beach runs along the coast as far south as Kingsdown. Here the chalk ridge that runs along the south of the country rises up to form the White Cliffs of Dover.

The art study site extends from the historic ruin of Reculver Church, to the east of Herne Bay on the North Kent coast, eastwards, past the seaside resorts of Margate, Broadstairs and Ramsgate, and south from Pegwell Bay, past Deal and Dover, to the southern boundary of the site at Folkestone; a total distance of approximately 80km (50 miles). The site is located entirely in the County of Kent in the south-east of England, and is bounded on the north by the mouth of the River Thames, to the east by the North Sea, and to the south by the Straits of Dover. The coastline of the study area is predominantly composed of chalk, for which its White Cliffs are particularly famous, although there are also outcrops of sands and clays, which over-lie the extensive deposits of the chalk within an area known as the Weald of Kent.

The north western end of the study site is marked by the famous ruin of St Mary's Church at Reculver, which is the principal landmark along a 10 mile (16km) stretch of coast between Herne Bay and Margate; this is the first art case study location to be considered (B1). Passing the open coastline of Minnis Bay, one reaches Westgate-on-Sea and then the popular seaside resort of Margate, which forms the second art case study site (B2). Rounding North Foreland, the coast runs south past the resort of Broadstairs and Ramsgate, to the south of which is situated Pegwell Bay. At Pegwell Bay the important Pre-Raphaelite artist, William Dyce (1806-1864), painted an iconic view and this location forms art case study B3.

South from Ramsgate, past Pegwell Bay, the extensive Sandwich Flats and the golf links lead down towards Deal, with its fine castle built by King Henry VIII in 1540, and shaped like a Tudor rose. The coastal scene at this location was painted by William Daniell in the early nineteenth century, and forms art case study B4 (Daniell and Ayton, 1814). Just to the south of Deal a further fortification, Walmer Castle, also built during the reign of Henry VIII, forms art case study B5. From Walmer, the coast continues southwards towards the entrance to the Straits of Dover, and then past the port of Dover, before reaching the southern boundary of the East Kent study site at Folkestone, which represents art case study B6 (see Section 3B.5.3 Art Field Data Gathering Results).

3B.1.1 Geology and Geomorphology of the Area

Kent is the most south easterly county in England, being bounded by sea on three sides. It is located just 21 miles (30km) from the coast of continental Europe and is separated by the Straits of Dover. The main physical features of this region are determined by a series of ridges running west to east across the County that are the relics of the 'Wealden Dome', a denuded anticline, which stretches across the County and which resulted from the mountain-building of the Alpine Orogeny, when its outer ripples caused the formation of the Paris Basin, the Weald and the Hampshire-Dieppe Basin; these movements occurred between ten and twenty million years ago.

The Wealden Dome was formed of a layer of chalk, which overlies earlier deposits of the Upper Greensand, the Gault Clay, the Lower Greensand, the Wealden Clay, and the Hastings Beds. The top of the dome was eventually eroded away, leaving weathered ridges or valleys depending on the durability of the strata, and exposing them further to the processes of weathering and erosion. The North Kent coastline at the west end of the study area sees outcrops of London Clay and then, moving eastwards, the Thanet Beds, before reaching the chalk which extends round the headland between Margate and Pegwell Bay. To the south of this, a further outcrop of the Thanet Beds can be seen extending down past Sandwich towards Deal, whereupon the main outcrop of the chalk occurs round past Dover towards Folkestone.

The eastern part of the Wealden Dome was lost as a result of coastal erosion, and the White Cliffs that can be seen at Dover outcrop at the point where the North Downs meet the coast. The coastline of Kent is changing continuously due to coastal erosion, which leads to cliff falls, coastal instability problems, and longshore drift transports beach material round the coast. Most of the coastline has been designated on account of its nature conservation interest and, except in those locations where significant development has taken place, a policy of allowing continued erosion of the clifflines is encouraged to support biodiversity. Most of the conservation designations also recognise the earth heritage (geological and geomorphological) importance of the cliff features.

There are also important geomorphological features within the littoral and sub-littoral chalk zones, which support key marine communities. The preferred policy of allowing cliff retreat on the chalk cliff frontages should provide for continued exposure of chalk platforms as the cliff retreats in response to sea level rise. Shingle beaches along part of the frontage are also important on account of their nature conservation and geological significance.

Historically the area of Thanet, around the towns of Margate and Ramsgate, was an island, separated from the mainland by the rivers Wanstum and Stour. Approximately 1,000 years ago, silting of the Wanstum blocked its mouth and today it is little more than a drain. The River Stour, which used to open into the sea in a considerable channel, also began to silt up approximately 1,200 years ago. Land reclamation in the Post Medieval period caused the development of a spit and an increase in sediment in the area of Pegwell Bay, which eventually closed the channel off so that the river exits into the sea in a narrow channel through mudflats and marsh (Wessex Archaeology, 2011: 39). The coast west and south of Thanet has extended by some two miles in the last 100 years.

3B.1.2 Summary of the Archaeology and History of the Kent Study Area

The majority of settlements in the north of the study area were originally centred on mills and fishing harbours. Urbanisation has absorbed most of these settlements so that a near continuous urban area runs around the coast as far as Pegwell Bay. Inland, agriculture activity appears to have been taking place since the Bronze Age. To the south, Sandwich was an important Medieval port, whilst inland Richborough and smaller settlements along the River Stour have Roman origins. Roman roads follow the edges of the river's flooplains.

The southern part of the study area is the closest part of the isle of Great Britain to mainland Europe and as such has an extensive history of maritime trade and military defences. Dover may have been in use as a port since the Bronze Age and flourished in the Roman period. During the Medieval period it was one of the Confederation of Cinque ports, along with Sandwich, allowing it special rights and near guaranteeing it extensive trade.

The proximity to France has also necessitated defences – some of which were centred on the defence of the ports. Dover Castle was constructed in the 12th century, whilst to the north, Deal and Walmer castles were constructed during the reign of King Henry VIII. The area was further fortified in the 19th century and heavily reinforced during the World Wars, particularly in the Second World War.

Early Prehistory (Palaeolithic and Mesolithic)

Throughout the Lower and Middle Palaeolithic periods, Kent was part of a larger landmass that connected the present day British Isles to mainland Europe, and the coastline that we know today did not exist. A number of finds in the form of handaxes suggest that early humans (likely *Homo Heidelbergensis*) were in the area, possibly migrating across the landscape between ice ages. With the beginning of the Upper Palaeolithic and the arrival of anatomically modern humans (*Homo Sapiens Sapiens)* in around 40,000 BC, some of the earliest archaeological evidence of settlement is found in the study area. There are two possible sites on the Isle of Thanet, both identified by flint scatters (The Museum of Thanet's Archaeology). Further south two other flint scatter sites may similarly indicate working sites (HER).

Further inland a number of Mesolithic occupation sites have been identified, such as a cave system in Royal Tunbridge Wells (Kent County Council). In the study area however, Mesolithic records are patchy and no features have been accurately dated to the period. A number of prehistoric cropmarks and some earthworks have been identified, but they cannot be reliably dated and are generally believed to be from later prehistory (HER). A number of findspots of a variety of flint tools demonstrate a presence; within the study area these mainly take the form of flint axeheads. A macehead was also discovered on the north coast of the Isle of Thanet (Lawson & Killingray, 2004: 9).

Neolithic, Bronze Age and Iron Age

As prehistoric peoples became more sedentary in the Neolithic period, a number of new forms of archaeological evidence become apparent in the study area. Several sites, including a hearth, pits, stakeholes and enclosures have been identified. A number of burials also exist in the area of Thanet and cropmarks suggest a number of Long Barrows may have once existed in the area (although none of the sites are confirmed) (The Museum of Thanet's Archaeology). A possible causewayed enclosure at Ramsgate (HER) and another just inland of the study area near Tilmanstone (Lawson & Killingray, 2004: 11) may represent the earliest examples of monuments in the study area. Numerous Neolithic pottery and flint axes findspots may also suggest habitation sites (Lawson & Killingray, 2004: 11).

The archaeological record suggests that settlements were more numerous in the Bronze Age. This is supported by the increased number of burials (some 25 such sites or cemeteries are present in the study area) as well as an increase in finds and other indications of usage. Thanet appears to have been an area of some importance in the newly evolving metal working industry, particularly by the late Bronze Age (Lawson & Killingray, 2004: 14). Some evidence of field systems and enclosures suggest possible occupation sites at Thanet, Deal and further inland towards Canterbury (Wessex Archaeology, 2011: 43). The site of Thanet, at South Dumpton Down, may represent one of the first defended settlements in the country (Lawson & Killingray, 2004: 15). Plant remains found at Guston near Dover show that the crop emmer was cultivated in the area throughout the first millennium BC. A Bronze Age boat, discovered in Dover in 1992 and dating to approximately 1600BC, is the largest prehistoric artefact known in Kent and is argued to suggest possible maritime trade with Europe (Williams, 2007: 97). This is further supported by the import of gold into Kent, the scatter of bronze artefacts found on the seabed in Langdon Bay and the similarity of many European bronze artefacts to those found in Kent (Williams, 2007: 114).

By contrast, there is somewhat less evidence of early Iron Age settlement in Kent. Bronze Age field systems and settlements show little sign of subsequent re-use and there are significantly fewer identified Iron Age sites than Bronze Age (Williams, 2007: 102). There are few hillforts from the early Iron Age period; one potential site near Worth and one near the Bronze Age defended settlement at Dumpton on Thanet (Lawson & Killingray, 2004: 17). Only one fort from the late Iron Age can be found in the study area; an unverified camp under Dover Castle (William, 2007: 119). In the later Iron Age other settlement sites are more prominent and better recorded. Settlement is relatively dense along the north coast of Kent and Canterbury appears to have become a site of some economic importance, although it was most likely still a collection of separate settlements rather than a formally laid out town (Williams, 2007: 121). The Late Iron Age also sees more formal trade taking place with Europe and the introduction of new cultural values (such as hygiene, burial styles and fashion) recognisable in the archaeological record. The county was the seat of power of the Cantiaci (or Cantii) tribe (this tribe probably gave their name to the Roman title of Cantium, which later became Kent (Williams, 2007: 138)). Although little is known about the political relations with Gaul, there appears to have been trade with the Roman Empire and it is suggested that a Gaulish leader claimed sovereignty over much of Kent (Williams, 2007: 130).

Roman Period

Richborough, which was an island surrounded by sea on three sides during the Roman era, is widely believed to be the site of the earliest Roman landings in AD43. The presence of 1st century ditches there suggests an attempt to secure a beachhead before expanding into the south east of England. The site developed into a civilian settlement of some size, including temples, amphitheatres and numerous dwellings. A large (25 metre high) arch was constructed on the main road to London and a port was developed on the River Stour which, along with Dover port to the south, became a major trading port (Kent County Council). A fort was established at Dover to provide safe anchorage for the Roman Navy. In the 3rd century a number of so-called Saxon Shore forts were constructed around the south east coast to defend against Saxon raiders. Both Richborough and Dover were reinforced in this way, the Dover fort replacing the earlier 1st century fort.

This activity has left extensive archaeological evidence in the study area. Of two lighthouses built on the heights above Dover, one remains extant in the grounds of Dover Castle (archaeological evidence of the other also remains). Extensive remains of the fort exist in the grounds of buildings and were preserved underneath the A256 bypass when it was built. Extensive remains of Richborough fort are also extant, although the silting up of the channel means that some sections of wall that originally abutted the coast are now two miles inland. The HER records more than 550 individual Roman era findspots in the study area, seven separate settlement sites, numerous cemeteries and burials, farmsteads and an aqueduct.

Medieval Period
A number of different types of earthworks within the study area can be dated to the Medieval period. These include holloways and trackways, field boundaries, early examples of ridge and furrow farming, square and circular enclosures and defensive structures (Wessex Archaeology, 2011: 45).

Agriculture appears to have become more formalised during the Medieval period, with a number of field systems that were likely defined by earthen banks and ditches. These are particularly evident around the River Stour and Richborough. Additionally almost 200 hay stack stands; raised circular earthworks used to store hay above the floodplain) were mapped as part of the Rapid Coastal Zone Assessment (RCZA). Again, the majority of these are congregated around the River Stour (Wessex Archaeology, 2011: 45). Salt was another growing industry around the Kent coast, and saltmounds frequently appear in the study area. The mounds, used in a similar way to Haystacks, sometimes survive as extant monuments, or more commonly as cropmarks. Many salt houses and other agricultural buildings were listed in the Domesday book, and evidence for some of these timber structures can still be found in roof timbers. Monastic granges and tithe barns also survive. A large number of enclosures also attest to the growth in agriculture in this period.

A number of buildings from the Saxon era survive only as cropmarks. More prevalent are a number of cemeteries on Thanet, first discovered in the 18th and 19th centuries, which may represent a small part of much larger burial areas that date to the Saxon era (The Museum of Thanet's Archaeology). A motte and bailey castle built near to the site of Richborough Roman fort most likely dates to the period after the Norman Conquest, although it has not been reliably dated (Small, 2002: 21). Similarly, it is likely that an early motte and baily castle was built at Dover during King William's reign. Nearby on Thanet, several churches date to the Norman period and are testament to the rising influence of the church in Kent and across the country (The Museum of Thanet's Archaeology).

The establishment of the Cinque Ports in 1155 AD was extremely beneficial to two ports within the study area; Dover and Sandwich. The Cinque Ports were required to be on hand for military action in the event of a war and in return received generous tax exemptions and trading rights. With these privileges both ports flourished, as did their subsidiary (or 'limb') ports. Ringwould, Margate, Broadstairs, Birchington, Ramsgate, Sarre, Reculver, Stonar and Deal all served as limbs of Sandwich and Dover (Lawson & Killingray, 2004: 52).

The Medieval period would also mark the end of some of these ports. Gradual land reclamation and natural silting of the Wantstum Channel meant that by the end of the 15th century, the channel was no longer navigable to shipping. Eventually the Isle of Thanet would become part of mainland Britain and the historic ports of Richborough, Sarre, Stonar and Sandwich were no longer accessible to ships. Archaeological evidence of some of the sea defences built to reclaim land still remain extant today, including the Monk's Wall north of Sandwich, an earthen wall that created local conflict when built in the 13th century, as it accelerated the silting of the channel (The Museum of Thanet's Archaeology).

The ports also required defending and Dover Castle was substantially reinforced in the 12th century as a stone keep. Inner and outer baileys were also built, turning the castle into one of the most reinforced sites in the country. This strength meant that Louis VIII of France was unable to take the castle despite a three month siege in 1216AD (Dover Town Council).

Post-Medieval Period

As in the Medieval period, agriculture continued to play an important role in the region and several earthworks are likely date to the Post-Medieval period. Additionally, it is highly likely that many Medieval features continued to be used well into the Post-Medieval period. By the 17th century the county was covered in small field enclosures and agriculture dominated the landscape (Lawson & Killingray, 2004: 70). This increased the prosperity of the market towns; most were inland but within the study area Margate evolved as a market town (Lawson & Killingray, 2004: 66).

Urban growth in Kent increased rapidly and by the end of the 16th century, over one third of the county's population lived in towns (Lawson & Killingray, 2004: 70). Both Sandwich and Dover had populations of approximately 4,000 people each, compared to Canterbury (the largest town in Kent) which had 5,000 people (Lawson & Killingray, 2004: 66). Of England's seventy towns with over 2,000 inhabitants, ten were in Kent (Lawson & Killingray, 2004: 70). Inland, new industries stimulated this growth, but on the coast it was maritime trade that continued to benefit the towns. Despite the silting of its harbour, Sandwich was able to maintain trade links with the Baltic and Low Countries up to the 17th century, but Dover soon expanded to become the South-East's principal cross-channel port (Lawson & Killingray, 2004: 67). Hythe, to the south west of the study area was the next most prosperous, but Folkstone, Ramsgate and Margate also saw trade and benefitted from the fishing industry. By the dawn of the 18th century Margate and Ramsgate had surpassed all other ports in Kent and saw by far the greatest proportion of shipping traffic in their harbours (Lawson & Killingray, 2004: 91).

Both Dover and Langdon priories were dissolved by Henry VIII in the 16th century (Lawson & Killingray, 2004: 80). As was the case at many of the other dissolved monasteries around the country, it is possible that stone from the buildings was re-used in coastal defences built in the period between 1539 and 1545. As hostilities with Europe increased (due in part to Henry's break from the Roman church), defence became an important issue on the Kent coast and the sheltered anchorage of the Goodwin Sands. Three 'Device Forts' – large stone artillery castles – were built along a 2.6 mile stretch of coast, at Deal, Sandown and Walmer (Lawson & Killingray, 2004: 92). An earthen rampart and three earth artillery positions linked the three forts (Pastscape). Sandown, the smallest of the forts, was slowly eroded by the sea; by 1785 the moat had been breached by the sea. The fort was repaired in 1808 but by 1882 it had been almost completely demolished. Today only the foundations remain; likewise, the earthen rampart has been totally removed (Pastscape). Dover Castle was substantially reinforced during the reign of Henry VIII, with the addition of a moat bulwark. Further massive expansion took place at the end of the 18th century; large bastions were added to the outer defences. A substantial redoubt – the Dover Western Heights – was constructed on the other side of Dover (just outside of the study area) and Dover became a garrison town during the Napoleonic Wars (Lawson & Killingray, 2004: 136).

Both Dover and Ramsgate ports were completed in their modern form in the late 18th and early 19th centuries. This further improved their prosperity, whist north shore towns like Margate and Whitstable grew as seaside resorts, aided by the development of steamships and railways. In 1854, Deal and Sandwich ceased port operations, but Ramsgate became one of the major modern ports (along with Dover and Folkstone) (Lawson & Killingray, 2004: 129).

Modern

A considerable number of coastal features dating to this period are military coastal defences established during the World Wars. The proximity to the European coast means that a wide range of military sites were constructed in the study area, ranging from anti-invasion constructions, coastal defence, passive and active anti-aircraft defences and airfields.

In addition to a seaplane base in Dover, of which some buildings still survived in 1997, a number of grass airstrips were established in the study area during the First World War; four were at Thanet, one at Walmer and another near Dover (Lawson & Killingray, 2004: 141). One of the Thanet airfields was RAF Manston, which was used in both the First and Second World Wars. Its location meant that aircraft based there took part in many notable engagements during the wars and was the base of the first RAF jet fighter squadron. After the war it became a civil airfield, however, this continued re-use means that little of the original airfield infrastructure survives.

Between the wars, two sound mirrors (an early form of aircraft detection) were built at Fan Bay near Dover, and Joss Gap at Thanet. The Fan Bay mirrors were buried by Kent Council after the Second World War and may still survive in the Cliffside (Burridge, 1997: 24).

Between Birchington and Hythe a near continuous line of anti-invasion, anti-aircraft and coastal defence was constructed during the Second World War, a great deal of which still survives today. Numerous pillboxes of different designs were constructed on the waterfront and inland to counter possible invasions (the HER records well in excess of 100 pillboxes in the study area). Coastal batteries of different sizes were built, in many instances adjacent to, or on the site of existing coastal defences (such as the Tudor forts). Although many of these defences survive, the majority are in a state of dilapidation. A radar station at Dover was an early target during the Battle of Britain, but remained in service throughout the war (Lawson & Killingray, 2004: 142).

The vast majority of the wrecks within the study area date to the modern period. Most of these are ships sunk as a result of military action during the world wars (HER), although there are some exceptions. A pair of hulks sunk on the eastern shore of the River Stour may have been placed to prevent coastal erosion (Wessex Archaeology, 2011: 48).

3B.1.3 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for the Project

In researching the archaeology, palaeoenvironment and coastal heritage of the east Kent coast, a number of existing databases, archives and publications were consulted. Authoritative general histories of Kent were provided by An Historical Atlas of Kent (edited by Terence Lawson and David Killingray) and The Archaeology of Kent to AD 800 (edited by John Williams). These two texts, along with an online archive of material from the Museum of Thanet's Archaeology (maintained by the Trust for Thanet Archaeology), provided much information on the background history and archaeology of Kent.

East Kent has benefitted from a Rapid Coastal Zone Assessment (RCZA) Survey that has been informed by the National Mapping Programme. English Heritage have recognised that there is a lack of understanding of the archaeology of the nation's coastal areas and that the historic environment needs to be integrated into coastal management schemes. The result is a series of RCZAs that have been commissioned along the English coast. The Kent RCZA has drawn preliminary data from the National Mapping Programme, a project that seeks to enhance knowledge of particular areas by assessing a wide range of aerial information (including historic and modern aerial photography, Lidar data and other similar materials such as historic maps) in order to identify previously unrecorded sites. This has provided information on a wide range of newly identified sites in the study area that have helped confirm the understanding of the area's history so far gathered from other sources.

Other specialist sites were researched with the aid of the county Historic Environment Record and the National Monument Record (via Pastscape). These are useful sources to track the history of a site over a long period of time. Researching 20th century military heritage sites in Britain has been made substantially easier by the Council for British Archaeology's Defence of Britain project (CBA 2006). Along the east Kent coast this has catalogued many dozens of sites that were not previously recognised, including temporary positions that left little or no remains immediately after the war. Although the levels of recording undertaken at sites differed in detail, Kent appears to have been very well researched, a fact borne out by the publication of a book (20th Century Defences in Britain: Kent) using the data gathered.

3B.1.4 Art History of the Area

One of the earliest and finest topographical paintings of the region was a '*View of Dover*' by Richard Wilson RA (1714-1782), a founder member of the Royal Academy. This work marked the start of a long tradition of coastal landscape art in south east England. Although 'schools' of artists did not develop around the Kent coastline as on the East Anglian and Cornish coasts, the region has a rich resource in terms of landscape paintings, watercolour drawings and illustrated topographical books. In the early 1820s William Daniell included numerous delicate aquatints of the Kent coast in his *'Voyage Round Great Britain'* (Daniell & Ayton, 1814).

After visiting Margate, Broadstairs, Ramsgate and the fortifications at Deal and Walmer Castle Daniell produced detailed depictions of the expanding ports and resorts including Dover and Folkestone. J.M.W. Turner was also working along the Kent coastline in the early nineteenth century producing watercolours for inclusion in '*Picturesque Views of the Southern Coast of England'* (Cooke, 1826). Over this period he painted at Margate, Ramsgate, Whitstable, Dover, Folkestone, Deal and Hythe in Kent. Later, the Finden Brothers also passed along this coast, whilst preparing their two volume *'Ports, Harbours, Watering Places and Picturesque Scenery of Great Britain*' (Finden & Finden, 1838), which contained steel plate engravings of the expanding coastal towns. James Baker Pyne RBA (1800-1870) also visited the North Kent coast painting two large oils of '*Whitstable Sands with Women Shrimping*' and '*Sunset on Whitstable Sands*' in 1847. Pyne was a self-taught artist and these two works show that he was a great admirer of Turner, who had also painted there. Pyne's views show one of the many Martello Towers built along this part of the English coast as protection against Napoleonic invasion.

At Margate on the northern tip of the Isle of Thanet, Thomas Rowlandson painted a view of the harbour wall and town from the sea in the mid-1780s. He painted there again in 1800 as the town was a subject for the artist when Ackermann published an engraving entitled '*The Pleasures of Margate*' after his drawing. John Rubens Smith painted a '*Panoramic View of Ramsgate, Kent'* in 1802 whilst, later, James Webb painted '*A View of Margate from the Pier'*

(1868). William Parrott painted '*No-Man's-Land, Margate*' in 1869; an attractive oil showing the indented chalk cliffline with the town behind.

Nearby, at Pegwell Bay close to Ramsgate on the east coast of Kent, the Pre-Raphaelite artist, William Dyce RA HRSA (1806-1864), painted his celebrated view of the Bay in 1858, illustrating the chalk cliffline, and the beach in minute detail. Later, Thomas Bush Hardy RBA (1842-1897) painted one of his best watercolours there entitled '*Shipping off Ramsgate*', whilst just to the north the marine and coastal artist, John Callow (1822-1878), painted '*A Breezy Morning at Broadstairs'*. A visit to the resort of Ramsgate provided the inspiration, in 1851, for the major work by William Powell Frith RA (1819-1909) '*Ramsgate Sands - Life at the Seaside'* (1854), which was exhibited at the RA in 1854 and was purchased by Queen Victoria. The town was also painted in watercolour by the landscape artist and engraver, Robert Brandard (1805-1862) in 1854. At Deal, Anthony Vandyke Copley Fielding POWS (1787-1855) followed in Daniell's footsteps and painted a watercolour looking northwards along the beach towards the castle with a fishing boat in the foreground. Just to the south at Walmer Castle, also located adjacent to the beach, the foreshore was painted by James Holland OWS (1800-1870) in 1850 and by Henry Pether (c.1801-1880) two years later.

The waters around the Kent coastline and the eastern English Channel, busy with shipping, provided subject matter for numerous artists. Marine painters Clarkson Stanfield RA (1793-1867), Anthony Vandyke Copley Fielding POWS (1787-1855), Dominic Serres RA (1722-1793), Nicholas Pocock OWS (1740-1821), Nicholas Condy (1793-1857) and Robert Cleveley (1747-1809) all painted views in the vicinity of Deal and off Dover. On land the early landscape and architectural watercolourist John Varley OWS (1778-1842) painted '*Cornfields at Folkestone*' (c.1820s), whilst Thomas Charles Leeson Rowbotham RI (1823-1875) painted the cliff-top scenery at Dover. Frederick William Watts (1800-1862) painted a fine pair of views of '*Dover Castle*' from Shakespeare Cliff and from above the town showing the militia marching up the steep hill towards the castle.

The Kentish chalk cliffs were a favourite location for the animal painter Thomas Sidney Cooper RA (1803-1902) with groups of cattle often depicted adjacent to the cliff edge thus allowing the beach and the sea to add to the composition. Another artist painting on the south Kent coast was Henry Pether whose '*Sandgate Castle near Folkestone'* looks along the coastline and out to sea by moonlight.

As the Kent coastal resorts expanded, the demand for high quality views, in the form of both paintings and also illustrated guide books, led to an influx of artists, whilst, later, on the introduction of colour picture postcards, artists such as Alfred Robert Quinton were commissioned to produce views of the coastal towns in the early twentieth century. Some of these views are remarkable for the detail they provide in terms of the sea fronts, coast protection structures and beach conditions.

3B.1.5 Art Resources Consulted for the Project.

In order to establish the art resource available for this study it was necessary to review the topographical paintings, drawings and prints held by the principal national, region and local collections covering the Kent coastal frontages. To achieve this objective, online reviews were carried out of the collections held at national level within key museums and art galleries including the Tate Britain, the Victoria and Albert Museum, the National Maritime Museum, the British Museum, the National Gallery and the Witt Library at the Courtauld Institute in London.

In addition the research established the location of relevant artworks contained in museums and art galleries in Kent, including Canterbury City Council Museums & Galleries, Dover Collections, Folkestone Museum, Maidstone Museum & Bentlif Art Gallery, Turner Contemporary - Margate, Margate Old Town Local History Museum, Ramsgate Maritime Museum and others. As part of the research it was necessary to contact museum and gallery curators and search available publications, as well as undertaking research on the Internet, taking advantage of new facilities such as the Public Catalogue's Foundation volume (Ellis, 2004) and the BBC *Your Paintings* website.

Additionally an assessment was been made of art from the study area contained in important publications and, in particular, catalogues of exhibitions at principal London galleries and also in Kent itself. The literature sources relating to works exhibited are comprehensive and comprise reviews of the artists and their works (eg. Graves, 1901), together with catalogues and dictionaries published by the museums themselves and interested publishers (e.g. the Antique Collectors' Club). The published works of this kind do, therefore, represent a considerable resource of assistance to this study (Wood, 1978; Russell, 1969; Archibald, 1980; Lambourne & Hamilton, 1980; Mallalieu, 1984; MacKenzie, 1987).

A brief review of historic maps was carried out, this involved an online search as well as downloading Ordnance Survey maps from the online service *Digimap.*

3B.2 Current Environmental Impacts, Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the Kent coastline and reviews the current coastal management issues and approaches.

3B.2.1 Review of Key Contributors to Coastal Change

The Kent coastline is extremely diverse, with dramatic white chalk cliffs, extensive lowlands and a mixture of large urban areas and agricultural land. There are also many designations along this coast for its heritage, landscape, geological and biological value including SPA's, Ramsar sites, SAC's, SSSI's and is an AONB. There are also many Scheduled Ancient Monuments, conservation areas and listed buildings.

As the coastline is extremely varied, there are a variety of contributors to coastal change. Generally the coast here is retreating, and the Shoreline Management Plans (SMPs) recognise that erosion and flooding is nothing new. A wealth of historical records demonstrate the loss of communities along the coast over the last few centuries and as such there is clear evidence of long-term natural change (South East Coastal Group, 2006, 2008). Although coastal change has been an ongoing process, the management of this has become increasingly difficult with climate change increasing the rate of sea level rise as well as the number and severity of storm events (South East Coastal Group, 2006, 2008).

As well as rising sea levels and erosion, the Kent coast also faces issues from limited natural input of sediment from offshore, partly due to development along the coast. Extensive areas of the coast have also been reclaimed for agriculture and development including the former Wantsum Channel. Erosion of the shoreline is well known and an ongoing process, however, alongside this the backshore, beach and nearshore zones are also changing with deepening of the seabed evidenced by narrower and steeper beaches. Defences may help slow down the retreating shoreline, but won't prevent lowering of the foreshore (South East Coastal Group, 2006, 2008).

The coastal defences which have been built on many of the Kent frontages mean that there are only limited sections which are free to erode therefore providing little material back into the shoreline system as beach building material. The construction of groynes also affects the alongshore transport of sand and shingle. These defences and groynes mean that much of the shoreline is generally ‘unnatural’, the extent of management along this coast means it would be very difficult to now revert to using natural evolution of the coast to manage the shoreline (South East Coastal Group, 2006, 2008).

3B.2.2 Summary of Current Coastal Management Approach

Coastal risk management issues within the East Kent coast study area have been considered in detail through a coordinated approach between Kent County Council, the coastal District and Borough Councils, which are the coast protection operating authorities, and the Environment Agency, together with other key stakeholders. For this frontage, two shoreline management plans (SMPs) have been completed, covering the coastline from the Isle of Grain at the mouth of the Thames Estuary, eastwards to South Foreland (South-East Coastal Group, 2008) and a second plan extending from South Foreland around the East Kent coast and westwards along the south coast as far as Beachy Head.

The shoreline management plans provide a broad-scale assessment of the risk associated with coastal processes, and present a policy framework to reduce the risks to people and the developed, historic and natural environments in a sustainable way. Beneath these over-arching shoreline management plans are coastal defence strategy studies a number of which have also been completed; they suggest how the SMP policies may be implemented in practice. This strategic approach has been coordinated by the South-East Coastal Group, one of a number of long established ‘regional coastal groups’ with a membership comprising local authorities, the Environment Agency, Natural England and other key organisations with a direct interest in coastal risk management.

This strategic approach is essential for a number of reasons. First, sea levels have risen in Kent by approximately 115mm over the last ten years, and 10% of Kent’s population is at risk from coastal flooding. Over 160,000 people live in zones at risk from coastal flooding, and this has led to a substantial investment in coast protection and flood defence works. The predicted impacts of climate change require a strategic approach that has been put in place by those involved in coastal risk management within the county.

Due to the diverse geology of the Kent coastline the key contributors to coastal change are varied and as such the SMPs in place are adapted for different locations. As defined by Defra (Halcrow, 2006) each policy unit is assessed and the generic policy options are;

- Advance the Line (ATL);
- Hold the Line (HTL);
- Managed Realignment (MR);
- No Active Intervention (NAI).

Areas like the Isle of Thanet which are dominated by cliffs currently have a policy of NAI in many sections where the erosion of the cliff is providing a sediment source for the beaches and no new defences will be built. However, in more low-lying areas further south from Cliffs End to Oldstairs Bay flood defences will be maintained as the nature of the landscape means that flooding could inundate thousands of hectares of land. Further details on the SMP’s can be found online at http://www.se-coastalgroup.org.uk/

3B.3 Archaeological and Palaeoenvironmental Ranking

This section outlines the results of the archaeological and palaeoenvironmental scoring from the Kent study area, followed by a discussion of the results. The scoring methodology applied is detailed in Section 2.

3B.3.1 Results of the Archaeological and Palaeoenvironmental Ranking

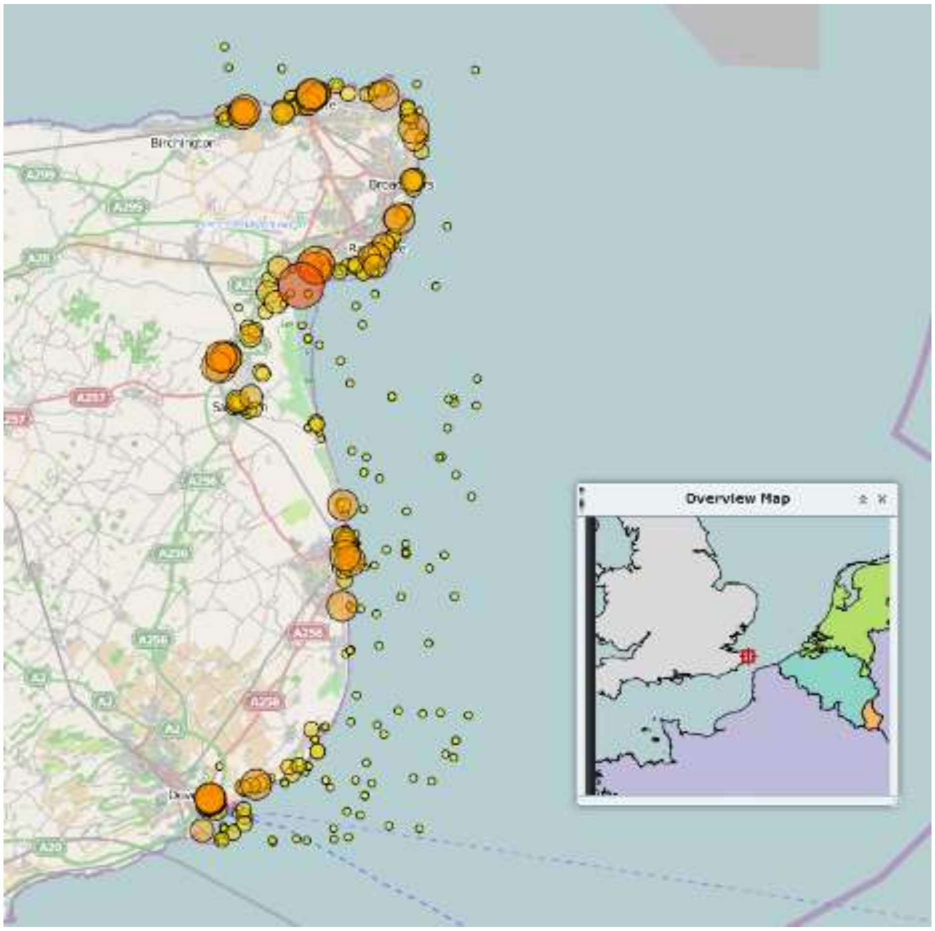

Figure 3B2. Map showing the distribution of archaeological and palaeoenvironmental sites within the Kent study area.

Within the Kent study area data was obtained from the local Historic Environment Record (HER), the National Record of the Historic Environment (NRHE), the United Kingdom Hydrographic Office (UKHO) and the English Heritage Peat Database. It should be noted that the data obtained from the HER was often limited, and where sites scored highly further research was then required in order to understand the full nature and extent of the site. Each data set went through a process of cleaning, in order to prevent the duplication of sites, this process is detailed further in the Methodology section. A total of 697 sites and records were assessed.

The highest scoring sites are listed in the table below, the total score has been normalised to give each site a score out of 100.

APE uid	Site Name	Site Type	Period	Score – Sea Level	Score – Environ mental	Score – Temporal Continuity	Total Score	Coastal Context
715	PEGWELL BAY – Submerged Forest	Submerged Landscape	Unknown	High	High	Medium	88	Hard Cliff
3029	DOVER - Castle	Coastal Defence	Medieval	Medium	Medium	High	77	Coastal
2563	WESTGATE ON SEA – Occupation Site	Monument	Early Medieval	Medium	Medium	Medium	66	Hard Cliff
2589	DEAL - Settlement	Monument	Bronze Age	Medium	Medium	Medium	66	Marine
2739	MARGATE – Settlement Remains	Monument	Iron Age	Medium	Medium	Medium	66	Hard Cliff
2745	DOVER - Hillfort	Monument	Iron Age	Medium	Medium	Medium	66	Marine
2747	MARGATE - Settlement	Monument	Iron Age	Medium	Medium	Medium	66	Marine
2748	MARGATE - Settlement	Monument	Iron Age	Medium	Medium	Medium	66	Marine
2750	BROADSTAIRS - Settlement	Monument	Iron Age	Medium	Medium	Medium	66	Hard Cliff
2776	DOVER - Settlement	Monument	Iron Age	Medium	Medium	Medium	66	Marine
2800	PEGWELL - Building	Monument	Medieval	Medium	Medium	Medium	66	Hard Cliff
2851	DOVER - Settlement	Monument	Early Medieval	Medium	Medium	Medium	66	Hard Cliff
2867	RICHBOROUGH - Castle		Unknown	Medium	Medium	Medium	66	Above high water
2883	MARGATE - Settlement	Monument	Roman	Medium	Medium	Medium	66	Hard Cliff
2884	RICHBOROUGH - Temple	Monument	Roman	Medium	Medium	Medium	66	Above high water
2911	BROADSTAIRS - Tower	Monument	Post Medieval	Medium	Medium	Medium	66	Intertidal
3001	RICHBOROUGH - Temple	Monument	Roman	Medium	Medium	Medium	66	Above high water
3030	RICHBOROUGH - Settlement	Monument	Roman	Medium	Medium	Medium	66	Above high water
3032	RICHBOROUGH - Amphitheatre	Monument	Roman	Medium	Medium	Medium	66	Above high water
3033	DEAL - Castle	Coastal Defence	Post Medieval	Medium	Medium	Medium	66	Marine
3034	DEAL – Sandown Castle	Coastal Defence	Post Medieval	Medium	Medium	Medium	66	Marine
3035	DEAL – Walmer Castle	Coastal Defence	Post Medieval	Medium	Medium	Medium	66	Marine

3036	MARGATE - Settlement	Other Find Spot	Iron Age	Medium	Medium	Medium	66	Hard Cliff
3044	RICHBOROUGH - Settlement	Monument	Iron Age	Medium	Medium	Medium	66	Above high water
3067	WRECK	Wreck	Bronze Age	Medium	Medium	Medium	66	Hard Cliff

Table 3B1. Ranking results showing the highest scoring archaeological and palaeoenvironmental sites within the Kent study area.

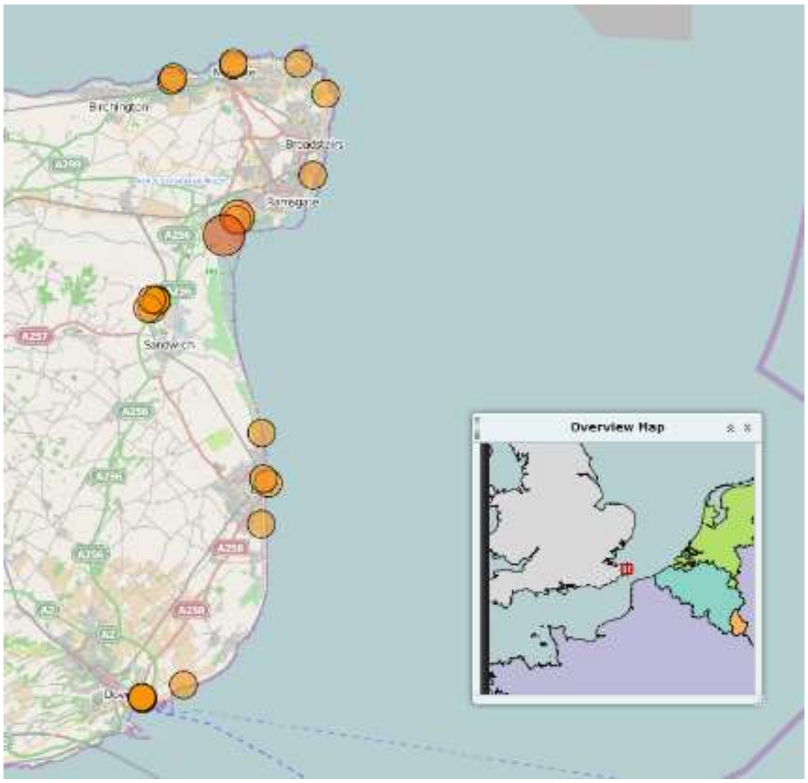

Figure 3B3. Map showing the distribution of highest ranking archaeological and palaeoenvironmental sites within the Kent study area.

Ranks for sea level change

	High	Medium	Low
Number of sites	1	148	548

Ranks for environmental change

	High	Medium	Low
Number of sites	1	31	665

Ranks for temporal continuity

	High	Medium	Low
Number of sites	0	102	595

Table 3B2. Results of the archaeological and palaeoenvironmental three ranking categories

3.3.2 Discussion of the Ranking Results

The majority of the sites that ranked highly in Kent, were either prehistoric settlement remains or military coastal defences, and are located around the major towns of Margate, Deal, Dover, and

Broadstairs.

The earliest of the coastal defences that scored highly is Dover Castle. Prior to the construction of a castle the site was originally an Iron Age hillfort, there is also evidence of Roman occupation with a Roman lighthouse dating from around 46-50 AD still relatively well preserved. A castle was later built by William the Conqueror and saw numerous reinforcements under Norman rule in the 12th century. Henry II built the medieval fortress which was maintained by his successors including Henry VIII in the 16thCentury, whose fortification of the southern coast of England also lead to the construction of Device Forts at Deal, Sandown and Walmer (Deal Castle and Walmer Castle are also depicted in historic artworks, see Section 3B5.3). The site was continuously occupied for nine centuries. Such dateable structures located on the coast can help improve our understanding of sea level and environmental change as associated geomorphological features can be monitored, they can also provide evidence of responses to changing climate.

Several sites which ranked highly are located in Richborough, although the site is now some distance from the sea, prior to the silting of the Wantsum Channel this area would have been at the southern end of the channel up until the early Medieval period and became an important natural harbour, its importance is demonstrated through the numerous Roman sites and finds in the area and is thought to have been the landing place of the Roman invasion. Such sites demonstrate that our coasts are not only affected by erosion and sea level rise, but also by siltation and gradual change.

Several Iron Age sites around Margate also ranked highly, this reflects their potential to provide information on sea level and environmental change as many have not been fully excavated. An Iron Age hillfort has been partially excavated, the site overlooks Margate harbour and finds suggest that the settlement was long lived.

Another of the high ranking sites is a submerged forest at Pegwell Bay. The peat deposits have been sampled however, there is currently no known date for the site. Further work is required in order to determine the nature and extent of this site to provide information on sea level and environmental change. Further prehistoric remains have ranked highly, several sites were recorded in the HER, again further work is required in order to understand the full nature and extent of these sites.

One possible wreck from the study area ranked highly, the site is located in Langdon Bay and includes over 350 bronze artefacts recovered from the seabed. It is thought that this may be the remains of a cargo vessel, although no vessel remains have been recovered. Based on the finds the site has been dated to around 1100BC and the items are thought to have originated from France. The site has been subject to systematic excavation, although affected by sediment from the construction of the Channel Tunnel the site has the potential to be used as a proxy against which sediment levels and changes in the coastline can be measured.

Some of the sites can be used as markers from which to measure physical coastline changes; the most notably useful for this purpose being the buildings of Richborough which are known to have once been situated on the coast approximately 2,000 years ago. Other sites which ranked lower, but still have the potential to provide information on coastal change, include coastal defences, these include WWI and WWII gun emplacements, anti-tank blocks, pill boxes and air raid shelters, as well as historic buildings that are found all along the coast of the Kent study area, and can provide information on the rate of coastal change over the last century.

Many wreck sites were also assessed, although the majority are modern (1901-Present) in date, around seventeen Post Medieval wrecks were ranked, along with a single Iron Age wreck. Of more importance to the project is the Bronze Age wreck previously mentioned and two 20th century hulks that were sunk in the River Stour. The two hulks are believed to have been placed in the river to help reduce coastal erosion (RCZA).

3B.4 Ranking Artistic Depictions

The ranking system developed for artworks, historic photographs, maps and sea charts is set out in Section 2.2. The ranking system has been applied to each of the selected artworks, which are described in more detail below. The focus of the Kent study area was on artworks, no historic photographs or historic maps were assessed within the framework of the project. Examples of available maps are presented below, these serve to highlight the potential for such resources to provide information on coastal change, further work is required in order to assess the accuracy and reliability of these resources.

Twenty four works of art from the east Kent art case study site were assessed. The highest ranking artwork, a detailed watercolour of Folkestone Beach, gained 70 points whilst several coastal aquatint engravings scored up to 55 points. These are followed by oil paintings from the early and mid-nineteenth century which, with the exception of the Pre-Raphaelite artists and their followers, generally provided less detailed information, and hence scored fewer points.

Artists tended to paint attractive or dramatic coastal locations as well as meeting specific demands of their patrons. On the east Kent coast they were drawn to the expending coastal towns and villages either on account of their locations or because of the interest in the activities of fishermen and their craft working along the shoreline. This has resulted in many of the sites of key geomorphological and coastal risk management interest being painted by artists particularly during the nineteenth century. Within the higher ranking artworks there are examples which include locations affected by coastal landsliding, marine erosion, flooding and beach change. Where a particular location has been painted by a limited number of artists or perhaps just one artist that work has been included to illustrate a particular feature or issue.

These differing coastal landforms and processes and their impacts on coastal residents, assets and infrastructure could not have been easily matched to the most informative works of art without the provision of the ranking system. The system has identified ten case study locations and at each at least one artwork has been examined in more detail below as follows:-

Case Study Number	Location	Artist	Date	Score type	Score period	Score style	Score enviro	Total Score
1	Reculver Church	William Daniell	1824	Aqua-tint	Early	Topog.	Detailed View	55
2	Margate	William Daniell	1824	Aqua-tint	Early	Topog.	Detailed View	40
3	Pegwell Bay	William Dyce	1858	Oil	Mid.	Topog.	Very Detailed View	62
4	Deal Castle	William Daniell	1824	Aqua-tint	Early	Topog.	Detailed View	55
5	Walmer Castle	William Daniell	1824	Aqua-tint	Early	Topog.	Detailed View	55
6	Leas, Folkestone	Alfred Robert Quinton	1920	Water-colour	Late	Topog.	Detailed View	70

Table 3B3. Highest ranking artworks within the Kent study area

A more detailed explanation of each site and the interpretation of the individual artworks is provided in the case study descriptions below. The assigning of scores to each artwork suggests names of those artists who have depicted different aspects of the east Kent coast across the timeline 1770-1920. These artists include William Dyce, William Daniell, Henry Pether and John Wilson Carmichael; they can be relied upon in terms of the accuracy of their depictions of the Kent coastline.

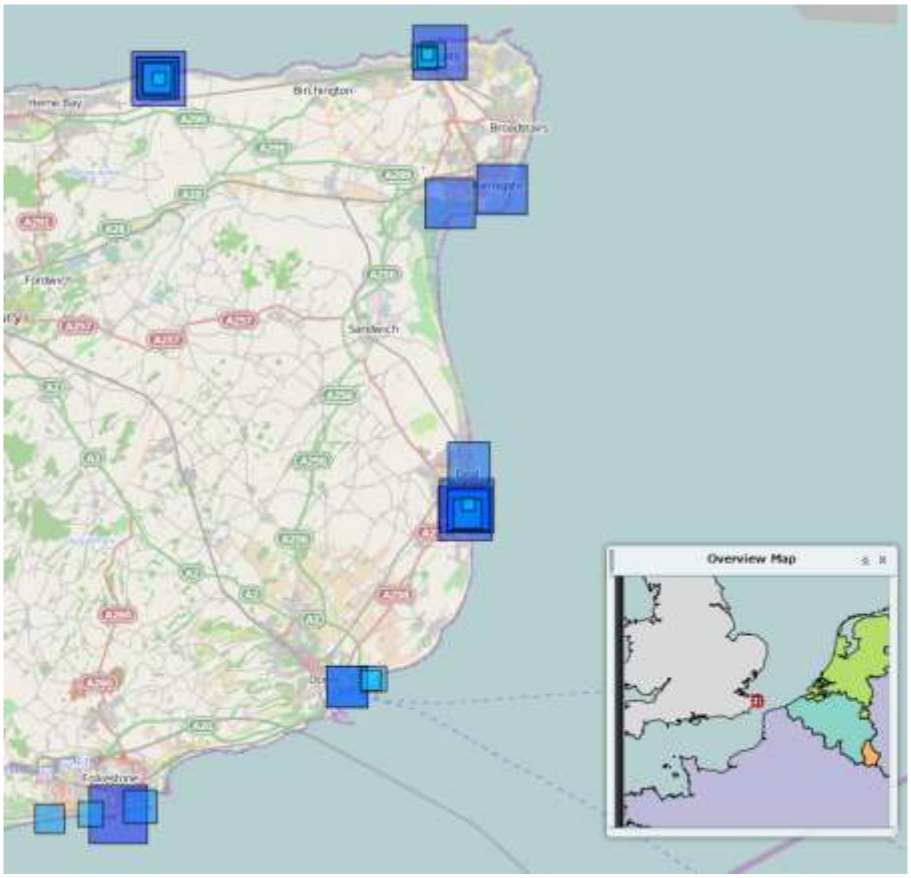

Figure 3B4. Map showing the distribution of artworks ranked within the Kent case study area.

3B.4.1 Discussion of Art Scoring Results

Parts of the east Kent coastline have been progressively developed over the centuries with some significant impacts on both coastal processes and the natural environment. Over the last ten years considerable efforts have been made to encourage improved coastal management and this has led to the development of risk management plans for the coast in support of the principle of sustainable development. As part of this process, thorough consideration has been given by the coastal group to natural hazards, and the resulting risks to people, property and the environment. Climate change is with us now and is going to exert an increasing influence on the lives of coastal residents over the next decades by affecting the severity of coastal erosion, flooding and landslide events.

Through the case studies the value of various artworks has been tested at sites of differing geomorphology. The combined approaches of desk-based research, museum and gallery searches and field visits have confirmed the added value of art from the period 1770-1920 to support other coastal surveying and monitoring technologies (e.g. Space-borne, air-borne, ship-borne and terrestrial). It is important to remember that artists in the late Georgian and Victorian eras worked for very demanding, wealthy clients who often sought exact views of the coastal landscape to remind them of their visit. Before the days of photography precise images were, therefore, a prerequisite in most cases. The examination of the works of many artists painting the Kent coast testifies to their considerable artistic skills in capturing accurately the coastal topography.

Some of the artworks examined in these case studies show significant coastal change over time as well as telling the story of human intervention on the coast. Other artworks show very little change over the last two hundred years and this information is of equal interest to the coastal scientist. Importantly, in many cases the artworks also illustrate the nature of the natural undeveloped coastline and suggest what conditions might be experienced if coastal defences were not maintained in the future. This is particularly significant as along certain coastal frontages it will not be possible to continue to defend the coast as has been the case in the past for physical or environmental reasons.

The east Kent study focused on the use of historic paintings, however a review of historic maps, charts and photographs was carried out to highlight the potential of these data sources. Because of the dynamic nature of this coastline historic photographs can be a valuable resource with many historic photos containing depictions of the cliff with recognisable heritage features nearby, including churches, wells and houses. These can be compared to the modern situation and from this an accurate idea of the rate of erosion since the date of the photograph can be gained.

3B.4.2 Maps and Charts

As mentioned above it has not been possible to assess many historic maps or charts along the Kent coast as part of the project. A brief review of available maps was carried out to highlight the potential of this resource in improving our understanding of coastal change, however, these have not yet been assessed in detail for their reliability and accuracy.

Figure 3B5 shows a map of Dover by Rutger Hermannides in *Britannia Magna* from 1661. The map shows Dover Castle and the early harbour. Alongside the map is an aerial photograph of the area today.

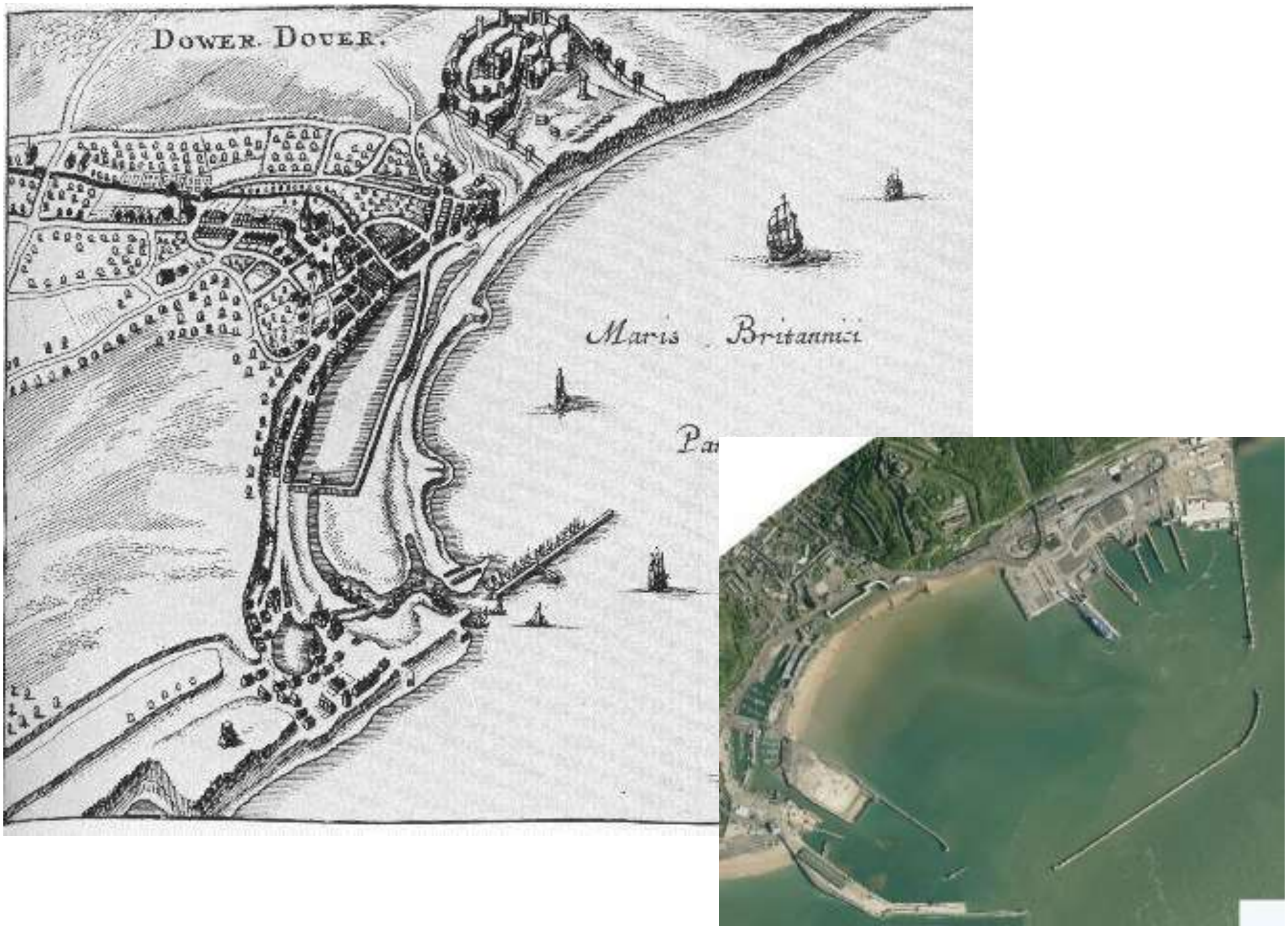

Figure 3B5. The image on the left is a map of Dover from 1661 (courtesy of genealogy.rootsweb.ancestry.com, the image on the right is an aerial photograph of Dover from 2013 (courtesy of the CCO).

Figure 3B6 is a map of the Isle of Thanet from 1836, coastal structures such as piers and jetties are depicted, but there is little detail on the geology or geomorphology of the coastline. However, such maps often include illustrations of coastal sites, in this case there is a depiction of Ramsgate Harbour and North Portland light house. These images can also provide useful information on how the coast looked in this period.

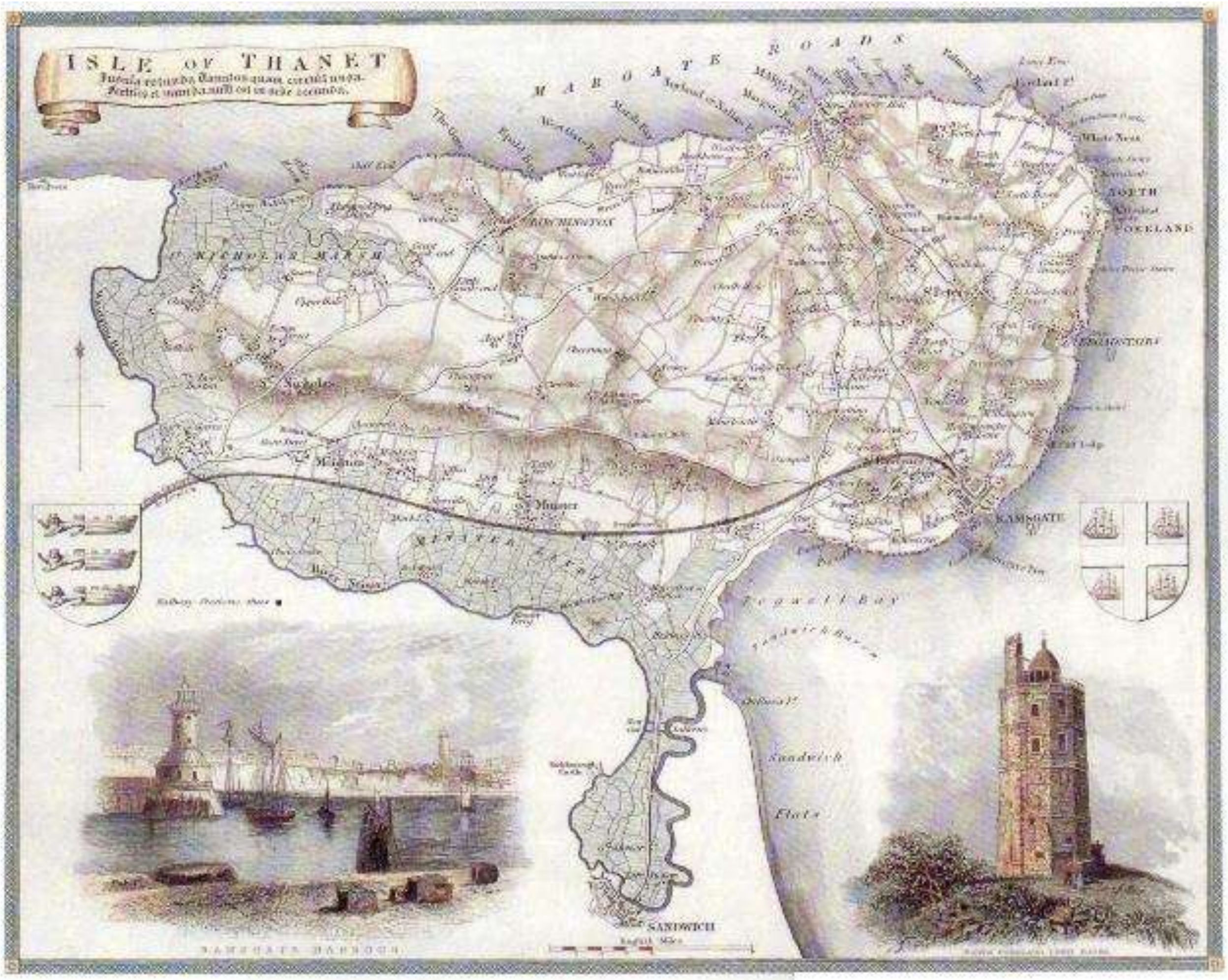

Figure 3B6. Map of the Isle of Thanet from 1836, from John Dower in Thomas Moule's The English Counties Delineated. (courtesy of genealogy.rootsweb.ancestry.com)

Such maps need to be assessed for their reliability and accuracy before being used to provide information on coastal change. A methodology for evaluating maps is outlined in Section 2.

Another source of historic maps is from the Ordnance Survey. After fifty years spent on triangulation of the whole of England the first one inch OS Map was published in 1853. Although not recommended for developers these maps are extremely accurate. Several OS maps are used later to look at changes around Deal Castle, see Section 3B.6 below.

3B.5 Art Field and Research Studies

No archaeological or palaeoenvironmental fieldwork was carried out within the Kent case study area, this section, therefore, outlines the field studies undertaken as part of the art study.

3B.5.1 Key Research Questions to be Addressed from the Artistic Depictions

Having established, through the art ranking system that the images are likely to be true representations of the conditions that would be seen at the time they were painted, the research questions to be answered through examination of the artworks at the case study sites are:-

- What information can the historical images provide to support understanding of long-term coastal change?

- How can the potential of this resource be used most effectively by the end-user?

Following the ranking of twenty four artworks six examples have been the subject of more detailed analysis involving site visits. Art images were selected to reflect the varying physical conditions in this area of the coast. Site B1 at Reculver considers eroding, unstable cliffs and explores the chronology of coastal change and provision of defences. Site B2 at Margate reviews changes to the coastline as a result of nineteenth century development whilst Site B3 reviews cliff and foreshore change at Pegwell Bay. Sites B4 and B5 at Deal and Walmer Castle are interesting because they have fine castles situated at the back of the beach; here beach change is examined. At site B6 the Leas Beach at Folkestone is well documented in terms of historical images, and slope stability and beach management issues are examined. Each site considers the potential of the artwork to be used as a qualitative or quantitative tool to support our understanding of long term coastal change and coastal management more widely.

3B.5.2 Approach to Information Gathering and Fieldwork for Assessing Coastal Artworks

Where it has been practical to gain access and relevant to the study, present day photographs were taken in the field to try, as far as possible, to match the views painted by the eighteenth, nineteenth and early twentieth century artists. It also provided the opportunity to assess the conditions of the cliffline and beach and changes that may have taken place over time. In terms of work in this field each of the locations has been visited and photographed in varying weather conditions. Inspections were timed to coincide with Low Water and a walk-over survey was made along the beach and base of the cliff returning along the cliff top. This ensured that thorough comparison could be made between the geomorphological conditions depicted in the artwork and the present day situation.

The fieldwork element has been largely visual in terms of identifying the location of the paintings and making judgements, on site, of the role that art can fulfil as a qualitative or quantitative tool to support coastal risk management. The field inspections allowed a more accurate appraisal to be made of current physical conditions rather than relying upon written accounts and reports particularly as storm events can cause significant alterations over relatively short time periods.

3B.5.3 Art Field Data Gathering Results

The approach adopted for each case study has been the examination of one particular artwork and to make an assessment of what it tells us about changes over time from field observation. However, for some of the study sites it has been found that several artists painted the view from the same or a similar spot. This helps to establish a chronology of coastal change through the nineteenth and twentieth centuries. The results for each case study location are described below.

B1. Reculver Church

Location

The study site is Reculver Church (Towers) situated approximately 5km to the east of the seaside resort of Herne Bay on the North Kent coast.

Why was the study site selected?

The study site illustrates historic problems associated with erosion of the soft cliffs at this point, and is particularly well illustrated through a chronology of landscape paintings, produced since the early nineteenth century. It is believed that these artworks illustrate clearly how historical information can be gained to inform us of the rate and scale of long term coastal change.

Figure 3B7. Reculver Church', North Kent coast by Wiliam Daniell, RA engraved in 1824. Some rudimentary coastal defences can be seen, which were helping to preserve this important landmark for navigation. A substantial rock revetment now protects the site.

Geomorphological setting

This coastal site is located on eroding soft clay cliffs composed of London Clay, which are of Tertiary Age. Immediately to the east are the Thanet Beds, which are named after this part of the Kent coast which has historically been known as the Isle of Thanet, whilst, to the south and to the east, are extensive outcrops of chalk for which the county is famous. The rocks exposed are of Cretaceous and Tertiary Age, dating from between 140-50 million years ago. They represent a fixed sequence of sands, clays and chalk (limestone), which has been gently folded into an anticline known as the Wealden Dome.

Cliff erosion takes place along the undefended frontages and where it is uneconomic for defences to be maintained erosion will be allowed to continue looking ahead over the next 100 years, in order to maintain the nature conservation interest of the locality.

Key coastal risk management issues for the frontage

The eroding cliffs at Reculver (except immediately in front of Reculver Towers) are of high conservation and landscape importance. In the shoreline management plan for the frontage, the long-term recommendation is to allow continued erosion of the cliffs, which will maintain the geological exposures and the landscape quality of the frontage. There will, however, be potential for loss of buried unknown heritage as the cliffs erode and retreat. Development along this frontage is minimal, and in most cases the built assets are set well back from the cliff face. However, in the medium term, some assets may be at risk and the coastal footpath will need to be re-routed.

An element of shoreline protection is provided by cliff fall debris as these events take place, and certainly it is not deemed necessary or visually desirable to defend this section of the coastline. With sea level rise it is anticipated that erosion rates will increase between the next 20 and 50 years, and increased erosion is likely to make a modest contribution to the sediment budget, which is transported along the coast by the process of longshore drift. With sea level rise, the naturally functioning coastline will continue to provide sediment inputs from the cliffs to the foreshore, albeit at a greater rate than those experienced historically.

How can the artwork inform coastal risk management?

The historic church of St Mary at Reculver has been depicted by numerous artists over the last 200 years. In 1798 James Malton painted a watercolour called *'The Two Sisters* near *Margate*', the title reflecting the twin towers of the church (Figure 3B10). Later, in 1813, the Reverend J. Skinner recorded the wall of the Roman fort of Reculver in his diary. The wall used to be located seaward of the church, and was long since lost to coastal erosion. The drawing by Reverend Skinner illustrated the drastic undercutting of the cliff as a result of coastal erosion (Figure 3B11). Later Charles Lyell, the celebrated geologist, cited the Roman shore fort of Regulbium (Reculver) as evidence of the scale and pace of coastal erosion (Lyell, 1838). Lyell's own view of 1834 shows the significant retreat of the coastline since an earlier engraving made in 1781 (Figures 3B8 and 3B9).

William Daniell, on his *'Voyage round Great Britain'*, passed along the Kent coast in 1824, and he noted that *"this important landmark is also known by the name of the Sister Churches, assigned to it in reference to the two spires which crown the towers on the west front of the church. The following inscription, copied from a stone tablet over the door of the edifice, will serve to explain their present condition: these towers, the remains of the once venerable church of the Reculvers, were purchased for the Parish by the corporation of the Trinity House of Deptford Strand in the year 1810, and the groynes laid down at their expense to protect the cliff on which the church had stood. When the ancient spires were afterwards blown down, the present structures were erected, to render the towers still sufficiently conspicuous to be useful in navigation"* (Captain Joseph Cotton, Deputy Master in the year 1819). Daniell continued *"the abrupt bank of earth on which the church stands has been much wasted by the sea... to break the impetus of the tide, and prevent further encroachments, the Trinity House have laid down groynes on the beach, which it is hoped will be sufficient for the security of so valuable a land mark as her sister churches"*.

Daniell continued *"at this station, denominated regulbium by the Romans... their ancient lease to the castle, which defended the northern entrance of the Roman haven. The church is dedicated to St Mary, and is supposed to have been built on the foundations of one which belonged to a Benedictine abbey erected here by Bassa, a Saxon priest and noble, in the reign of King Egbert"*.

Reculver once occupied a strategic location of the north western end of the Wantsum Channel between the Isle of Thanet and the Kent mainland. This led the Romans to build a small fort there at the time of their conquest in Britain in 43 AD. After the Romans left Britain in the early fifth century, Reculver became a land estate of the Anglo-Saxon kings of Kent. The site of the Roman fort was given over to the establishment of a monastery dedicated to St Mary in 669 AD, and King Eadbhert the Second of Kent was buried there in the 1760s. The twin spires of the church became a landmark for mariners known as 'The Twin Sisters' supposedly after daughters of Geoffrey St Clare. The population of Reculver declined as the Wantsum Channel silted up, and coastal erosion claimed many buildings constructed on the soft sandy cliffs. The village was largely abandoned in the late eighteenth century, and most of the church was demolished in the early nineteenth century. Protecting the ruins and the rest of Reculver from erosion has been an on-going challenge for the coast protection authority.

After Daniell's view of Reculver the next artwork in chronological succession was a painting by James Ward of 1818 entitled '*Reculver Church*' (Figure 3B12), which shows a view of the building dramatically located on the cliff edge taken from the west looking eastwards, whilst a further view by Stuart Westmacott (Figure 3B13), painted in 1851, shows the building from the east side looking west.

This sequence of images of Reculver church frontage tells the story of coastal change over the last 1,000 years, and without these images it would be less easy to appreciate the dramatic rate of coastal change that has taken place. Along most coastal frontages erosion is episodic rather than uniform, in other words significant retreat takes place after particular storm events or wet periods when the cliffs become saturated and liable to instability problems. There may be long periods where cliffs appear relatively stable but, over a time span of 100 years, the overall rate of retreat can be very significant. Images of this kind can be useful when explaining to stakeholders about long-term coastal change and how their particular frontage may be affected if natural processes continue in the event of an increase in the rate of erosion as a result of climate change.

Figure 3B8. Charles Lyell cited the Roman shore fort of Regulbium (i.e. Reculver) as evidence of the scale and rate of marine erosion. In this view of 1781 Lyell observed that there had been a notable distance between the church and cliff line.

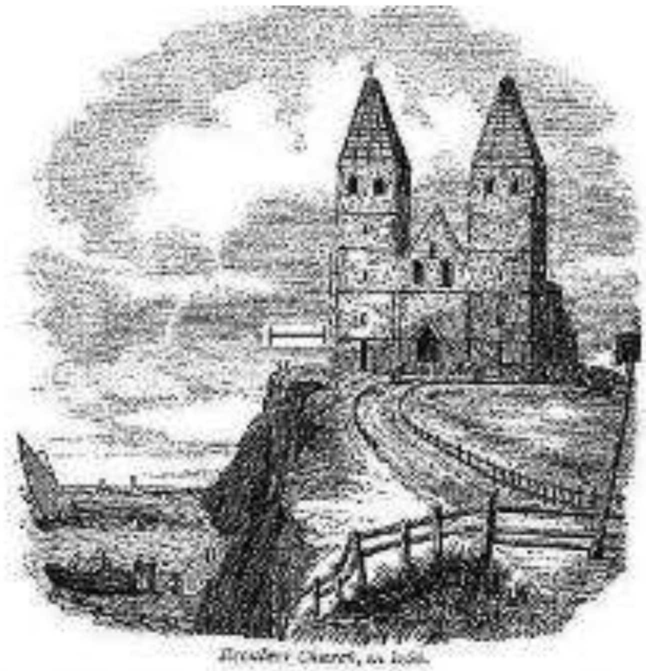

Figure 3B9. Lyell's view of 1834 shows the significant retreat of the shoreline since the previous engraving (above) was made in 1781.

Figure 3B40. The Reculver', commonly called 'The Two Sisters' by James Malton, 1798. Malton's watercolour drawing shows a building existing between the seaward side of the church and the cliff edge. Image: Courtesy Bonham's. Private collection.

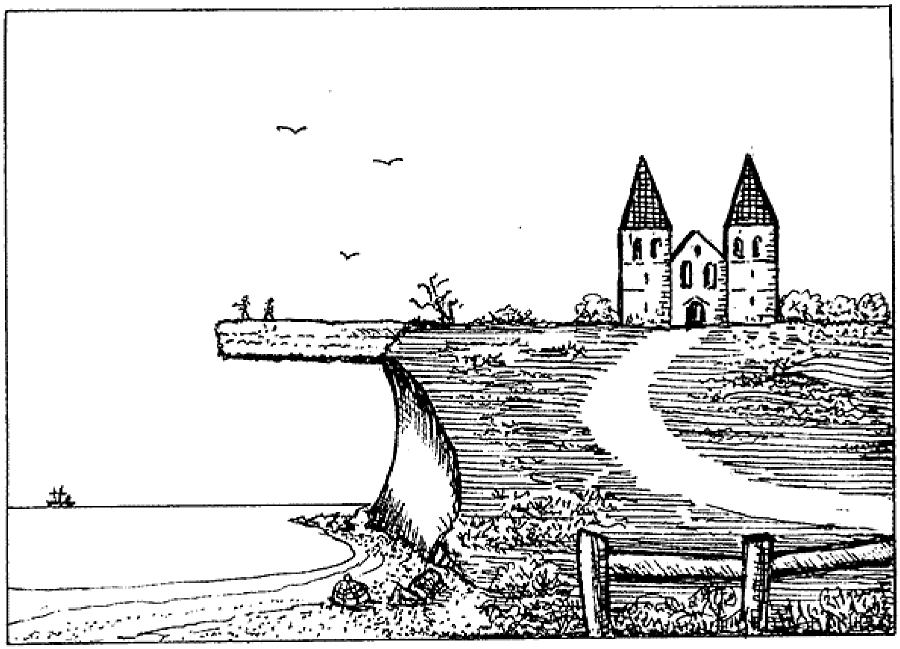

Figure 3B11. The Rev. J. Skinner recorded the wall of the Roman fort at Reculver in his diary around 1813 after the cliff had been drastically undercut by erosion. This diagrammatic drawing provides a simplistic summary of the erosion issue as he perceived it.

Figure 3B52. In this view of Reculver by James Ward painted in 1818 a range of coastal defences can be seen at the foot of the soft cliff line. Image courtesy of Canterbury City Museum & Art Galleries.

Figure 3B63. A further view of Reculver Church from the east side by Stewart Westmacott painted in 1851. Image courtesy of Canterbury City Museum & Art Galleries.

Where can the original artwork be viewed?
The view of 'Reculver' by William Daniell can be viewed on the Internet. The oil paintings can be viewed at www.bbc.co.uk/yourpaintings.

Ranking score achieved by the William Daniell image: 55

B2 Margate, North Kent Coast

Location
Margate is a popular seaside resort located on the north coast of Kent between the resorts of Westgate-on-Sea to the west and Foreness Point and North Foreland to the east.

Why was the study site selected?
This site was selected to illustrate the role that historical artworks can play not just in informing us of long-term coastal change but also physical and structural change to the coastline, as a result of human intervention.

Geomorphological setting
Margate is located on the Isle of Thanet in the north eastern corner of the county of Kent, and has been developed along the chalk cliffline, which dominates the frontage, and is recognised as being of international importance on account of the geology, environment and landscape character. To the west of the town, the wave cut chalk shore platforms at the base of the cliff are of particular geological significance, whilst, in the town itself, the frontage has been heavily developed and defended with coast protection and harbour structures. Because of the extent of

the development, the beach at Margate is dependent on management including the use of groynes and nourishment where appropriate. The coast protection structures, including groynes and the harbour arm, restrict sediment movement along the frontage.

Key coastal risk management issues for the frontage
The town of Margate is of particular significance in terms of its residential, commercial and strategic activities, particular tourism. As a result, coastal defences will continue to be maintained and upgraded to protect these valuable assets. Figure 3B14 shows a view of Margate harbour by William Daniell, painted in 1824, it forms part of his *'Voyage round Great Britain'* and illustrates the growing resort taken from a vantage point just to the west of the harbour arm. An advantage of Daniell's work was his topographical accuracy including the form of the small beach in the foreground, the shape of the harbour arm, and its proximity to the seawall and seafront properties, and the view looking along the coastline in an easterly direction beyond.

Works of art, which depict seawalls and harbours can be particularly useful to designers who are having to replace or improve these structures. Often the original harbour structure may have been covered by reinforced concrete or, other later, additions and alterations. It is, therefore, useful to understand how the nature of the original construction, which could help reduce costly investigations and studies that might otherwise be deemed necessary.

Observations on the artwork
This view is typical of the meticulous observation and eye for detail in William Daniell's aquatint engravings. It provides a wealth of information on the state of the coast in the emerging resort of Margate in the early part of the nineteenth century.

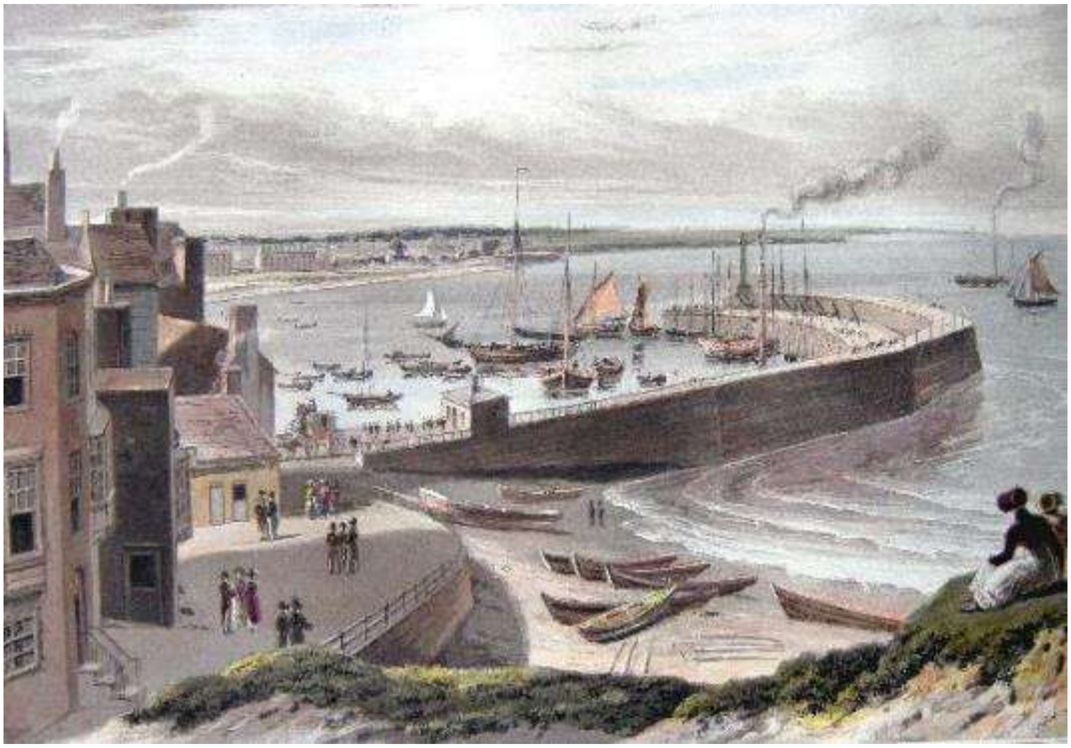

Figure 3B74. 'Margate' by William Daniell engraved in 1824. His view illustrates how artworks can depict not just physical change but also the history of coastal development and sometimes the modes of construction used.

Figure 3B85. The present day view of Margate

How can the artwork inform coastal risk management?

This view by Daniell was selected to illustrate the role that art can fulfil in terms of understanding not just physical changes on the coast but also the history of coastal development and construction. Not only are features such as harbour arms influential in terms of interruption of sediment transport but an understanding of their form can be particularly helpful to designers and coastal engineers who may wish to repair or replace these structures. It can be seen from Daniell's view (Figure 3B14) and from the present day view (Figure 3B15) that the harbour wall has stood the test of time and remains unaltered. Part of the former beach is now occupied by a dinghy park and the new Turner Contemporary Art Gallery can be seen on the left.

It can be seen that artwork such as this can inform not just coastal risk management but integrated coastal zone management more widely as the view encompasses a range of features and issues relating to the coastal zone.

Where can the original artwork be viewed?

The William Daniell view of Margate can be viewed easily on the Internet.

Ranking score achieved by the William Daniell image: 40

B3 Pegwell Bay, Kent

Location

Pegwell Bay is located on the east Kent coast just to the south and west of the seaside town of Ramsgate. The town faces south looking along the Kent coast, past Sandwich and Deal, in the direction of Dover and out across the Straits of Dover.

Why was the study site selected?

Pegwell Bay is famous in terms of art history for the painting by William Dyce RA (1806-1864) entitled *'Pegwell Bay – Recollections of the 5th October 1858'* (Figure 3B16). Dyce was an artist of the Pre-Raphaelite Brotherhood who wished to capture nature in every detail and as precisely as possible. The painting is remarkable for its almost 'photographic' quality, and proved fascinating to Victorians at the time on account of the emerging science of geology but also the conflicts it posed in relation to the biblical account of '*The Creation'*. The study site shows a chalk cliff frontage affected by coastal erosion and weathering, together with a detailed portrayal of the foreshore, which bears comparison with the present day situation.

Geomorphological setting

Pegwell Bay is located at the southern end of the chalk cliff-line to the west of the town of Ramsgate, and north of the Minster Marshes and Ash Level, which form the floodplain of the River Stour, which flows northward from Sandwich, to emerge into Pegwell Bay. The Bay is backed by a rugged well-jointed chalk cliff with a wave-cut platform and a rocky foreshore, whereas, to the south, there are extensive sand dunes and a shingle foreshore forming part of the Sandwich Bay Nature Reserve. Within the floodplain of the Stour there are extensive saltmarshes with a hinterland of dunes.

Key coastal risk management issues for the frontage

Pegwell Bay lies to the west of the main developed area of Ramsgate but an important strategic road links Ramsgate with the community of Cliffs End to the west. Existing coastal defences will be maintained and may require upgrading in the future, but the cliff top is susceptible to weathering and cliff falls. To the west of the Bay at Cliffs End, the steep chalk cliffs give way to relict, undefended sandstone cliffs, before the transition between the Isle of Thanet and the predominantly low-lying east Kent coast to the south.

Observations on the artwork

The painting by William Dyce is of particular interest on account of the extraordinary detail that has been achieved in this oil painting. In terms of the cliff-line the structure of the cliffs, including the jointing, is particularly well defined, as are the details of the caves running along the foot of the cliff. Along the foreshore one can see the wave-cut platform, which extends into the intertidal zone, and, in the foreground, details of a groyne forming a rudimentary coast protection structure. At the time the view was painted by Dyce it coincided with the emerging art of photography and many people thought this painting had been copied from a photograph, which was incorrect. However, it demonstrates the almost photographic detail that could be achieved through art by the followers of the Pre-Raphaelite ethos of capturing nature in its precise detail.

Figure 3B96. 'Pegwell Bay – Recollections of 5th October 1858' by William Dyce, RA demonstrates the precise detail that could be achieved by the Pre-Raphaelite artists. Dyce has achieved a depiction that has the appearance of a photograph.Courtesy of Tate Images 2014.

Figure 3B107. The chalk cliff frontage at Pegwell Bay today

How can the artwork inform coastal risk management?
Paintings of this kind can inform coastal risk management by providing a reliable comparison with the conditions to be found in later works of art, in photographs and when viewed at the present day. From the same spot estimates could be made of cliff retreat because it is possible to identify sections of cliff that may have fallen away as a result of undercutting of the toe of the cliff by the sea, and weathering over the last 160 years. It can, therefore, advise coastal engineers of the rate and scale of coastal change over a very long time span.

Where can the original artwork be viewed?
At the Tate Britain or on the BBC '*Your Paintings*' website (www.bbc.co.uk/yourpaintings).

Ranking score achieved by the William Dyce oil painting: 62.

B4 Deal Castle, East Kent Coast

Location
Deal Castle is located on the east Kent coast along the Deal town frontage, and is situated immediately behind the beach.

Why was the study site selected?
Deal Castle was chosen as a study site because it is located adjacent to the low-lying coast and an aquatint engraving is available, which provides precise details of the structure in the year 1824. The heritage importance of this structure adds further value for the Arch Manche project.

Figure 3B118. Deal Castle' by William Daniell, RA engraved in 1824. His fine draughtsmanship shows us the relationship between the structure and the shore at that time. A substantial beach now provides flood protection for this low-lying coastline. Private Collection.

Geomorphological setting
The town of Deal lies on the open coast, with a mixed shingle and sand beach to the north and shingle beaches along the frontage, which is defended. The area to the north of Deal is low-lying, whereas to the south of the town the land begins to rise to meet the cliffs at St Margaret's Bay and South Foreland.

Key coastal risk management issues for the frontage
To the north, the frontage consists of shingle beaches backed by an embankment of shale and a narrow dune system. The beach and dunes are of international environmental importance. Along the coastline of the Deal frontage assets are protected by a shingle beach with timber groynes and a concrete seawall. Flood defences also provide protection for a large area of the town from flooding. The coastal risk management policy is to seek an improvement to reduce erosion and flood risk, through beach management, by increasing the volume of the shingle beach. There is also the possibility of improving the seawall along the Deal frontage to reduce the risk of overtopping. South of Deal Castle there are no formal defences and the intention is to carry out minimal work and maintain the beach; it is unlikely that any properties will be at risk if this approach is adopted.

Observations on the artwork
This view of Deal Castle from the south was produced in 1824. It shows the fortification constructed directly on the beach. The castle had been built by King Henry VIII in 1540, in the shape of a Tudor Rose, and aimed to provide a powerful deterrent from attacks by the French.

How can the artwork inform coastal risk management?
This view of Deal Castle by William Daniell provides a very precise depiction of the location of this important heritage structure on the beach at Deal. Beach levels can be compared with later images and photographs over time to assist the understanding of coastal change along this part of the open east Kent coast. The coastline has since been defended with a concrete seawall approximately 20m seaward of the foremost element of the castle defences.

Where can the original artwork be viewed?
The image can be viewed easily on the Internet.

Ranking score achieved by the William Daniell aquatint engraving: 55.

B5 Walmer Castle, Kent

Location
Walmer Castle is located on the east Kent coast at the southern end of the Deal town frontage, and is situated immediately behind the beach.

Why was the study site selected?
Walmer Castle was chosen as a study site because it is contiguous with Deal Castle and is located adjacent to the low-lying coast. An aquatint engraving also by Daniell was available, which provides details of the castle structure and its relationship to the beach in the year 1824. The heritage importance of this structure adds further value for the Arch Manche project.

Geomorphological setting

The town of Deal lies on the open coast, with a mixed shingle and sand beach to the north and shingle beaches along the frontage, which is defended. The area to the north of Deal is low-lying, whereas to the south of the town the land begins to rise to meet the cliffs at St Margaret's Bay and South Foreland.

Key coastal risk management issues for the frontage

To the north, the frontage consists of shingle beaches backed by an embankment of shale and a narrow dune system. The beach and dunes are of international environmental importance. Along the coastline of the Deal frontage assets are protected by a shingle beach with timber groynes and a concrete seawall. Flood defences also provide protection for a large area of the town from flooding. The coastal risk management policy is to seek an improvement to reduce erosion and flood risk, through beach management, by increasing the volume of the shingle beach. There is also the possibility of improving the seawall along the Deal frontage to reduce the risk of overtopping. South of Deal Castle there are no formal defences and the intention is to carry out minimal work and maintain the beach; it is unlikely that any properties will be at risk if this approach is adopted.

Observations on the artwork

This view within Figure 3B19 shows the southern-most of three castles (the others are at Deal and Sandown) built in the 1530s by King Henry VIII. In the view by William Daniell (c.1824) the castle appears situated immediately above the beach. The beach appears to have taken on a barrel form with a crest, along which people can be seen walking, whereas, behind, shallow lagoons of water indicate where the sea has flooded through the barrier beach. A low wall appears to protect the foot of the slope below the castle from coastal erosion. The view describes, in a very precise way, the morphology of this part of the coastline, in particular the form of the cliffline and the extensive beach, looking northwards towards Deal.

Figure 3B19. In his view of 'Walmer Castle' (1824) Daniell provides us with an extensive and detailed depiction of the shoreline and cliffs. The form of the beach at low water can be seen cleanly. Some defences have been put in place around the frontage of the castle, which forms a hard point along this relatively soft coastline. Private Collection.

Figure 3B120. An oil painting by Henry Pether (c.1852) shows how the castle frontage has been extended seawards to create a lawns and a coastal path. Image courtesy of Woolley & Wallis, Salisbury.

How can the artwork inform coastal risk management?
The coloured aquatint engraving illustrates coastal conditions in the early nineteenth century and contrasts significantly with the present day situation where the beach appears much more stable, with the upper beach being vegetated. Whereas, in the view by Daniell, the Castle appears vulnerable to erosion and demanded the provision of a seawall, the present structure appears much more secure. The frontage could become increasingly vulnerable in the future as a result of coastal erosion promoted by rising sea levels, and so it is likely that the defences will be maintained for the foreseeable future, but may require replacement in the long term.

Where can the original artwork be viewed?
The image can be viewed easily on the Internet

Ranking score achieved by the William Daniell aquatint engraving: 55.

B6 Leas Cliff Hall Beach, Folkestone

Location
Folkestone is located on the south east coast of Kent, eight miles (12km) to the west of the port of Dover. It faces directly out across the Straits of Dover.

Why was the study site selected?
The site was selected to illustrate how art can demonstrating historical beach levels.

Geomorphological setting
The geology of Folkestone comprises rocks of the Cretaceous period, including the Wealden Clay, which is overlain by the Lower Greensand, the Gault Clay and Upper Greensand and, above that, the Chalk. Each of these strata are exposed in turn along the coastal frontage between Folkestone and Dover. The site in question, known as 'The Leas', comprises an unstable coastal slope, which has been developed on the relic sandstone cliffs, with a sand and

shingle beach at the toe. Along the top of the coastal slope there is substantial tourism and residential development, whilst the slopes have been cultivated into extensive public gardens.

Key coastal risk management issues for the frontage

There are substantial assets in terms of property and infrastructure along this frontage, which will continue to be maintained and improved as required. The policy along the Folkestone frontage is to hold the coastal defence line by maintaining the existing seawall and the arms of the harbour, as well as the groynes, which help manage the shingle beach along the western and central sections of the frontage and provide toe support for the slope behind, which is prone to instability.

It may be necessary to upgrade the coastal defences in the future as a result of sea level rise and possible coastal squeeze, with rising sea levels causing scour in front of the existing seawall structures. Maintaining a beach for tourism purposes along the frontage may be increasingly difficult in the future, and may require artificial recharge.

Observations on the artwork

This view of the Leas Cliff Hall frontage at Folkestone was painted in the 1920s by the prolific artist Alfred Robert Quinton (1853-1934) (Figure 3B21). Although painted as an illustration for a colour picture postcard, the work is surprisingly accurate in terms of the detail of the coast protection structures and in terms of showing the beach levels. It is interesting to compare it with the photographic postcard from the early 1900s (Figure 3B22). Because of the considerable number of views produced by Quinton around the English coast during the Edwardian period and later, they are particularly useful when making comparisons of beach levels against the seawalls and groynes.

How can the artwork inform coastal risk management?

The artwork can be used to demonstrate changes in the form and volume of the beach over time. Bearing in mind that along much of the coastline of England, no formal monitoring systems existed until some 20 years ago, it is possible to use images such as this to gain a longer term perspective on beach change and to gain insight of past conditions which may assist the selection of coast protection options for frontages in the future.

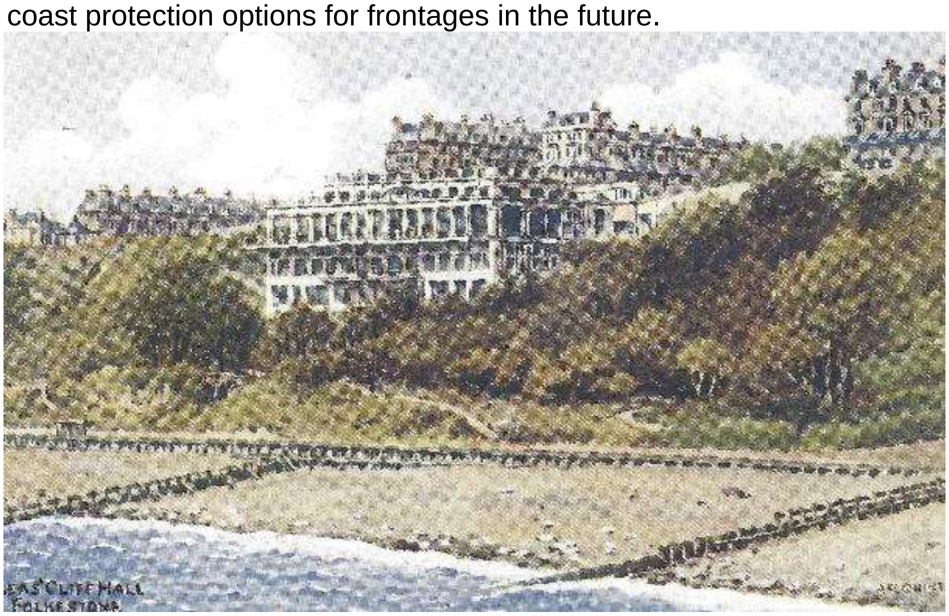

Figure 3B131. The Leas Cliff Hall in about 1900. The view was painted by the prolific coastal watercolourist, Alfred Robert Quinton. His view shows the wooded coastal slope and the beach levels against the coastal revetment and groynes (Image courtesy of J.Salmon of Sevenoaks).

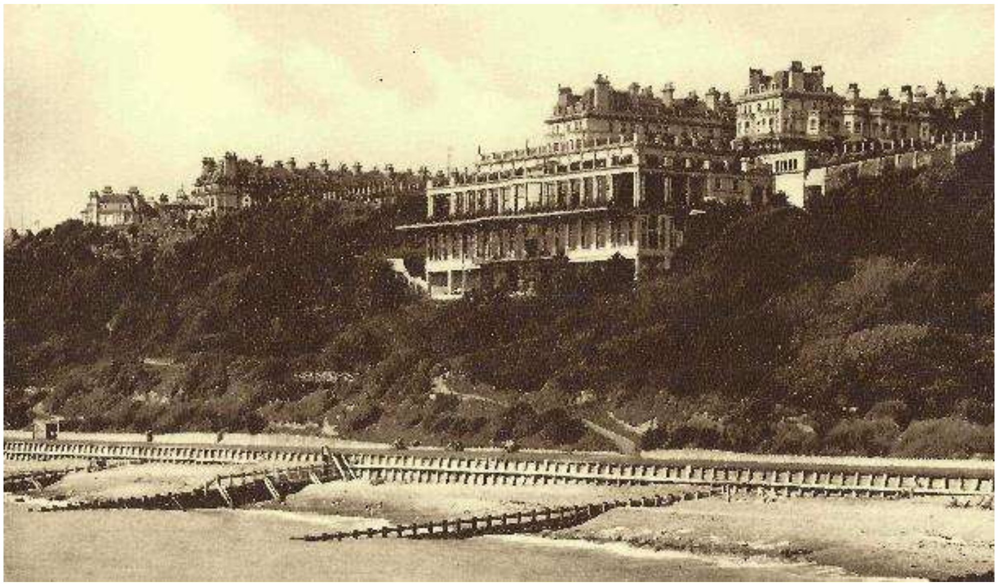

Figure 3B142. Photograph taken in 1900 and compares closely with Quinton's watercolour (above); the beach appears lower and steeper in this view. Private Collection.

Figure 3B153. The present day view, shows the coastal slope, which has faced some instability problems and the upgraded coastal defences including rock groynes.

Where can the original artwork be viewed?
Colour picture postcards by Quinton can be viewed easily on the internet.

Ranking score achieved: 70.

3B.6 Analysis

The Kent study area has combined the use of archaeological and palaeoenvironmental data with historic artworks in order to demonstrate how these tools can be used to improve understanding of coastal change in the long and short term. A particular focus has been on the use of coastal heritage features, namely the coastal defences built during the reign of Henry VIII and Dover Castle built in the 12th Century. Such heritage features have a long history of use and are also regularly depicted in historic paintings and easily identifiable on historic maps. This section presents the most informative and reliable data gathered from this study area for contributing to understanding of the scale and pace of coastal change.

3B.6.1 Archaeology and Heritage Features

As described in Section 3B.3 the archaeological assessment runs along the eastern coast of the county, from Margate in the north, to Dover in the south. This stretch of coastline contains evidence of human activity from all periods of history; from prehistoric settlements, possible Bronze Age wrecks and Iron Age hillforts, through to Medieval and Post Medieval fortifications and up to the Second World War. However, many of the highest scoring sites, in particular the prehistoric sites, require more in depth study in order to understand the full extent of the sites and what they can tell us about sea level and environmental change.

More recent sites particularly the Medieval and Post Medieval defences provide key information on coastal change. The Tudor 'Device' forts, constructed during the reign of King Henry VIII, are considered the first purpose built coastal structures to defend against military attack in the country. The forts were built in two phases. The first, in response to a perceived threat of French invasion, were constructed between 1539 and 1540. The later forts were constructed between 1543 and 1545 and their different designs reflect the changing nature of siege warfare and firearms. Although they were quickly rendered obsolete by technological advances, many of them were remodelled and reinforced through history, up to and after the Second World War.

These sites are often depicted in historic artworks and are clearly identifiable on historic maps, the analysis has therefore focussed on the use of combined resources to inform past coastal change. This is discussed below in Section 3B.6.3.

3B.6.2 Artistic Depictions

The Kent art study sites have provided six good examples which demonstrate how historical artworks can inform us of changing coastal conditions over the last two hundred years. Four of the images that have been studied are aquatint engravings by William Daniell RA, which were engraved in 1824; one view is an oil painting and the final view is a watercolour drawing. The works by Daniell, in particular, provide, in effect, an illustrated *State of the Coast* report for the 1820s because his views are numerous.

The establishment of a list of key artists that painted the Kent coastline through the ranking system directed research to the higher scoring case study locations. However, where a particular site offered interesting potential for study of coastal change the highest ranking image available was selected for study even if the score was not as high as at other sites. Initial assessment sought to undertake a qualitative assessment of the artworks in terms of their usefulness in informing coastal risk management. Analysis of works by some artists also allowed quantitative assessments, particularly where structures such as harbour walls, groynes or historic buildings exist and where beach levels are clearly indicated or where actual cliff retreat can be measured against a structure. For example, at Deal and Walmer Castles or against the timber groynes at Folkestone.

In terms of the case study examples for soft cliffs the story of erosion at Reculver is particularly interesting to observe through the eyes of the numerous artists drawn to this location. Natural change has now been halted through the provision of a substantial rock revetment, which now protects the church ruins. As described above the church at Reculver has been painted by several artists over the last 200 years, and the rate of erosion can clearly be seen. At Folkestone the coastal cliffs and slope are partially masked by vegetation, which together with coastal defences help to reduce instability problems. Here artistic evidence can be compared to photography of the period and they show a close similarity. Again substantial defences provided added risk reduction measures for the frontage.

Perhaps the most striking image from the east Kent coast is the detailed oil painting by William Dyce RA of Pegwell Bay. The painting demonstrates the extraordinary skill of some of the Victorian artists and the detailed information that their works can impart. The two views by Daniell of the Deal frontage showing Deal and Walmer Castles are interesting because they provide detailed information on the form of the beach, which constitutes a key element of the flood defences for low-lying parts of the town.

3B.6.3 Combined Resources

Heritage sites are well represented in historical surveys, artworks, plans and maps, which provides an excellent opportunity to assess them using a mixture of sources. This is particularly true of sites like castles and forts that receive surveys for military purposes and often inspire painting and engravings.

The three forts built along the Kent coast at Sandown, Deal and Walmer were built to protect the Downs Roadstead, an offshore anchorage protected from the worst of the weather by the Goodwin Sands. They were part of the first phase of construction that took place in 1539 and 1540. Sandown and Walmer Castles, the northern and southern forts, were both constructed to a similar design, the whole castle was surrounded by a dry moat, itself enclosed by a counterscarp (outer) stone wall. Deal Castle, the central fort, was significantly larger with six small 'lunette' platforms around the central tower and six outer bastions. It too was surrounded by a dry moat. All three forts were linked by a series of earthen entrenchments and bulwarks that ran along the shoreline between them (Saunders, 1989, 38-39).

A major survey of all the Crown fortifications was conducted in 1623. The three 'Forts on the Downs' were all found to suffer from leaks within the towers themselves, and many cannon were unserviceable. However, the most costly repair for all three forts was the outer wall of the moats, which had been battered by the sea. A great breach was thought to be imminent at Walmer and at Deal the wall's impending failure left the fort "in a perpetual imminent danger to be ruined". Some 80 metres of the 5 metre high wall needed repairing at Sandown; at Walmer a new 85m wall with a sluice was recommended (Kenyon, 2013: 131-137).

Figure 3B164. William Stukeley's 'bird's eye view' of the southern forts, showing Deal Castle (foreground) and Walmer Castle. 1725.

The three forts were sketched by William Stukeley in 1725 (Figure 3B17). Stukeley produced two views of the northern flank of the defences, and a bird's eye view of the southern side. The sketches are revealing in that they show the water running right up to all three forts and against the earthen defences. The beach would appear to be right against the outer moat wall and may have even breached Walmer's moat (Saunders, 1989: 39). This is supported by a 1725 War Department plan of Walmer Castle that shows the moat wall as incomplete on the coastal side of the fort and that the mean high water mark is only 10 to 11 metres from the two eastern bastions. An annotation suggests that the loopholes on this side have been walled up to prevent the sea from flooding through them.

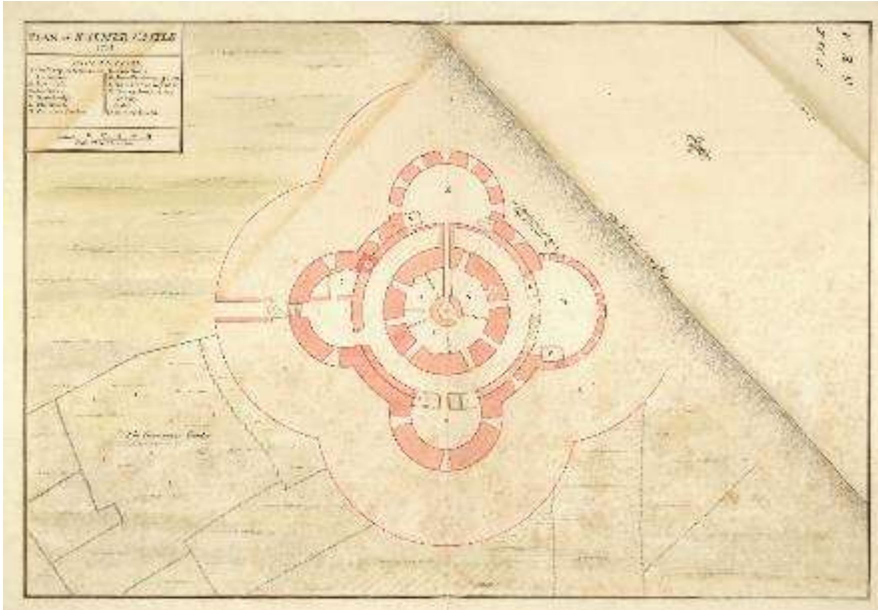

Figure 3B175. War Department plan of Walmer Castle (1725)

This state of the coast is reflected in Daniell's painting 'Walmer Castle' (1824), which clearly shows the proximity of the shoreline to the fort (Figure 3B). In fact the high water mark seems to have moved even closer to the fort and defences installed to prevent the water from flooding the moat. Since then a slow process of land reclamation appears to have been undertaken. By 1872, the date of the first OS County Series map, the dry moat has been fully enclosed and the mean high water mark is a full 120m away from the eastern bastions. By 1906 it is 140m and by 1938 it is 170m away and a fully surfaced road runs between the fort and the shore.

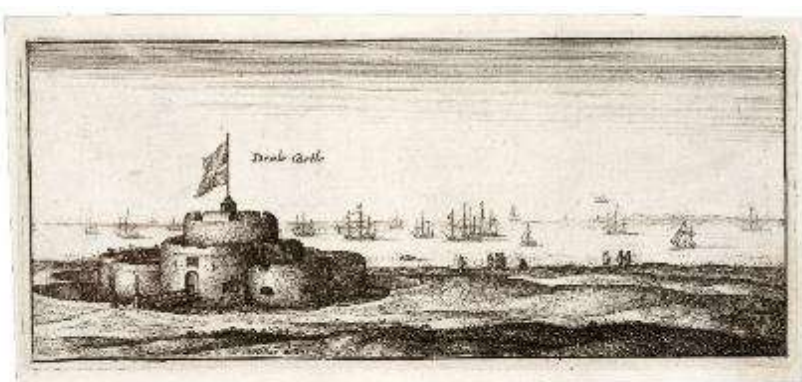

Figure 3B186. Wenceslaus Hollar's engraving of Deal Castle, 1824.

At Deal the fort was built to a similar standard at Walmer, but had six bastions instead of four. A 17th century engraving by Wenceslaus Hollar shows the moat as dry, but the proximity to the coast is notable. Daniell's Deal Castle engraving of 1824 appears to show the shoreline creeping closer to the fort and even beginning to undermine the moat's external wall. Again, the OS County Series maps chart a slow reclamation of the shore and the mean high water mark moves from 20m away from the moat in 1872 to 45m in 1938.

Figure 3B197. Ordnance Survey maps of Deal Castle. From left to right, top to bottom: 1st edition (1872), 2nd edition (1898), 3rd edition (1906), 4th edition (1938), modern aerial imagery (2014) and merge of the 1st edition map with modern aerial imagery, showing the full extent of coastal change since 1872

Sandown, the northernmost of the three forts, has suffered the most form coastal erosion. Although evidently in use up until the 19th century, the moat was apparently breached at the end of the 18th century and a Victorian plan from 1860-1865 shows the fort itself half sat on the beach; the dry moat has been totally lost on the east side and the two eastern bastions face directly onto the beach. An attempt has been made to close the remaining moat off from the sea and there are a number of groynes on the beach, presumably to try and stabilise the shoreline. This condition is reflected in an 1853 print from the Illustrated London News that shows the sea lapping against the eastern bastions (Figure 3B28).

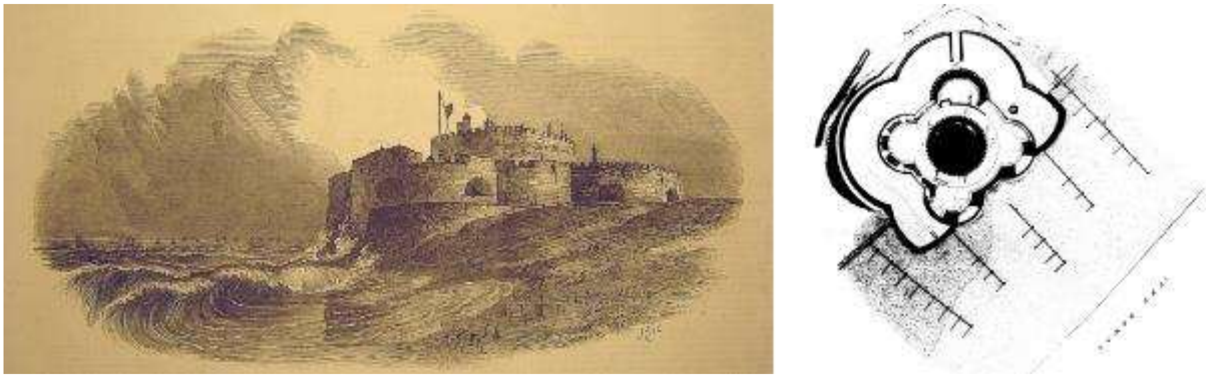

Figure 3B208. Two views of Sandown Castle; a plate from the London Illustrated News, 1853 and; a Royal Engineer Map from 1860-1865.

By 1872 the condition is much worse; the OS County Series first edition map shows the castle to be largely destroyed by the sea. Artwork from the Illustrated London News on 18th November 1882 shows the fort at the time of its demolition (the War department having decided that nothing could be done to sustain it); the fort's central keep and bastions are largely ruined. All trace of the fort bar the foundations of the two westernmost bastions has been removed by the second edition map of 1898.

Figure 3B29. Sandown castle seen from the beach in the early 1900's.

3B.7 Conclusions and Recommendations

The Shoreline Management Plan Review for the Isle of Grain to South Foreland does recognise the historical perspective, noting that erosion and flooding is nothing new. Such historical evidence can be used to help with future planning and management, however, much of the Kent coast has had coastal defences built and witnessed land reclamation meaning that very little of the coast is now natural. Human intervention here has had a dramatic effect on natural change, with large concrete defences reducing erosion and therefore preventing any sediment being recycled resulting in the loss of beaches.

The Kent coastline was painted by numerous artists, allowing a chronological succession of works to be viewed, which describe coastal change in detail, a good example is the site of Reculver on the north coast. William Daniell created numerous views of the Kent coastline providing a *State of the Coast* visual report for the county in the 1820's. These can demonstrate social and development changes as well as physical and environmental conditions at that time.

Such artworks should be used to support investigations of long-term coastal change, in particular where buildings and other structures are visible it is possible to make judgements on the rate and scale of cliff and beach change. The ranking system has provided a list of artists that depict this coastline most accurately and can be used by those wishing to learn more about coastal change at specific locations.

Data from prehistoric sites is limited, with little known about specific dating or environmental analysis. Further work would be required to investigate these sites in detail in order to reconstruct the ancient landscape and create an evolution model of change over time. The Medieval and Post-Medieval record is more detailed, particularly the coastal defences built in the 12th Century and later by Henry VIII. Even in the 17th Century these sites were recorded as being at risk from erosion by the sea. Later human intervention along this coast has meant that two of the three main forts are now further from the sea than they were when built, but one has now been destroyed by the sea.

Combining artworks, archaeological data, coastal heritage, maps, charts and photographs demonstrates coastal change over at least the last 1,000 years on the Kent coast, providing additional material for ongoing coastal monitoring which only started in the last 10-20 years.

This report is a section of the Technical Report for the Archaeology, Art and Coastal Heritage – tools to support coastal management and climate change planning across the Channel Regional Sea (Arch-Manche) Project. To cite this report please use the following:

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3B.8 Case Study References

Archibald, E. H. H., 1980. '*Dictionary of Sea Painters*'. Antiques Collector's Club. Woodbridge

Burridge, David. 1997. *20th Century Defences in Britain*: Kent. London: Brassey's.

Cooke, W. B., 1826. *Picturesque Views of the Southern Coast of England*. Private Press.

Council for British Archaeology (2006) *Defence of Britain Archive*. York: Archaeology Data Service (doi:10.5284/1000327)

Daniell, W. & Ayton, R., 1814. *A Voyage Round Great Britain.* Longman & Co..

Dover Town Council. 2014. Dover Castle. Available from: http://www.dovertowncouncil.gov.uk/article/dover_castle.aspx [Accesses April 2014].

Ellis, A (Ed.), 2004. '*Oil Paintings in Public Ownership in Kent'.* The Public Catalogues Foundation.

Finden, E. & Finden, W., 1838. *Views of the Ports, Harbours, Watering Places and Picturesque Scenery of Great Britain*. Virtue & Co. London.

Graves, A., 1901. '*A Dictionary of Artists who have Exhibited Works at the Principal London Exhibitions 1760-1893.* Kingsmead Press.

Halcrow, 2006. *Risk assessment of coastal erosion*. Joint Defra/EA flood and coastal erosion risk management R&D programme. Technical report: FD2324.

Kent County Council. 2013. *Archaeological Sites.* Available from: http://www.kent.gov.uk/leisure_and_culture/heritage/explore_kents_past/days_out_in_the_past/archaeological_sites.aspx. [Accessed January 2014].

Kenyon. J. R. 2013. The State of the Fortifications in South-east England in 1623. *Fort: The International Journal of Fortification*. Fortress Study Group. Volume 41. PP 127-140.

Lambourne, L. & Hamilton, A. J., 1980. '*British Watercolours in the Victoria and Albert Museum'.* Crown Copyright. London.

Lawson, T., and Killingray, D., (Eds). 2004. *An Historical Atlas of Kent*. Chichester: Phillimore & Co. Ltd.

Lyell, Charles, 1838. '*Elements of Geology'.* James Murray. London.

MacKenzie, I., 1987. '*British Prints'.* Antique Collectors' Club. Woodbridge.

Mallalieu, H., 1984. '*The Dictionary of British Watercolourists up to 1920'*. Antique Collector's Club. Woodbridge.

Russell, R. 1969 '*Guide to British Topographical Prints'.* David & Charles. Newton Abbot.

The Museum of Thanet's Archaeology. 2014. *Virtual Museum Galleries*. Available from: http://www.thanetarch.co.uk/Virtual%20Museum/1_Virtual%20Museum%20Main%20Pages/Virtual_Museum_Museum_Guide.html [Accessed April 2014].

Saunders, A. 1989. *Fortress Britain*. Liphook, Hampshire. Beaufort Publishing.

Small, F. 2002. R*ichborough Environs Project, Kent: Report on the Aerial Photographic Transcription and Analysis*. English Heritage. Ref: AER/12/2002.

South-East Coastal Group, 2006. '*South Foreland to Beachy Head Shoreline Management Plan Round Two'.*

South-East Coastal Group, 2008. '*Isle of Grain to South Foreland Shoreline Management Plan Round Two'.*

Williams, John (Ed). 2007. *The Archaeology of Kent to AD 800*. Woolbridge: The Boydell Press.

Wessex Archaeology. 2011. *South East Rapid Coastal Zone Assessment, Phase 1: National Mapping Programme Report.* Ref: 71330.01.

Wood, C., 1978. *'The Dictionary of Victorian Painters'* (2nd Edition). Antique Collector's Club. Woodbridge.

CASE STUDY 3C – HASTINGS, UK

Case study area: Hastings, UK.

Main geomorphological types: Soft cliffs, sand and shingle beaches.

Main coastal change processes: Cliff erosion and instability, beach change.

Primary resources used: Art, archaeology, maps and charts, photographs.

Summary: The cliffs at the eastern end of the Hastings frontage are subjected to coastal erosion and instability. The main beach is affected by erosion processes and sediment accumulation and depletion. A combination of historic paintings, maps, charts, photos and archaeological data has demonstrated the long term changes in terms of erosion and sediment levels.

Recommendations: Coastal managers should use these resources to understand the long term changes, in particular where humanly-made structures (the harbour arm) have influenced the sediment regime. These resources provide hundreds of years' worth of data which can contribute to ongoing monitoring of the coast and modelling for future change.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

Hastings is one of six UK case study areas for the Arch-Manche project. This report section introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented along with the results of the art study. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. For further details about the project and the methodology see Section 2.

Within the Hastings area the archaeological and palaeoenvironmental resource and the available art resource have been researched, ranked and analysed. The extents of the detailed study areas are shown in Figure 3C1 below. The area considered for archaeology and palaeoenvironment has been selected to provide a representative range of types of evidence across a range of periods spanning from Palaeolithic through to more recent coastal heritage. The art, photograph and map case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time.

Figure 3C1. Map of the Hastings Study Areas. The dotted line is the extent of the archaeology area and the red square is the extent of the art area.

3C.1 Introduction to the Hastings Study Area

The historic town of Hastings is situated on the coastline of East Sussex, approximately 16 miles (21km) to the east of the large seaside town of Eastbourne. The study area comprises Hastings main beach, and the beach and cliff line to the east of the seafront.

3C.1.1 Geology and Geomorphology

Hastings is situated on the south coast facing the English Channel, and lies within the wider geological structure of the Wealden Dome of Kent and East Sussex. The coastal geology in this area is comprised of the Hastings Beds, named after the locality, which, geologically, lie beneath the Lower Cretaceous rocks of the Wealden Clay and the Lower Greensand. These are in turn overlain by the Gault and Upper Greensand and the Chalk, which outcrop to the east and to the west.

Essentially the cliffs on the Hastings frontage, extending east towards the village of Fairlight, are composed of weak clays, siltstones and sandstones of the Lower Cretaceous, which form a high but unstable cliff line that is prone to coastal erosion at the toe; the frontage is also affected by cliff face weathering and instability problems. Sea spray and groundwater, together with a reduction in horizontal stress due to erosion, causes softening of the clay sections of the cliffs to take place. Joints in the overlying rocks open and blocks rotate and move forward as secondary toppling takes place.

Eventually massive siltstone blocks break away from the cliff, causing a loss of support to the overlying blocks, which will also eventually fall into the sea. The talus or debris at the base of the cliff is quickly removed by the sea, enabling the process to initiate once more. The eroding sandstone cliffs contribute to the sedimentary system and the material is carried along the coast by the process of longshore drift. Fronting the town of Hastings, the beach is composed of shingle in its upper part with an extensive sandy foreshore.

3C.1.2 Summary of the Archaeology and History of the Study Area

Early Prehistory

The shoreline of Sussex underwent several changes during the Palaeolithic period as ice ages affected sea levels. At some periods the sea level was anywhere between 8 metres and 40 metres above the present day sea level, whilst at times of lower sea level Sussex was connected directly to mainland Europe (Rudling, 2003: 1-2). It is likely that groups of hunter-gatherers travelled across the area of modern day Sussex when conditions became habitable again following the last Ice Age, around 11,000 BC. The Holocene sea level rises caused by thawing ice caused large lakes in the area of the North Sea to breach, eventually flooding the river valley between Britain and France and creating the English Channel. After this, sea levels along the Sussex coast continued to rise, before stabilising in the Neolithic period (Rudling, 2003: 2). The exact rate of sea level change would have been affected by a variety of factors; particularly the topology and geology of the land surfaces at different points along the coast (which vary from chalk ridges to peat bogs) and the rate at which the south east of Britain was 'sinking' as the land mass of Great Britain geologically 'tilted' (Rudling, 2003: 2).

The precise extent of the coastline in the Palaeolithic, Mesolithic and Neolithic periods is open to some debate. Certainly during the Palaeolithic, any shoreline sites in the vicinity of the study area most likely lay somewhere nearer to the centre of the present day English Channel than the Sussex coast. To date, their presence has only been suggested by the recovery of flint axes and barbed harpoon points dredged from the seabed. The area of the present day coastline would have been several miles inshore during the Late Upper Palaeolithic and Mesolithic periods; as a result freshwater conditions in the river valleys would have encouraged peat and other organic material to flourish. This is particularly true in the Pett Levels to the east of Hastings, where some 11m of organic sediments have been recorded offshore, representing a build-up of organic matter over 10,000 years (Rudling, 2003: 2).

There are therefore, few Palaeolithic records in the study area; only three find spots are identified in the Hastings locality. Conversely, there is a lot of activity identified in West Sussex particularly along the old shoreline at Boxgrove (Rudling, 2003: 24). Much the same is true in the Mesolithic period, with identified sites tending to be dominant in the west and only a few within the study area. Flintwork suggests there may have been a settlement around the present day site of the castle (Hastings Chronicle, 2014: Key Events – The Origins of Hastings).

Later Prehistory

This trend of increased activity in the west continues into the Neolithic period; it is likely that the coastline may not have reached close to its current position by this time. The South Downs dominate western Sussex and it was here that Neolithic peoples began to settle in the landscape. There are no identified cursus', causewayed enclosures or other signs of industry or settlement in East Sussex, despite the plethora of such sites to the west. Neolithic Pottery has been recovered from East Hill and the site of the present day castle. Stone axes have been found at Fairlight and other flint tools have been found in the Bourne Valley, indicating at least the presence of Neolithic communities in the area at this time (Hastings Chronicle, 2014: Key Events – The Origins of Hastings).

During the Bronze Age, it is likely that the sea level was still several metres below its present day level. Research at the Pett Levels to the east of the study area suggests that a prehistoric forest dominated the coastline (Rudling, 2003: 6, 11). This is most likely the same forest that stretched right across the study area's coast to Bulverhythe and Little Galley Hill, and onto the hills inshore (Hastings Chronicle, 2014: Key Events – The Origins of Hastings). During the driving of piles for Hastings Pier in 1872, huge tree trunks were discovered embedded beneath a layer of clay. One of these; a two ton 7.3m by 1m trunk had to be removed and was displayed in Alexandra Park for a number of years. It is presumed that it was part of the Bronze Age forest that ran along the shore (Hastings Chronicle, 2014: Hastings Pier). Elsewhere metal axeheads and a probable barrow on East Hill suggests activity in the area (Hastings Chronicle, 2014: Key Events – The Origins of Hastings).

By the Iron Age the coastline was most likely beginning to assume a familiar shape, although it may well have still been slightly offshore of its present day location in the study area. The first confirmed settlements at Hastings date from this period (although they are not to be taken as an indication of continual subsequent occupation). A large Iron Age hillfort was constructed on East Hill and there was almost certainly another on the site of the present day castle on the west side of the Bourne Valley. Although inland, they would have had a dominant view of the English Channel (Rudling, 2003: 4). Excavations at Beauport Park have suggested a pre-Roman round-house may have existed here (Wealden Iron Research Group, 2014), and it is possible that iron extraction and working was taking place at this site long before the Romans arrived. If this is the case, it is possible that the settlements at Hastings were already doing a brisk trade with Gaul and the Roman Empire before 43 AD.

Roman Period

The Roman 'invasion' of 43 AD may have resembled a peaceful take-over or even liberation in areas like Sussex, where there is little evidence of conflict or defences to oppose them. A 'client' kingdom was quickly established in Sussex. A new king, loyal to the Romans, quickly established Roman influence in the area (Rudling, 2003: 111-112).

Although a number of Roman settlements developed along the south coast (such as at Pevensey to the west and in Kent to the east), there is no archaeological evidence of any settlement at Hastings. A number of findspots have suggested some Roman presence in the study area, but many of these are poorly recorded. The suggestion of a Roman camp on East Hill is confirmed only by the presence of a coin hoard and an undated earthworks (Fradley & Newsome, 2000: 4). However, there is the possibility of a substantial, but as yet unrecorded, Roman presence in the area (Fradley & Newsome, 2008: 26).

Although outside of the study area, Beauport Park, three miles from present day Hastings town centre, shows that Roman industry was based nearby. Within these grounds, excavation has revealed a substantial amount of Roman remains, including a bath-house and substantial iron works (Open University, 2006: Beauport Park). This is believed to be the third largest iron works in the Roman Empire and iron will have been traded back into Europe. It is possible that a natural harbour at Hastings could have been used for such a purpose; the Classis Britannica (Roman fleet) would have been ideally situated to control the Channel and exports of this iron (Rudling, 2003: 227), but the absence of significant structures in Hastings itself means that this remains conjecture (Hastings Chronicle, 2014: Key Events – The Origins of Hastings).

Medieval Period

With the withdrawal of the Romans, Britain fragmented into a number of separate Kingdoms. The area of modern day Sussex was originally the Kingdom of Suth Saxe (South Saxons) but Hastings appears to have been a separate territory and kingdom of the Haestingas tribe. Raids by other nations were a constant risk on the south coast and it is recorded that King Offa of

Mercia defeated the Haestingas tribe in a battle near Hastings in 771. However, it may have continued to exist as a separate province within Sussex until the 11th century (Rudling, 2003: 159). This separation may have been a result of the relative isolation caused by the Pevensey Levels to the west, Romney Marsh to the east and the Forest of Weald to the north (Hastings Chronicle, 2014: Key Events – The Origins of Hastings).

Hastings Castle almost certainly had pre-Norman conquest origins. It is often claimed that a reference to a castle at Hastings in the 10th century Burhal Hidage actually refers to upgraded works at the Roman fort at Pevensey (Pevensey Castle), but it seems likely that a Motte and Bailey Castle already existed on the hilltop at Hastings when William the Conqueror arrived (Rudling, 2003: 157). This would itself have been built on the site of the supposed Iron Age promontory hillfort (Fradley & Newsome, 2008: 25). The first settlement in the location of present day Hastings probably began in the 9th century. Whether this was centred in Priory Valley (the land to the west of Hastings Castle) or the Bourne Valley (to the east of the castle, the area known today as the Old Town), is uncertain. However it is most likely that the town was a favoured port; a natural harbour that was ideally placed for cross Channel trade (the Stade beach in front of the Old Town comes from the Saxon term ‘landing place’). However the shingle harbour will have been prone to coastal movement and another port was established at Bulverhythe (meaning ‘harbour of the borough’) (Hastings Chronicle, 2014: Key Events – The Origins of Hastings).

Shortly after his arrival in Britain, William ordered the castle reinforced and by 1100 AD it was a Rapal Castle, the centre of the Rape of Hastings (Rudling, 2003: 173), an administrative area that predated the Norman Conquest and was gifted by William to his cousin Robert, Count of Eu (Sussex Castles, 2014: Hastings Castle). At the peak of its development it had a stone keep and a church inside its outer earthworks. The castle would have been important to the defence of the harbour, especially as its prestige increased with the development of the Cinque Ports. In 1216 it was partially dismantled on the orders of King John, but he later took possession of the castle and refortified it (Hastings Chronicle, 2014: Key Events 771-1699).

The establishment of the Cinque Ports in 1155 AD was extremely beneficial to Hastings, one of five towns ports that was given generous tax exemptions and trading rights in exchange for being on hand for military action in the event of a war (the other four being New Romney, Hythe, Dover and Sandwich). With these privileges Hastings flourished, as did its subsidiary (or ‘limb’) ports of Winchelsea, Hydneye, Pevensey, Northeye, Seaford, Bekesbourne, Grange, Bulverhythe and Petit Iham (The Cinque Ports, 2014: Limbs – Past and Present).

Hastings’ success as a port was owed to its excellent natural harbour, but in 1287, a great storm, the last of several violent storms that century, battered the town. As well as destroying the natural harbour the storms caused part of the castle and keep to collapse into the sea. It may have also flooded Hastings town and caused it to subsequently be built on a new layout in the Priory Valley (now known as the Old Town) (Hastings Chronicle, 2014: Key Events 771-1699).

French forces twice attacked Hastings in the 14th century, causing damage to the castle and sacking the town. The castle was reinforced after the first raid of 1339 and significantly, some of the oldest houses still extant in the old town date to this period, suggesting that the sacking necessitated rebuilding the entire town (Hastings Chronicle, 2014: Key Events 771-1699). The second raid of 1377 was also very destructive; it caused substantial damage to the castle (which was not repaired) and town and made it into a small and weak port. A wall built along the seaward side of the old town in 1385 may have been to slow the rate of coastal erosion or as a military defence against French raiders (Hastings Chronicle, 2014: Key Events 771-1699). Hastings now consisted of a small town built along two roads running to the shore between the castle and East Hill, and would remain much the same until the mid-18th century.

Post-Medieval Period

By the 16th century, Hastings' natural harbour had by this time silted up entirely. In 1596 and again in 1597 efforts were made to construct a stone pier that could resist the weather and shelter a mooring area. Both were destroyed by the onset of winter (Rudling, 2003: 12). The remains of the piers, consisting of exposed timbers and a scatter of rocks, were still visible and recorded in 1833 (Rudling, 2003: 228).

Despite these setbacks, a fishing fleet continued to operate from Stade Beach in front of the town. The fishermen worked a two season routine; in the first half of the year, they would head west to catch mackerel, and in the second half of the year they would fish for herring in the North Sea. A series of huts were built for storage; it is believed that the huts date back as far as the 16th century, although they have almost certainly been rebuilt a number of times. The present layout dates from the 1830s when new regulations decreed that they may not be more than eight feet square. Many of them were thus made as tall as possible to provide the maximum amount of storage on a small plot of land. Some 109 were recorded in the 1830s, but only 45 remain in use today.

Until 1855, Hastings Council refused to construct any shore defences in front of the Old Town. This was partly an effort to force the fishing fleet to relocate, but when storms in 1882, 1883 and 1884 caused damage to the town, they were forced to build a groyne that was completed in 1887 (Hastings Chronicle, 2014: Key events 1850 - 1899). In 1896, work started on a new harbour in front of the Old Town. Insufficient funds and the presence of a prehistoric riverbed some 250m offshore, meant that the harbour was not completed. Instead, one arm of it was left sticking into the sea. By 1902, the idea of a harbour had been abandoned entirely and no further work has taken place since. The wall remains, despite regular battering from the sea, and has offered a degree of protection to the fishing fleet based on the Stade beach.

Hastings Pier was first conceived in the 1860s; work began in 1869 and it was opened to the public in 1872. The pier is 278m long and had a large pavilion at its seaward end. This was destroyed by fire in 1917 but rebuilt in 1922 and additional landing stages and landward pavilions were added to the pier over its lifetime (National Piers Society – Hastings, 2014). The success of the pier led to a rival pier and promenade being constructed further west at St Leonards. Begun in 1888 and completed in 1891, this pier had its principal pavilion at the landward end and a landing stage at the seaward end. This was washed away in an 1896 gale and had to be replaced (Hastings Chronicle, 2014: St Leonards Pier).

Despite the apparent vulnerability of the beach at Hastings, few significant anti-invasion defences were built in the study area in this period. The nearest Tudor 'Device Fort' was Camber Castle at Rye, although there may have been many less significant and unrecorded batteries all along the south coast. It is believed that the coastal wall between the ruined castle and East Hill was rebuilt in the 1540s; if this is the case, the remains extant today most likely date from this period and not the 14th century (Hastings Chronicle, 2014: Key Events 771-1699). A battery for seven guns was constructed overlooking the Stade in 1760; this was also recorded on an 1833 map and was presumably still armed at that time (Rudling, 2003: 230). Another battery was located on the shore between Bulverhythe and Pebsham. During the Napoleonic era, this battery was replaced by a Martello Tower, one of 74 built along the south east coast in the early 19th century. Although these were generally built 500m apart, there was a small cluster of five at Bulverhythe and a significant gap of seven miles between these and the next one at Pett Level, leaving Hastings itself largely undefended (Saunders, 1989: 142). The five at Bulverhythe (Martello Towers 39, 40, 41, 42 and 43) were all lost in the late 19th century; three were destroyed by the sea and two demolished to make way for the train line. The nearest Victorian defences to be constructed during the 1860 Palmerston Forts construction period were at Newhaven (Rudling, 2003: 191). However, a Victorian volunteer rifle range was established on East Hill, with targets to the east on Ecclesbourne Glen. There may also have been an earlier (Napoleonic era) fortification on East Hill, in the centre of the Iron Age hillfort (Fradley & Newsome, 2008: 15).

Modern

In the 1930s the town enjoyed some renewed expansion. As coastal resorts declined in popularity, the council initiated an extensive rebuilding project. In the 1930s, a long, two tier promenade was constructed between the coast road and the beach and to the west more frequent groynes were built. Inland the town continued to expand to the west, absorbing St Leonards and Bulverhythe (Hastings Chronicle, 2014: Key Events 1900-1949).

The only evidence of purpose built First World War defences in the area is a small group of trenches on East Hill that probably date from this period (Fradley & Newsome, 2008: 21). During the Second World War a number of beach defences were installed to resist an enemy invasion. To the west of the study area a number of road blocks, consisting of anti-tank blocks, pillboxes, minefields and machine gun posts were established at Bulverhythe (Defence of East Sussex Project, 2009: Roadblocks). Little remains of any of these today, although there are eight anti-tank blocks on the beach in front of the railway line. These defended localities continued east along the coast into St Leonards and a number of buildings were fortified to contribute to the overall defence (Defence of East Sussex Project, 2009: Defended Localities). A number of defences were clustered around Hastings Old Town; German reconnaissance photographs show a number of anti-tank blocks and pillboxes around the harbour, although these are not visible today (Defence of Britain, 2006).

Hastings and St Leonards were extensively bombed during the war; a matter that was not helped by the fact that no anti-aircraft guns were installed until late 1940. Some 550 bombs, 760 incendiaries and 16 V1 Flying Bombs fell on the town, killing 154 people and injuring 700 (1066 Online, 2014: World War II). Hastings Pier was ‘sectioned’ (by removing sections of decking to isolate it from the shore) and occupied by the army. It suffered some damage from bombing raids but reopened in 1946. Various additions were made to it in the 1950s and 1960 and it continued to operate until 2006 when it was closed to the public (National Piers Society – Hastings, 2014). In October 2010, it caught fire in a suspected arson attack, destroying some 95% of its superstructure. Since then, Heritage Lottery Funding has paid for refurbishment of the pier that may see the pier re-open in spring 2015 (BBC, 2014). St Leonards Pier was also sectioned, suffered bomb and fire damage and was not re-opened. After it was severely damaged by a gale in 1951, its remains were subsequently removed (National Piers Society – St Leonards, 2014).

3C.1.3 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for the Project

A general overview of the prehistoric archaeology of the Sussex area, in particular the geological and coastal change the area has undergone was obtained in *The Archaeology of Sussex to AD2000*. This volume draws on a number of papers to create a thorough explanation of the history and archaeology of the county, which could be combined with records of individual locations within the study area.

Despite its title, *The Archaeology of Sussex to AD2000* really only focusses on history up to and including the Medieval period. Later periods were researched using local websites such as *The Hastings Chronicle* (an online evolution of the print newspaper) and *1066 Online*, an internet guide to Hastings.

A number of records for individual sites and features were identified in the NRHE and accessed through Pastscape. Other sites could be examined through archaeological reports such as *East Hill, Hastings, East Sussex: A Landscape Survey and Investigation* and the *South East Rapid Coastal Zone Assessment Survey*. However, the latter was conducted over some 150 miles of coast and was not therefore suitable for detailed analysis of the study area.

3C.1.4 Art History of the Area

The Sussex coast has a rich history of coastal landscape paintings. Views of the Hastings frontage were included by the great topographers, William Daniell and Richard Ayton, in their *Voyage Round Great Britain* (Daniell & Ayton, 1814), when they passed by in 1824. Daniell produced two fine aquatints of the town looking from both the easterly and westerly directions.

Relatively easy access from London encouraged artists to paint the scenery of the Sussex coast with its dramatic clifflines and the activities of fishermen living and working below from the shore. In the early nineteenth century it is believed that almost every member of the famous Old Watercolour Society visited and painted the scenery at Hastings. Later, the Finden brothers commissioned artists to produce views along this part of the Sussex coast to illustrate their publication *Ports, Harbours and Watering Places of Great Britain* (Finden & Finden, 1838).

During the nineteenth century, Pre-Raphaelite artists, including William Holman Hunt, painted the Sussex cliffs coastline at Fairlight for example *'Fairlight Downs – Sunlight on the Sea'* and his celebrated *'Straying Sheep'*, which shows a scene high on the cliffs above Fairlight Cove. Britain's most famous artist, J. M. W. Turner, also chose to visit Hastings to paint a view of the town from sea in July-August 1818.

The London artist, William Collins, painted the coastline here in the 1830s, whilst John Thorpe, a resident of nearby St Leonard's, painted the coast in the 1850s and early 1860s. Another topographic artist, James Francis Danby, visited the town regularly between the 1840s and 1870s. John Mogford, who was well known for his accurate portrayals of coastal scenes, also visited Hastings during the 1840s and 1860s, as did Charles Thorneley, who depicted coastal shipping off many of Britain's famous seaside resorts.

William Henry Borrow, who lived in Hastings from 1876, made an important contribution to the art heritage of the town, producing a series of detailed oil paintings showing the town, the beach and the cliffline from different aspects. In 1901 Charles A. Graves painted *'The remains of the Elizabethan Harbour at Hastings'*, which shows the relics of the structure located well down on the lower foreshore. In the 1920s the prolific watercolourist, Alfred Robert Quinton, painted the beach at Hastings and the cliffs to the east. A further active watercolourist, Ernest William Haslehust illustrated '*Hastings and Neighbourhood'* (Higgins & Haslehust, 1920).

3C.1.5 Art Resources Consulted for the Project

Full details of the data sources consulted for the project are available in Section 2.1. In order to establish the art resource available for this study it was necessary to review the topographical paintings, drawings and prints held by the principal national, region and local collections covering the East Sussex coastal frontage. To achieve this objective, on-line reviews were carried out of the collections held at the national level within key museums and art galleries including the Tate Britain, the Victoria and Albert Museum, the National Maritime Museum, the British Museum, the National Gallery and the Witt Library at the Courtauld Institute in London.

In addition it was necessary to establish if there were relevant artworks contained in museums and art galleries in East Sussex including Hastings Museum and Art Gallery, Hastings Library, Hastings Fisherman's Museum and the Royal Pavilion and Brighton Museum collections. As part of the research it was necessary to contact museum and gallery curators and search available publications, as well as undertaking research on the Internet, taking advantage of new facilities such as the Public Catalogue's Foundation volume (Ellis, 2004) and the BBC *Your Paintings* website.

In addition to searches of on-line databases and images held by national and local collections an assessment has been made of art from the study area contained in important publications and, in particular, catalogues of exhibitions at principal London galleries and also in East Sussex itself. The literature sources relating to works exhibited are comprehensive and comprise reviews of the artists and their works (e.g. Graves, 1901), together with catalogues and dictionaries published by the museums themselves and interested publishers (e.g. the Antique Collectors' Club). The published works of this kind do, therefore, represent a considerable resource of assistance to this study (Wood, 1978; Russell, 1969; Archibald, 1980; Lambourne & Hamilton, 1980; Mallalieu, 1984; MacKenzie, 1987).

A small assessment has also been carried out on historic photos, these were obtained through online research. Sources include www.sussexpostcards.info, www.1066online.co.uk and images from the Britain from Above project www.britainfromabove.org.uk. One map was also assessed in order to highlight the potential of this resource, this map was found through an online search of the website Old Sussex Mapped www.envf.port.ac.uk/geo/research/historical/webmap/sussexmap/sussex.html.

3C.2 Current Environmental Impacts, Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the Hastings coastline and reviews the current coastal management issues and approaches.

3C.2.1 Review of Key Contributors to Coastal Change

This shoreline has been retreating for many centuries, natural processes of rising sea levels and lowering sand levels have been occurring over a long time period meaning that erosion and flooding is nothing new. These natural processes have not been prevented by modern coastal defence works only delayed. However, many of the natural processes which circulate the sediment from eroding cliffs back into beach building material have been affected by anthropogenic development. Hastings is a popular seaside resort with an important tourism economy, many of these developments are tourism related or residential properties. The dense urban developments at Hastings extend to the edge of the low coastal slope and the town is fronted by a shingle beach. Due to the importance of the tourism economy and fishing industry this coastline is heavily managed, with only small sediment feeds coming from the Pevensey frontage (SMP2, 2006).

The Harbour Arms at Hastings are preventing shingle moving eastwards along the coast, but they also protect the town and support the fishing industry. To the east of Hastings the cliffs are largely undefended, these sandstone cliffs are witnessing continuous weathering and erosion. Erosion along this cliff will mean that sites like the Iron Age Cliff Castle at Hastings will be lost, although new archaeological material may also be exposed as the coastline changes. These cliffs are also of international environmental, geological and ornithological importance, with no significant cliff top development (SMP2, 2006).

3C.2.2 Summary of Current Coastal Management Approach

Hastings is covered within the South Foreland to Beachy Head Shoreline Management Plan (SMP2, 2006). Along this frontage there are two issues to be considered. First, coastal risk management relating to the Hastings resort frontage and, secondly, issues affecting the coastline to the east towards Fairlight. In terms of Hastings itself, there is a substantial value in terms of property, assets and heritage that is protected by existing defences, which have existed as far back as the fourteenth century. Over time, rising sea levels are expected to 'squeeze' the beach, and this may necessitate artificial replenishment in the future. Certainly the intention is to continue to maintain defences, upgrading them where necessary, over the next century.

From the eastern end of the town, eastwards towards Fairlight and Fairlight Cove beyond, the high sandstone cliffs are subject to continuous weathering and erosion. Where there is minimal development along the cliff top, the natural processes of coastal erosion and weathering will be allowed to continue, and certainly the eroding cliffs contribute to the overall sediment budget available along this part of the Sussex coast. However, at Fairlight, there has been significant loss of properties historically as a result of cliff retreat and cliff top instability problems. This has resulted in coast protection works and cliff drainage works being undertaken to reduce the impact of these processes. The intention is to continue to defend those frontages where it is economically justifiable and environmentally acceptable.

The long term policy for Fairlight to Hastings Cliffs will be no active intervention (SMP2, 2006).

3C.3 Archaeological and Palaeoenvironmental Ranking

This section outlines the results of the archaeological and palaeoenvironmental ranking from the Hastings study area, followed by a discussion of the results. The ranking methodology applied is detailed in Section 2.

3C.3.1 Results of the Archaeological and Palaeoenvironmental Ranking

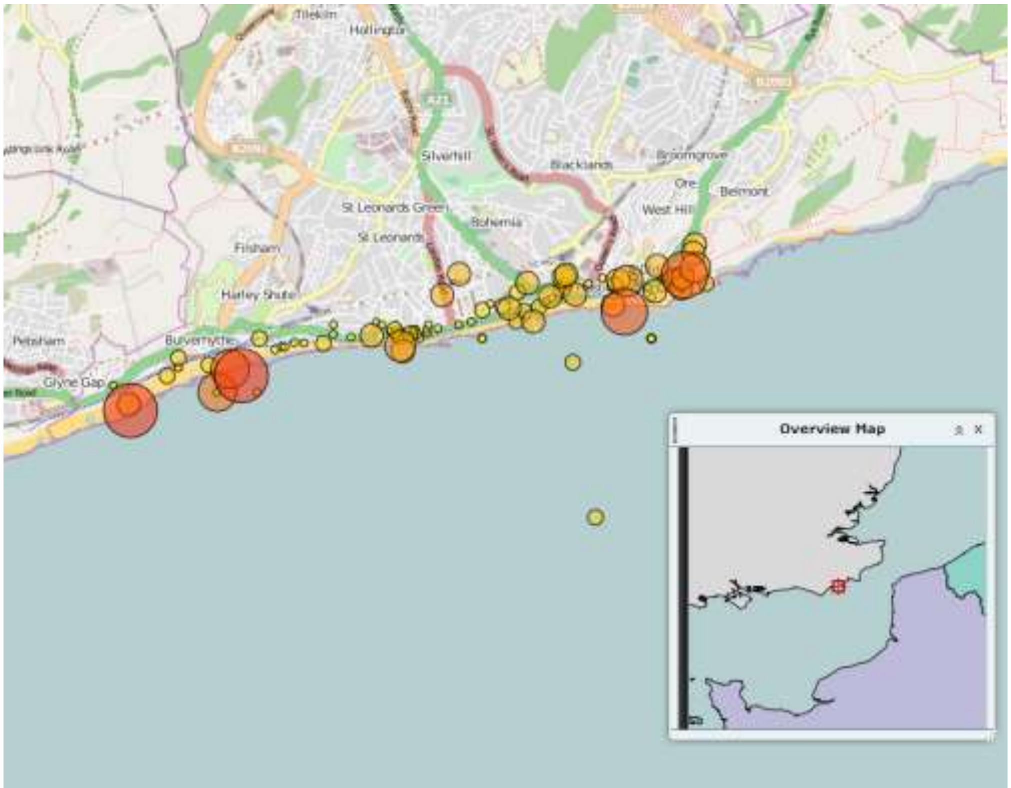

Figure 3C2. Map showing the distribution of archaeological and palaeoenvironmental sites within the Hastings study area

Within the Hastings study area data was obtained from the local Historic Environment Record (HER), the National Record of the Historic Environment (NRHE), the United Kingdom Hydrographic Office (UKHO) and the English Heritage Peat Database. It should be noted that where data from the HER and NRHE indicated sites of potential then further research was required in order to understand the full nature and extent of the site. Each data set went through a process of cleaning, in order to prevent the duplication of sites. A total of 150 sites and records were assessed.

The highest ranking sites are listed in the table below, the total score has been normalised to give each site a score out of 100.

APE uid	Site Name	Site Type	Period	Score – Sea Level	Score – Environ mental	Score – Temporal Continuity	Total Score	Coastal Context
708	BULVERHYTHE - Submerged Forest	Submerged landsurface	Prehistoric	High	High	High	100	Marine (below water)
713	LITTLE GALLEY HILL - Submerged Forest	Submerged landsurface	Bronze Age	High	High	High	100	Marine (below water)
2460	HASTINGS - Find Spot	Other find spot	Prehistoric	High	Medium	High	88	Above High Water
711	HASTINGS - Submerged Forest	Submerged landsurface	Unknown	High	High	Medium	88	Marine (below water)
2335	WRECK - Amsterdam	Wreck	Early Modern	High	Medium	Medium	77	Marine (below

								water)
3247	EAST HILL - Iron Age Hillfort	Monument	Iron Age	Medium	Medium	High	77	Above High Water
2368	HASTINGS - Caves	Monument	Prehistoric	Medium	Low	High	66	Above High Water
2464	HASTINGS - Find Spot	Other find spot	Palaeolithic	Medium	Low	High	66	Above High Water
2454	HASTINGS - Mound	Monument	Neolithic	Medium	Low	High	66	Above High Water
2380	BULVERHYTHE - Battery	Monument	Early Modern	Medium	Low	Medium	55	Above High Water
2375	HASTINGS - Battery	Monument	Early Modern	Medium	Low	Medium	55	Above High Water
2384	HASTINGS - Castle	Monument	Medieval	Medium	Low	Medium	55	Above High Water
2383	HASTINGS - Chapel	Monument	Early Modern	Medium	Low	Medium	55	Above High Water
2381	HASTINGS - Church	Monument	Medieval	Medium	Low	Medium	55	Above High Water
2374	HASTINGS - Church	Monument	Medieval	Medium	Low	Medium	55	Above High Water
2382	HASTINGS - Church	Monument	Medieval	Medium	Low	Medium	55	Above High Water
2484	HASTINGS - Church	Monument	Medieval	Medium	Low	Medium	55	Above High Water
2387	HASTINGS - House	Monument	Medieval	Medium	Low	Medium	55	Above High Water
2456	HASTINGS - Kiln	Monument	Medieval	Medium	Low	Medium	55	Above High Water
2394	HASTINGS - Market	Monument	Early Modern	Medium	Low	Medium	55	Above High Water
2373	HASTINGS - Mint	Monument	Early Medieval	Medium	Low	Medium	55	Above High Water
2451	HASTINGS - Pier	Marine Installation	Medieval	Medium	Low	Medium	55	Above High Water
2367	HASTINGS - Pier	Monument	Early Modern	Medium	Low	Medium	55	Above High Water
2385	HASTINGS - Priory	Monument	Medieval	Medium	Low	Medium	55	Above High Water
2508	HASTINGS - Well	Monument	Unknown	Medium	Medium	Low	55	Above High Water
2482	ST LEONARDS -	Monument	Medieval	Medium	Low	Medium	55	Above

	Church							High Water
2498	ST LEONARDS - Church	Monument	Early Modern	Medium	Low	Medium	55	Above High Water
2450	ST LEONARDS - Hoard	Other find spot	Bronze Age	Medium	Low	Medium	55	Above High Water
2389	ST LEONARDS - Pier	Monument	Early Modern	Medium	Low	Medium	55	Above High Water

Table 3C1. Results showing the highest ranking archaeological and palaeoenvironmental sites within the Hastings study area

3C.3.2 Discussion of the Ranking Results

The coastline of the study area, and that of East and West Sussex, has seen considerable change both during and since prehistory and the full extent of this is well demonstrated by a Bronze Age drowned landscape off Hastings. The most dominant features in the archaeological ranking are the submerged forests offshore of the study area. These examples of forests almost certainly made up one large prehistoric forest that stretched across this area of Sussex. This forest would have developed from the rich peat that had formed in this area and grown to its peak in the early to middle Bronze Age (Rudling, 2003: 6). It is also the flooding of the peat beds east of the study area that gives us a rough time frame for the advancement of the sea to this level (Rudling, 2003: 8). It is difficult to fully identify the prehistoric coast off East Sussex and its exact location and shift north over time is largely postulated (Rudling, 2003: 2). The Bronze Age forest is therefore the only hard evidence of a changing coastline, and certainly suggests a northward shift over time.

Above the mean high water mark, a number of other prehistoric sites might also suggest coastal change. Although further inland, the probable hillforts on East Hill and West Hill would have had commanding views of the coast, and may represent the promontory hillforts that are often seen in coastal locations (Fradley & Newsome, 2008: 25).

The concentration of medieval and post medieval sites along the present day shoreline of Hastings, although lower ranking, still tell us much about the stabilisation of the coastline in the study area in this period. The continued use of the fort on West Hill in both the Saxon and Norman periods and the establishment of settlements in the Bourne and Priory Valleys suggests settlement just inshore of the waterfront, making use of the lower ground protected from the elements by the hills (and by the fortifications on them).

A high ranking site that tends to support this is the wreck of the Dutch East India vessel *Amsterdam*. Wrecked in 1749, the stability of the wreck in the sandy mud of the foreshore has kept it well preserved (this stability continued after it was first photographed in 1911 until 1969 when it was first surveyed). This may suggest a stabilisation of the waterfront, doubtless aided by human activity, particularly the number of groynes built here and to the west at Bexhill. That said, exposed areas of the ship are slowly being destroyed by Toredo shipworm.

A result of this apparent coastal stabilisation is that more modern features tend to rank lower. A number of early modern and 20th century features rank quite lowly, owing to their recent construction and stable positions on land. On the other hand, the two piers have a slightly higher rank, reflecting the weathering they have suffered as extreme weather threatens the shore.

3C.4 Ranking Artistic Depictions

The focus on artistic depictions of the Hastings study area has been on historic paintings, however several historic photographs, maps and charts were also assessed in order to highlight the potential of this resource. The results of the ranking for each of these is presented below followed by a discussion.

3C.4.1 Art Ranking Results

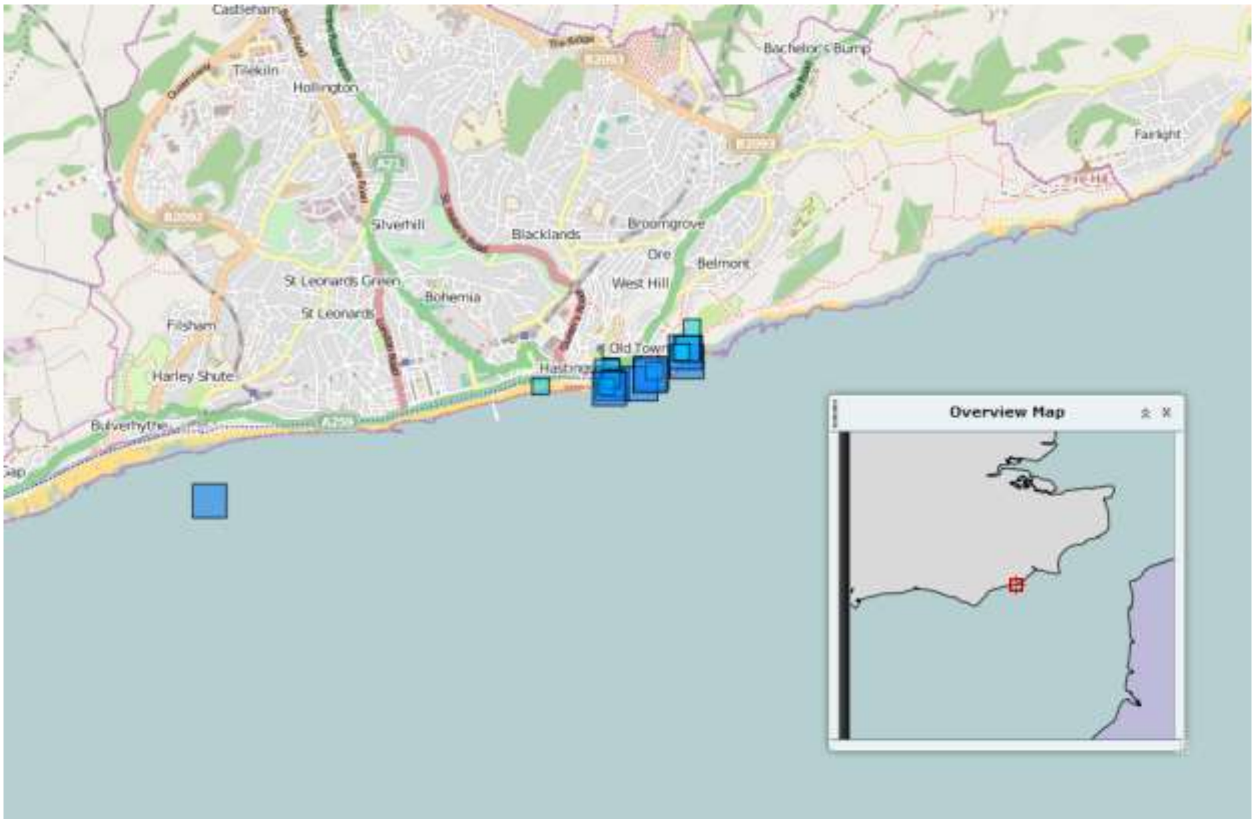

Figure 3C3. Location of artistic depictions ranked

The highest scoring artwork, a watercolour by A.R. Quinton, gained 70 points whilst two coastal engravings (a lithograph and a woodcut) each scored 59 points. Six oil paintings from the mid to late nineteenth century scored 59 points and have been the subject of more detailed study. The information imparted by these artworks is described in the case study below. The case study images depict the main beach fronting the resort and also show the sandstone cliffs and beach at the eastern end of the frontage. Further details on the ranked artworks are provided in Table 3C2 below.

Artists tended to paint attractive or dramatic coastal locations as well as meeting specific demands of their patrons. On the Hastings coast they were drawn to both the expanding and fashionable coastal resort and the activities of fishermen working along the shoreline from below the cliffs at the eastern end of the seafront. In many of the Hastings paintings, watercolours and prints the beach and cliffs are portrayed particularly well.

The result has been that many of the sites of key geomorphological and coastal risk management interest have been painted by artists particularly during the nineteenth century. As the aspiration of Activity Two was to illustrate how art can inform us of long-term coastal change it is fortunate that within the higher scoring artworks there are examples, which include locations affected by coastal and beach change.

These differing coastal landforms and processes and their impacts on coastal residents, assets and infrastructure could not have been easily matched to the most informative works of art without the provision of the ranking system. The ranking system has identified two case study locations along the Hastings beach frontage and, for each, several works are analysed as follows:

Case Study Number	Location	Artist	Date	Score type	Score period	Score style	Score enviro	Total Score
3.1	Hastings Main Beach	William George Moss	1814	Oil	Early	Topog.	Detailed View	48
3.2	Hastings Main Beach	William Henry Borrow	1879	Oil	Mid	Topog.	Very Detailed View	59
3.3	Hastings Main Beach	William Henry Borrow	1885	Oil	late	Topog.	Very Detailed View	59
3.4	Hastings Main Beach	Edwin Hayes	1885	Oil	late	Topog.	Detailed View	59
3.5	Hastings Beach & Old Harbour	Charles A. Graves	1901	Oil	Late	Topog.	Very Detailed View	59
3.6	Hastings Beach	English School	c.1880	Wood cut	Late	Topog.	Detailed View	62
3.7	Fish Market Hastings	Alfred Robert Quinton	c.1920	Water colour	Late	Topog.	Detailed View	70
3.8	East Cliff & Fishing Village	English School	c.1850	Litho-graph	Mid	Topog.	Detailed View	59
3.9	Hastings from East Cliff	William Henry Borrow	1881	Oil	Late	Topog.	Very Detailed View	59

Table 3C2. Top art ranking results for the Hastings case study

A more detailed interpretation of the individual artworks is provided in the case study description below. The assigning of scores to each artwork suggests names of those artists who have depicted different aspects of the Hastings Study Site coast most accurately across the timeline 1770-1920. These artists include William Henry Borrow, Edwin Hayes and Alfred Robert Quinton; they can be relied upon in terms of the accuracy of their depictions of the East Sussex coastline.

3C.4.2 Historic Photographs Ranking Results

Figure 3C4. Location of historic photos assessed within the Hastings study area

The focus of the Hastings case study area is on the archaeological/palaeoenvironmental data and historic paintings. However, in order to demonstrate the potential of historic photos a selection of six images were assessed, the results of the ranking are presented below, the ranking methodology is outlined in Section 2.2. Hundreds of historic images exist for this stretch of coastline, it should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic photos to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums and galleries, as well as private collections has the potential to provide many more.

The table below outlines the results of the ranking, note that photographs were ranked as either a heritage view or a non-heritage view.

Img_uid	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
1190	S.S. *Lugano* on fire off Hastings harbour arm	1906		High	Fair	88
1191	Hastings Harbour	1918		High	Good	100
1192	West Marina and Station	1920		High	Good	100
1193	Willowpit Wood Hastings Country Park from the west	1920	High		Good	100
1194	Rock a Nore Road and East Hill Cliffs	1946		High	Good	100
1195	The pier and town centre Hastings	1920		High	Good	100

Table 3C3. Results of the photo ranking within the Hastings case study area

The majority of photos assessed were of heritage views, containing features which can be identified today, the oldest photo assessed was taken in 1906.

3C.4.3 Maps and Charts Ranking Results

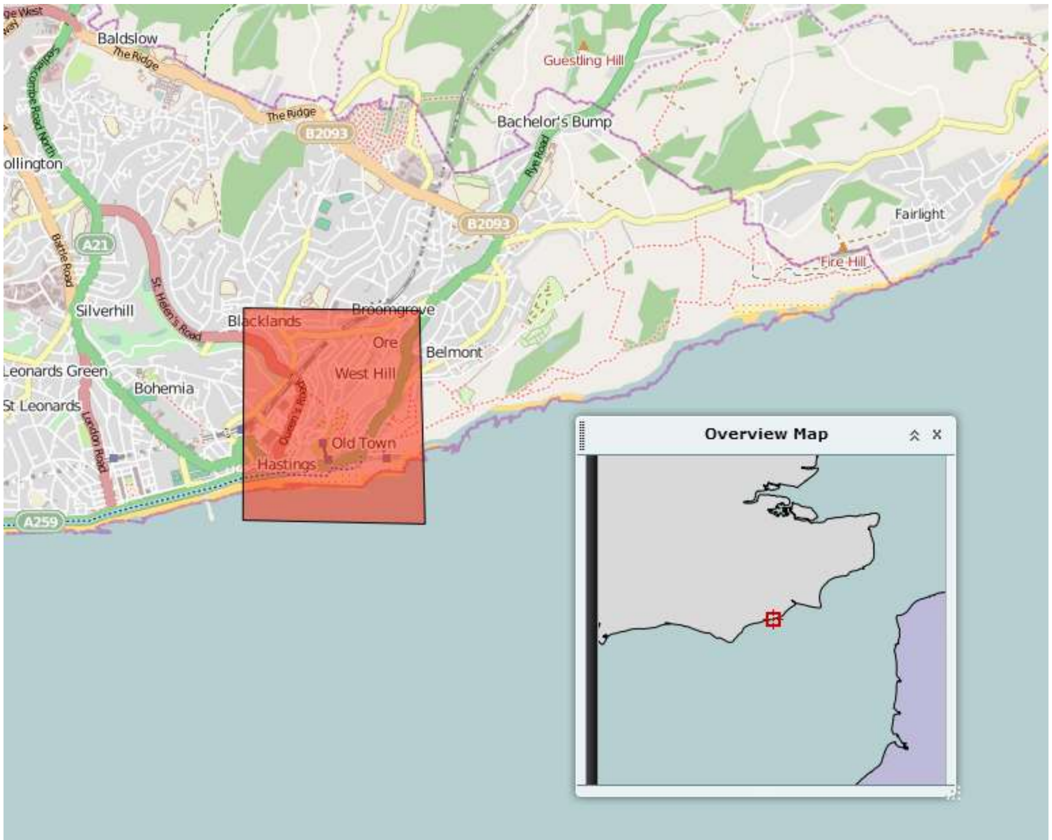

Figure 3C5. Location of the historic map ranked within the Hastings case study area

The focus of the Hastings case study area is on the archaeological/palaeoenvironmental data and historic paintings. However, in order to demonstrate the potential of historic maps a plan of Hastings and St Leonards from 1890 was assessed, the results of the ranking are presented below.

MAP_ uid	Title	Year	Score Chronometric Accuracy	Score Topographic Accuracy	Score Detail in non-coastal area	Score Geometrical Accuracy	Total Map Score
144	A Plan of Hastings & St Leonards	1890	93.33	50	100	100	85.83

Table 3C4. Results of the map ranking within the Hastings case study area

3C.4.4 Discussion of the Ranking Results

The Hastings case study has assessed the value of various artworks in terms of informing us about beach change and cliff conditions through a combined approach of desk-based research, museum and gallery searches and field visits. These have confirmed the added value of art from the period 1770-1920 to support other coastal surveying and monitoring technologies (e.g. space-borne, air-borne, ship-borne and terrestrial). It is important to remember that artists in the late Georgian and Victorian eras worked for very demanding, wealthy clients who often sought exact views of the coastal landscape to remind them of their visit. Before the days of photography precise images were, therefore, a prerequisite in most cases. The examination of the works of many artists painting the Hastings coast testifies to their considerable artistic skills in capturing accurately the coastal topography.

The artworks examined illustrate the form of Hastings beach over time. Some of the paintings show little change over the last two hundred years and this information is of equal interest to the coastal scientist.

The Hastings study focused on the use of historic paintings, however historic photos and a map were also consulted to review the potential of these data sources. Because of the dynamic nature of this coastline historic photographs can be a valuable resource with many historic photos containing depictions of the cliff with recognisable heritage features nearby. Five of the six historic photos showed heritage features, these include West Marina and Station, Hastings Pier, Hasting harbour and the Fairlight coastguard station. These can be compared to the modern situation and from this an idea of the rate of erosion since the date of the photograph can be gained.

Only one map was assessed in the scope of the project, this highlights the potential of historic maps to provide detailed information on coastal change. The map selected is from 1890 and scored highly. The high score means that the map is accurate and can be used to determine changes since 1890. Although the map scored highly overall the lowest score was for topographic accuracy which refers to the types of depicted elements. In this case the division between cliffs and beaches and the division between the coastal, intertidal and subtidal areas, was only scored as 'depicted' as opposed to 'well depicted' (see Section 2.2 for the ranking methodology). The geometric accuracy was high, this is mainly due to the detail of structures like churches, roads and other buildings which allowed for several accurate control points, this level of detail is also reflected in the maps high score for detail in non-coastal areas. The map also scored well for chronometric accuracy, the date of the map is known and terrain measurements are noted on the map.

3C.5 Art Field and Research Studies

No archaeological or palaeoenvironmental fieldwork was carried out for the Hastings case study site, this section, therefore, outlines the field studies undertaken as part of the art study.

3C.5.1 Key Research Questions to be Addressed from the Artistic Depictions

It has been possible to establish, through the art ranking system that the images are likely to be true representations of the conditions that would be seen at the time they were painted; the research questions to be answered through examination of the artworks at the Hastings case study sites are:

- What information can the historical images provide to support understanding of long-term coastal change?
- How can the potential of this resource be used most effectively by the end-user?

In order to identify the most suitable artworks that could be studied in more detail at the field study sites a national search was undertaken involving an extensive review of landscape paintings, watercolours and prints held in public and some private collections. Following ranking of 24 artworks twelve examples have been the subject of more detailed analysis involving site visits.

Along the Hastings frontage there are a range of physical conditions to be found that are of concern for coastal managers including eroding cliffs and cliff instability problems to the east of the town, and the potential for beach change. In order to reflect these varying conditions art images have been selected which examine the state of the main resort beach in front of the town and also the cliffs and beach at the eastern end of the frontage where the historic fishing village is situated.

3C.5.2 Approach to Information Gathering and Fieldwork for Assessing Coastal Artworks

Where it has been practical to gain access and relevant to the study, present day photographs were taken in the field to try, as far as possible, to match the views painted by the eighteenth, nineteenth and early twentieth century artists. It also provided the opportunity to assess the conditions of the cliffline and beach and changes that may have taken place over time. In terms of work in this field each of the locations has been visited and photographed in varying weather conditions. Inspections were timed to coincide with Low Water and a walk-over survey was made along the beach and base of the cliff returning along the cliff top. This ensured that thorough comparison could be made between the geomorphological conditions depicted in the artwork and the present day situation.

3C.5.3 Art Field Data Gathering Results

The Hastings case study was chosen to reflect two geomorphological processes, namely beach conditions along a developed frontage, and unstable coastal cliffs. Site inspections have confirmed that the locations selected do provide a good representation of these coastal geomorphology types against which the value of historical artworks can be tested.

The fieldwork element for Activity Two has been largely visual in terms of identifying the location of the paintings and making judgements, on site, of the role that art can fulfil as a qualitative or quantitative tool to support coastal risk management. The field inspections allowed a more accurate appraisal to be made of current physical conditions rather than relying upon written accounts and reports particularly as storm events can cause significant alterations over relatively short time periods.

The approach adopted for the case study has been the examination of each artwork to assess what it tells us about changes over time from field observation. At Hastings several artists painted the view from the same or a similar spot. This helps us to establish a chronology of coastal change through the nineteenth and twentieth centuries. The results for the Hastings case study are described below.

C1 Hastings Beach and Cliffs

Location

The case study site extends for a distance of approximately 2km along the Hastings resort frontage and east past the fishing village.

Why was the study site selected?

This site was selected in order to demonstrate how art reflects beach conditions over time. Hastings beach and the activities of the fishermen on the shore were a magnet for Victorian and Edwardian artists, and as a result there are numerous views of this location. The case study also includes views of the cliffs behind the fishing quarter at the eastern end of the frontage and reviews the depiction of the unstable sandstone cliffs.

Figure 3C6. 'Rescue at Hastings' by William George Moss, 1814. This oil painting shows the Hastings frontage from Low Water Mark, looking east along the extensive beach towards the town, and the high sandstone cliffline beyond. Image courtesy of Hastings Museum & Art Gallery.

Figure 3C7. An oil by the prolific Hastings artist, William Henry Burrow, dated 1885. The relatively gentle sloping foreshore can be observed. Hastings Castle on the top of the cliffs overlooking the expanding seaside resort. Image courtesy of Hastings Museum and Art Gallery

Figure 3C8. A further oil by W, H. Borrow, dated 1879, showing the steeper beach at the eastern end of the Hastings frontage; this is also reflected in the present day view. Image courtesy of Hastings Museum and Art Gallery

Figure 3C9. An oil by Edwin Hayes entitled 'Old Hastings', 1880, taken from Low Water Mark, showing the considerable expanse of beach at that time. Image courtesy of Hastings Museum and Art Gallery

Figure 3C10. 'Remains of the Elizabethan Harbour at Hastings' by Charles A. Graves, 1901. This view shows the timber relics of the harbour. Beyond is the fishing village and behind it the jointing and mechanisms of failure of the rugged sandstone cliffs are particularly well painted, Image courtesy Hastings Museum and Art Gallery

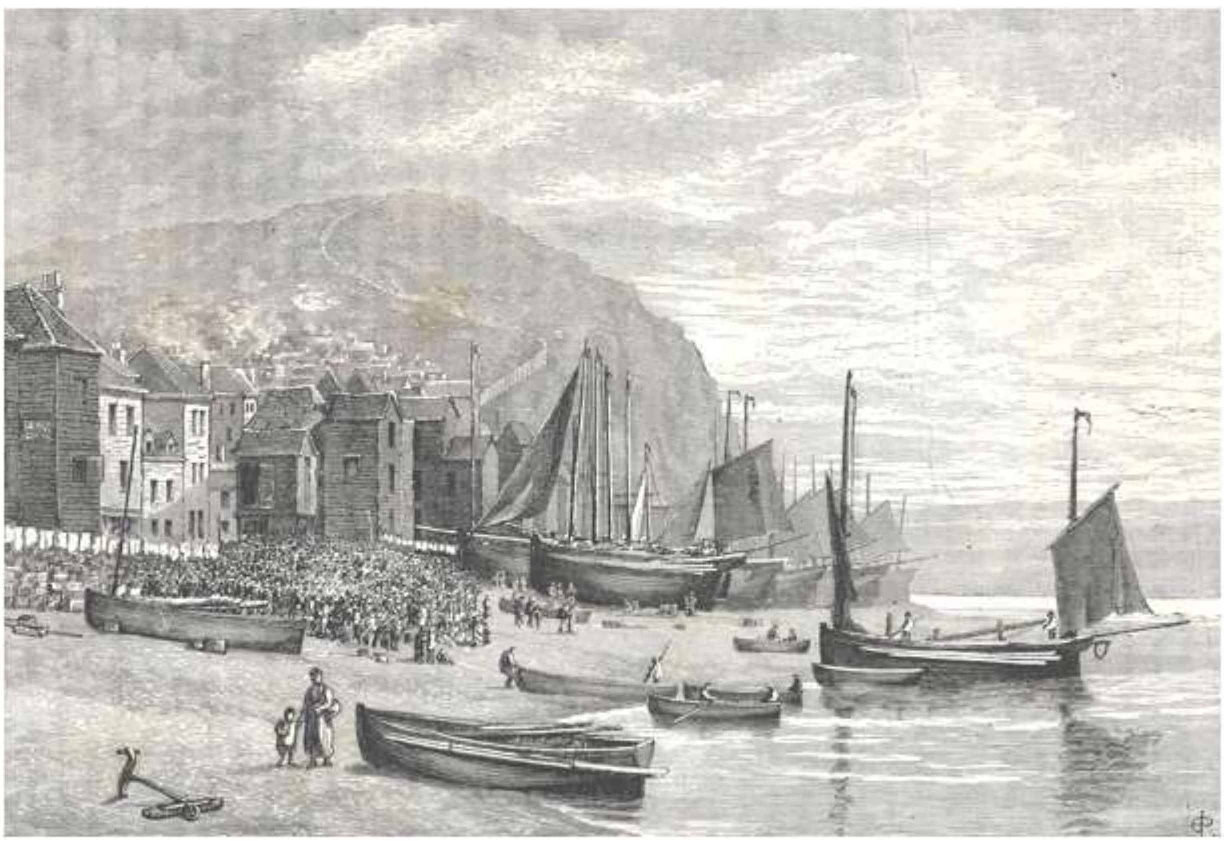

Figure 3C11. A woodcut, circa 1880, showing the beach and fishing village. The timber sheds belonging to the fishermen can be seen on the beach. Private Collection

Figure 3C12. A detailed watercolour of the eastern end of Hastings beach in about 1920 by Alfred Robert Quinton. The boats are beached at the waterline below a change in the profile of the shore, which is still present today. The castle is visible on the cliffs behind. Image Courtesy J.Salmon Ltd

Figure 3C13. This lithograph, published in about 1850, looks westwards from below the cliffs and shows the fishing village and town beyond. The cliffs in the foreground are well-jointed and crumbling; the beach looks extensive at this time. Private Collection

Figure 3C14. A panoramic view by W. H. Borrow from the top of the cliffs looking westwards in 1881. The geology is carefully painted and shows the dipping, jointed strata. The scene is painted at High Water as the sea abuts the promenade. Image courtesy of Hastings Museum & Art Gallery

Geomorphological setting

As well as considering the impact of erosion and historical sea level rise on Hastings amenity beach the study area included a weak sandstone cliffline at the eastern end of the town (see Figure 3C14). The cliffs are composed of sandstones, which are susceptible to the processes of weathering, and erosion at their toe by the sea along the undefended sections. The jointing in the cliffs means that sections are prone to breaking away in massive blocks and causing toppling failures. Once the material falls onto the beach, it is quickly removed by the sea, enabling the cycle of events to initiate once again. Ground water, soaking through the permeable cliffline and emerging at different points through the cliff face, is also an important process which speeds up the instability problems.

Where the main Hastings frontage is defended, rising sea levels and a possible increase in more unsettled weather patterns could lead to increasing beach drawn-down, changing its morphology in future years. This is likely to necessitate further coast protection measures in order to maintain the beach in the future.

Key coastal risk management issues for the frontage

The sandstone cliffs will be allowed to continue to weather and erode except where there is economic justification for protection of property and assets. Along the Hastings town frontage, the value of assets currently being protected by the existing seawall and beach is substantial. The policy is to continue to maintain and upgrade defences where necessary, looking ahead for the next 100 years.

Observations on the artwork

Nine views have been selected to illustrate different aspects of coastal change along this frontage. These relate particularly to beach conditions but three views also illustrate the nature of the cliffline and the wider geomorphological setting. Finally, an interesting painting by Charles

A. Graves, dated 1901, (figure 3C.10) shows the remains of the Elizabethan harbour projecting from amongst the rocks on the lower foreshore. Artworks containing information on historical structures such as this can help build up a picture of the changing coast over the centuries and, with other archaeological data can support our understanding of past coastal developments.

A lithograph by an artist of the English School, c.1850 (see Figure 3C.13) shows the fishing village located at the eastern end of the main beach. The view is interesting in that it shows the extent of the beach at the time, and also the cliffline displaying the well-jointed sandstone. Figures 3C.7 and 3C.8 provide views taken from the lower beach, looking eastwards along the frontage. They were painted by the prolific local artist William Henry Borrow in 1885 and 1879 respectively. They show the extensive beach at the time and also the steepening of the beach in the intertidal zone; a feature that exists at the eastern end of the beach today.

Figure 3.14, a further oil by Borrow, is taken from the cliff to the east of Hastings and looks westwards along the coastal frontage, with Hastings Pier in the middle distance. This view is taken at high water, and it shows the sea touching the promenade. In the foreground the cliffs are well depicted, showing the jointing and bedding planes. The weathered surface on the top of the cliff, partly vegetated, can also be seen.

How can the artworks inform coastal risk management?

The lithograph of the eastern end of Hastings beach (Figure 3.13) is relevant in this respect because it shows the extent of the beach in the mid-nineteenth century. It has been increasingly recognised that it is necessary to take a long-term perspective when looking at coastal issues and to understand the processes of coastal evolution over time. By making decisions about coastal risk management policy, looking ahead for the next 100 years, it is important to understand the rate and scale of change over time, and images of this kind can help explain beach conditions in the past.

The collection of views by Borrow of Hastings beach will be of interest to coastal engineers wishing to understand how the frontage may have changed over time. This and other works held in the Hastings museum illustrate the form of the beach over a 150 year period. It has been explained that the beach may become under increasing pressure as a result of rising sea levels and 'squeeze' over the next 20-50 years, and an examination of such historical images can allow the changes to the beach over time to be plotted and better understood.

The painting by Graves of the Elizabethan harbour (Figure 3C.10) is included in this case study because it provides a link with the work of Activity One of the Arch Manche project. It is one of many examples of coastal landscape paintings, which include archaeological and maritime heritage evidence. Such images can provide evidence alongside archaeological fieldwork to help understand past coastal developments and activities around the English coast.

Where can the original artworks be viewed?

There is a large collection of paintings of the Hastings area contained in the Hastings Museum including twenty-five oils by Borrow. They can also be viewed on the BBC Your Paintings website (www.bbc.co.uk/yourpaintings).

Ranking score achieved

The scores range from 48 -70 (see Table 3C2).

3C.6 Analysis

The Hastings study area has combined the use of archaeological and palaeoenvironmental data, paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve our understanding of coastal change in the long and short term. A particular focus has been on the area around the Harbour Arm and the impacts of this structure on the sediment regime as well as erosion to the cliffs further east. This section reveiws the most informative and reliable data gathered from this study area for contributing to understanding of the scale and pace of coastal change.

3C.6.1 Archaeological and Heritage Features

The archaeological and palaeoenvironmental data from the Hastings case study area can provide detailed information on the changing coastline from prehistory to more recent times. In particular, high ranking sites such as the dated submerged forest off Little Galley Hill provide key information on changes in sea level and the environment since the Bronze Age. Nearby the submerged forest at Bulverhythe is now exposed at low tide although the exact dates are unclear. These sites are now 150-230m from the current high water mark. The site of Little Galley Hill contains remains of an oak and hazel forest and the site of Bulverhythe contains deer antler which is thought to have been worked as well as 13th Century pottery in the upper peaty layers. Further east the submerged forest just south of Pelham place contains leaves, hazel nuts, acorns, oak and deer antlers.

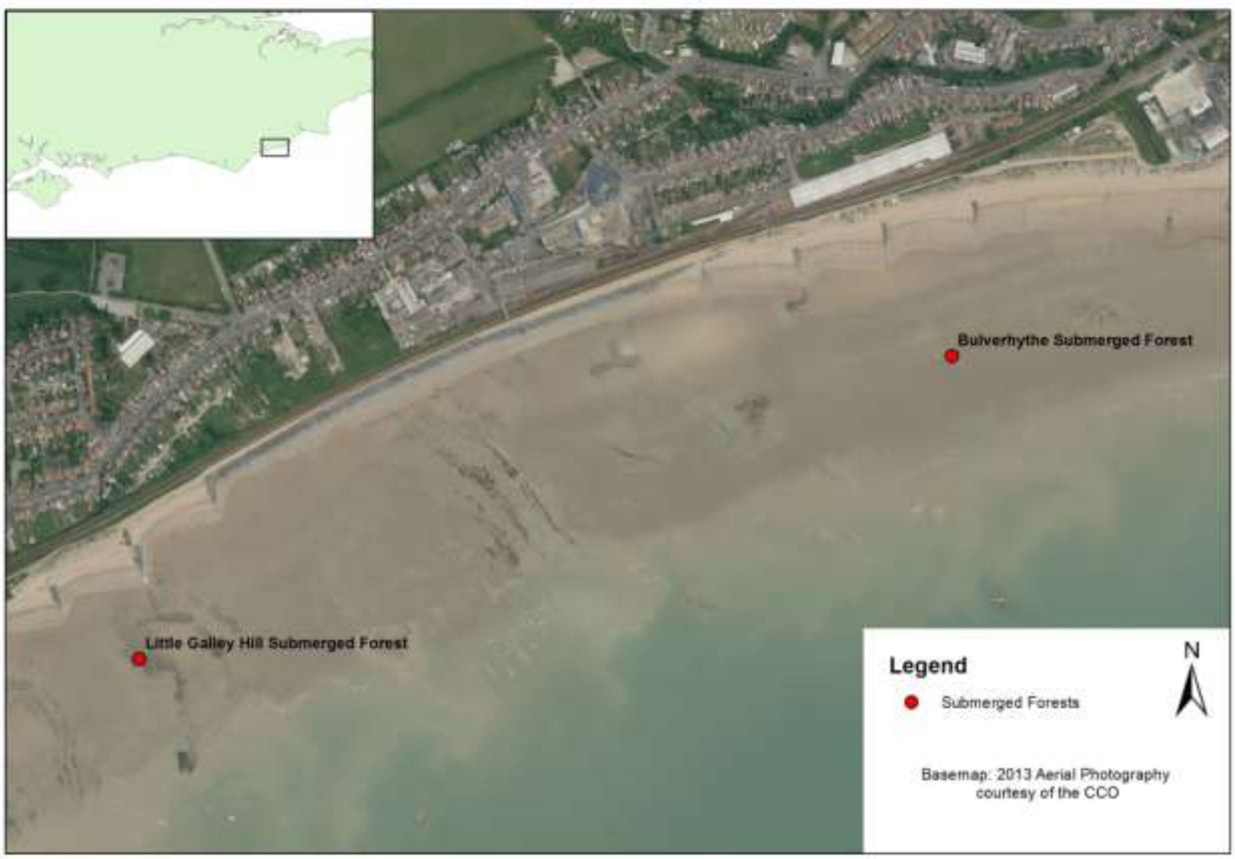

Figure 3C15. Aerial photo of Hastings showing the high ranking submerged forests of Little Galley Hill and Bulverhythe within the Hastings study area

Further work is required to understand the full nature and extent of these sites, but all have the potential to provide key data on changing sea levels and environment and with further analysis could be used to create evolution models of the changing coast from at least the Bronze Age.

Although the submerged forests scored highest, there are many other sites in the Hastings area which can still provide information on the changing coast. The concentration of medieval and post medieval sites along the present day shoreline of Hastings, although lower scoring, still tell us much about the stabilisation of the coastline in the study area in this period. The continued use of the fort on West Hill in both the Saxon and Norman periods and the establishment of settlements in the Bourne and Priory Valleys suggests settlement just inshore of the waterfront, making use of the lower ground protected from the elements by the hills (and by the fortifications on them).

A high scoring site providing data on changing coast conditions since 1749 is the wreck of the Dutch East India Company vessel the *Amsterdam*. Wrecked in 1749, the stability of the wreck in the sandy mud of the foreshore has kept it well preserved (this stability continued after it was first photographed in 1911 until 1969 when it was first surveyed). This may suggest a stabilisation of the waterfront, doubtless aided by human activity, particularly the number of groynes built here and to the west at Bexhill. That said, exposed parts of the ship are slowly being destroyed by Toredo shipworm.

3C.6.2 Artistic Depictions

The Hastings study site has provided a collection of artworks, which illustrate the performance of the beach over the last 150 years. It shows that although there have been some changes in beach profile, overall these have been slight and compare favourably with present day conditions. The study shows how coastal conditions can be monitored over an extended period if there is a sufficient resource of reliable artworks available for study.

Certain topographical artists such as W. H. Borrow were interested in providing a true record of coastal conditions without feeling the need to resort to changing the view to make it more 'pretty'. His views of the beach, and the cliffs to the east, which are subject to continued failure, demonstrate the processes of physical change on this coast since the 1850s.

The Hastings site, together with the Isle of Wight, represent two locations around the Channel coast on the English side where almost all the leading artists through the Arch-Manche art study period (1770-1920) visited and painted. Their artworks, therefore, provide a unique chronological succession of images that are available for analysis by coastal scientists, engineers, planning officers and other stakeholders.

The Hastings site was chosen for three reasons. First, because of the rich resource of artworks. Second, because of the concern to maintain the main beach, which is a vital tourism asset, and, finally because artworks also depict the nature of the unstable sandstone cliffs at the eastern end of the frontage.

In terms of illustrations of the beach, by Victorian artists in particular, there are numerous examples including many detailed works held by Hastings Museum and Art Gallery. Certain topographical artists such as William Henry Borrow were interested in providing a true record of coastal conditions without feeling the need to change the view in any way; his works exhibit a Pre-Raphaelite eye for detail. The views by Edwin Hayes (Figure 3C9) and by Charles Graves (Figure 3C10) show a flat lower shore with the beach rising more steeply to the east. The step in beach levels is indicated in the watercolour of the fishing fleet by Alfred Robert Quinton (Figure 3C122)

Figure 3C16. A view from Hastings Beach, comparison of the high ranking 1920's painting (Courtesy J.Salmon Ltd) with a current photo (copyright N Chadwiick). Raised beach levels can be seen

As a result it has been possible to examine the form of the beach from both the east and the west as well as from Low Water Mark. The images suggest that there have been fluctuations over the last 150 years, including a marked change in profile towards the eastern end of the beach below the fishing village. However, over time there does not appear to have been significant beach loss or gain.

It is important for those involved in coastal risk management to understand whether beach levels have been maintained at broadly the same levels over a long period of time or whether there is a trend towards beach lowering. With rising sea levels there are concerns about coastal squeeze and reduction of beach levels against the hard defences (the sea wall) at the top of the beach; this may require beach replenishment to maintain the required standard of protection over time. The historical evidence appears to show little change, over the last century in particular.

A further area of concern to coastal managers is cliff erosion and instability and this has proved to be a problem extending eastwards from Hastings towards Fairlight village. Several paintings and prints show the weak cliffs and the nature of the jointing and failure mechanisms. Studies of coastal instability elsewhere (eg: on the Isle of Wight and Dorset coasts), have recognised that an understanding of the history of landslide and cliff failure processes and mechanisms is fundamental to development of successful risk management strategies and planning policies.

Images of coastal cliffs such as those by W.H Borrow of Hastings to Fairlight (eg: Figure 3C.14) can contribute very usefully to this understanding by showing the state of the cliffs over time.

Historic photographs and maps/charts have also provided key information on coastal change. Figure 3C177 shows a 1920 image of the Hastings coast looking east towards the Fairlight coastguard station and a modern day aerial photo of the same area. Although it isn't possible to take exact measurements it does show that the cliff south of the coastguard station has retreated, the erosion of these soft cliffs is also noted in the Shoreline Management Plan (SMP).

Figure 3C17. The image on the left shows the view eastwards from Willowpit Wood, the Fairlight coastguard station can be seen in the distance (red star), the modern image on the right shows the current position of the coastguard station in the background, and the approximate position of the photographer above Willowpit Wood in the foreground (red stars). (Historic image © English Heritage)

Although it was only possible to look at a few historic photographs and maps in the scope of the project, a brief review of the Ordnance Survey County Series maps show the changes along Hastings waterfront between 1875 and 1938 (Figure 3C18). This covers the period in which the Stade beach harbour was built and abandoned and Hastings and St Leonards piers were built.

The first map of the series; the First Edition, completed in Hastings in 1875, shows the completed Hastings Pier, but construction of neither the harbour or St Leonards Pier have begun. The Stade beach is marked, as are a number of the fishermen's net huts. The mean high water mark is shown as running just below the Parade road along most of the waterfront and is clearly affected by the large number of groynes built in this area, resulting in an inconsistent height of high water between each groyne. At the Stade, the beach is presumably steeper as the high water mark is only half way up it and does not reach the huts. A large number of rocks, exposed at low tide, are shown in the vicinity of the Tudor harbour wall construction sites. These are labelled ‘Pier Rocks’ in the second edition map.

The second edition (or first revision) map of 1899 is of a markedly different design to the first. By this point, St Leonards Pier has been constructed and Hastings Pier has been expanded. The harbour breakwaters on the west and east sides of the Stade have been constructed, which has had a marked effect on the Stade beach itself. The beach has projected further out to sea pushing both the low and high water marks several meters to the south. Where previously the Stade was slightly inland as the shoreline followed the curve of the coast, the Stade beach is now level with the waterfront to the west in front of Hastings. This has also had a small impact to the west of the harbour in the area around the Pier Rocks. Previously these rocks marked the curve of the shoreline following the coast to the northeast; now longshore drift has built the beach right up to the new breakwater and the waterline continues almost due east despite the north east curve of the coast.

The third edition (or second revision) was completed in 1909 and shows a dramatic change within the harbour. To the west side, sediment has built up against the breakwater, moving the mean low water mark some 140 metres to the south. On the east side, the increase in sediment has not been so marked, so the waterfront within the harbour breakwaters now runs to the north east. At the same time, the mean high water mark has also moved several metres north on the east side of the Stade, suggesting that the beache slope has been much reduced. Outside the breakwaters, there has been no noticeable impact on the shore around Pier Rocks.

Some of these changes are visible in a number of historic photographs from the early 20th century. A photo of the steamship SS *Lugano* on fire just outside of the harbour breakwater was taken on the 27th April 1908. The tide is clearly in, possibly at the mean high tide level. The breakwater is shown to consist of a stone built outer arm running north-south, with a curved arm at the southern end that turns to the south east. This stone arm is connected to the shore by a wooden pier through which the water is clearly able to run at high tide. It might be considered surprising therefore, that such an extent of sediment has been able to build up on the harbour side of the breakwater; feasibly this should be eroded by the water from the west side of the breakwater even at low tide. In fact, a photograph of circa 1918 taken at low tide tends to support this; although the exposed beach within the harbour is significantly further south than the east side of the Stade or the beach west of the harbour, it is waterlogged and predominantly a level surface with a few raised sandbars.

The fourth edition (or third revision) map of 1938 shows several significant changes to the breakwater. The wooden pier is now buried by the beach, the mean high water mark to the west has been pushed some 80m out to sea and the mean low water mark is now 50m further out. Inside the harbour the mean high water mark has also been pushed a similar distance southwards, although the mean low water mark has remained where it is. However, it is obvious that construction on the roadside above the high water mark has had some impact. The construction of a boating lake and fish market just inshore of the western harbour wall has clearly involved some construction to shore up the coast; previously the high water mark ran through the boating lake and almost up to the door of the market. It is possible therefore, that the increased sediment deposition all around the harbour wall was deliberate.

Modern aerial imagery can be used to see the changes that have taken place since the 1930s. The most significant change has been the mean low water mark, which has again moved further out to sea. It is now some 120m further south and is only some 40m from the southern tip of the breakwater. The breakwater itself has been broken at several points, so water can flow through the curved southern section at all points of the tide; this may be the reason that the low water marks on both sides of the breakwater are now similar. However, the mean high water mark has again moved down the beach on the west side of the breakwater, now by approximately 90m. It is possible that this is deliberate shoring of the beach to allow fishing vessels to be parked on the beach in front of the market/boating lake area, but equally it is likely that eastward moving longshore drift has deposited increased quantities of sand against the breakwater.

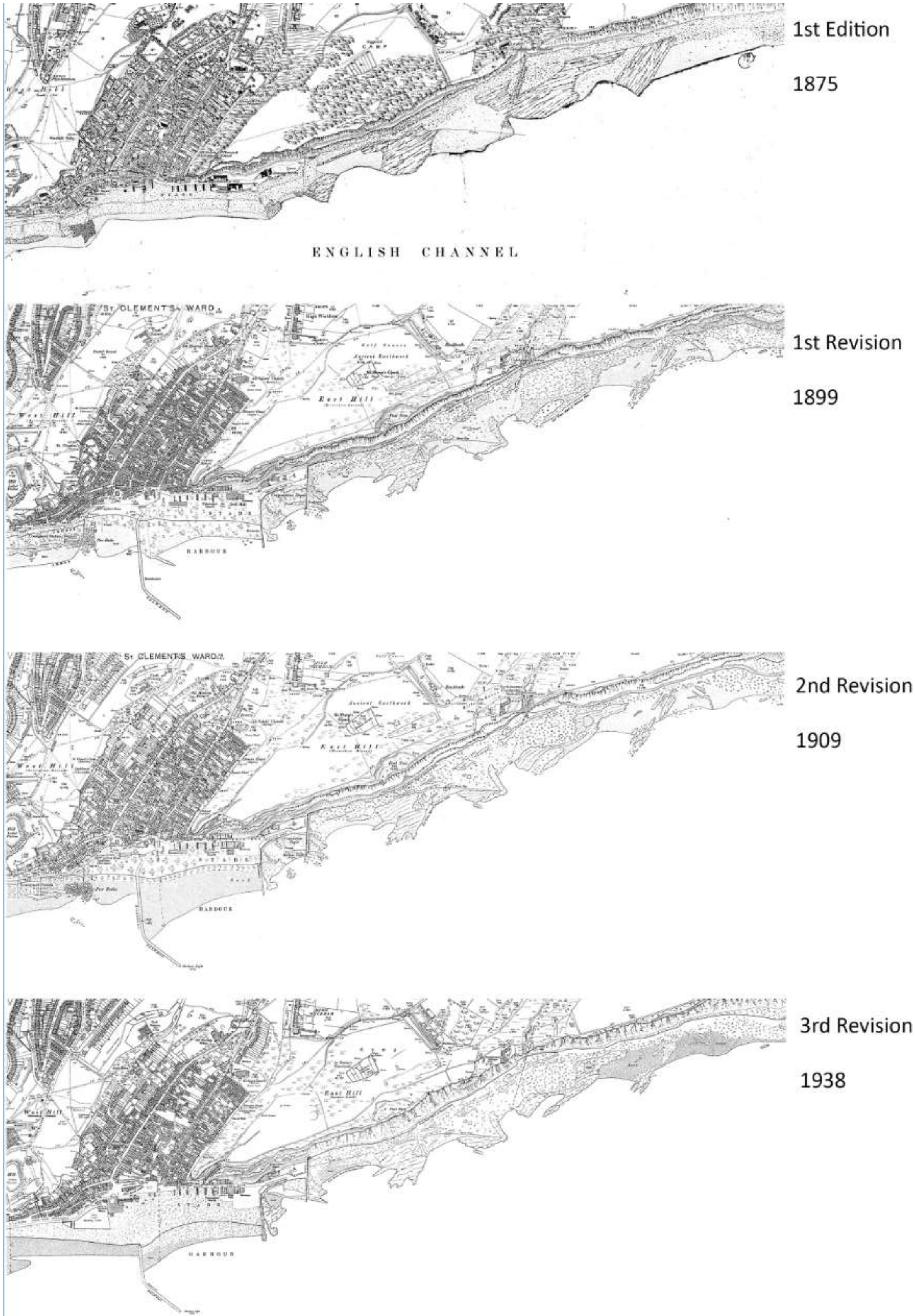

Figure 3C18. Historic OS Maps from 1875-1938. Images Courtesy Landmark Information Group Ltd

3C.6.3 Combined Resources

As demonstrated above, Hastings contains a wealth of information which can improve our understanding of coastal change, ranging from prehistoric archaeology to 19th Century paintings and 20th Century maps. Combining this broad range of data it is possible to understand coastal change in both the long and short term. Several areas along the Hastings coastline contain all types of data; archaeology, art, photographs and historic maps.

One example of this is the harbour wall. In the late 19th century the harbour Commissioner began construction of a harbour, however, due to the nature of the seabed and the inadequate financing work was stopped. The harbour arm is the remains of this construction attempt and has protected the beach and town for both tourism and fishing. As mentioned above the current SMP proposes that the arm is maintained in order to continue this protection. Historic photos and maps can help us to understand the sediment regime and the impact of the arm on the coastal processes along this frontage. In Figure 3C19 you can clearly see how sand has built up against the arm since the photo was taken in 1918, the timber section is now completely covered by sand and shingle.

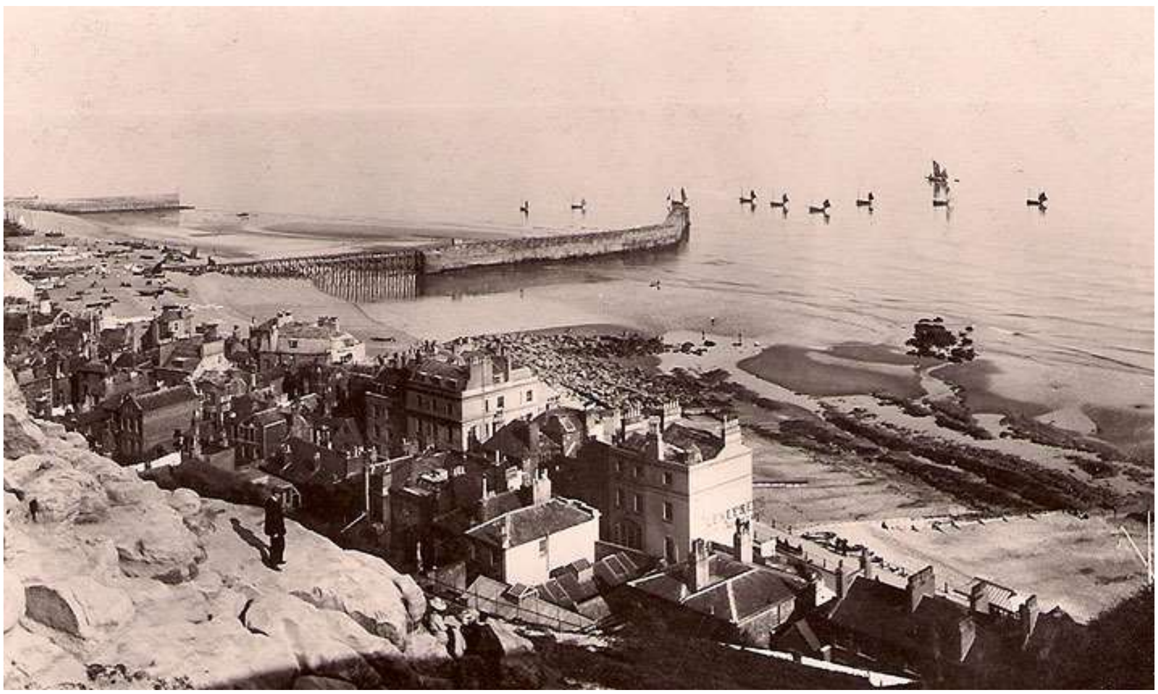

Figure 3C19 (A&B). The top photo (A) shows Hastings Harbour Arm in 1918, below (B) is a present day aerial image.

This area is also depicted in a map from 1890 prior to the building of the harbour arm, compared to a modern aerial image it is clear to see how the sediment has built up and provided a larger beach in the area around the harbour arm.

Figure 3C20. Plan of Hasting and St Leonards (left) Bacon 1890. Aerial photo of the same area, the yellow box marks the area covered by the 1890 plan (right).

This change over time can also be seen clearly in the historic OS maps discussed above (Figure 3C18).

Figure 3C21. 1st Edition OS Map overlaid on 2013 photography. The red arrow depicts the changing high water mark

The addition of the humanly constructed feature – the Harbour arm has clearly impacted the coast with increasing sediment levels and creating a shoreline which is artificially seaward of its natural position.

3C.7 Conclusions and Recommendations

- The Hastings art case study site appears to show no significant change to the beach over a very long period of time, however, historic maps and photos clearly show the changing sediment levels around the harbour arm to the east of the study area. Artworks of the Hastings coast should be used to support understanding of changing beach conditions over time. The fact that changes appear to have been modest over the last 150 years should be noted in the context of predicted changes for the next century.

- This part of the East Sussex coast was painted by numerous artists and this provides a chronological succession of works available for study. The paintings by William Henry Borrow, in particular, demonstrate the level of artistic detail that could be achieved by some nineteenth century artists. This can then be combined with historic maps and photographs to provide a detailed picture of change over the last 2-300 years.

- In order to understand changes even further back the Hastings case study area contains several examples of submerged prehistoric forests. Further work is required to date the sites more precisely and to carry out environmental analysis, this would then allow for an evolution model of the changing coast to be created from at least the Bronze Age to recent times when combined with the artistic depictions.

- More recent archaeological sites can also provide detailed information, in particular on sites where there is a programme of monitoring such as the wreck of the *Amsterdam*, these sites can provide information on changing sediment levels, and in the case of Hastings this area of the beach appears to be relatively stable.

- Monitoring of beach levels and erosion has been ongoing for the last 10-20 years. Archaeological and palaeoenvironmental data, historic paintings, maps, charts and photographs can extend this back hundreds and even thousands of years. The data can not only provide quantitative information on coastline position, but can also provide qualitative information that can assist in illustrating coastal changes to a large audience. While detailed coastal monitoring data is only available in Hastings for the last few decades, the data assessed above can help fill the large 'data gap' for the earlier periods from the Palaeolithic to the 20th Century.

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3C.8 Case Study References

Archibald, E. H. H., 1980. 'Dictionary of Sea Painters'. Antiques Collector's Club. Woodbridge.

Daniell, W. & Ayton, R., 1814. A Voyage Round Great Britain. Longman & Co.

Ellis, A. (Ed.), 2004. 'Oil Paintings in Public Ownership in Kent'. The Public Catalogues Foundation.

Finden, E. & Finden, W., 1838. Views of the Ports, Harbours, Watering Places and Picturesque Scenery of Great Britain. Virtue & Co. London.

Fradley, M. & Newsome, S. 2008. East Hill, Hastings, East Sussex: A Landscape Survey and Investigation. English Heritage Research Department Series 35-2008.

Graves, A., 1901. 'A Dictionary of Artists who have Exhibited Works at the Principal London Exhibitions 1760-1893. Kingsmead Press.

Higgins, C. & Haslehust, E. W., 1920. Hastings and Neighbourhood. A & C Black. London.

Lambourne, L. & Hamilton, A. J., 1980. British Watercolours in the Victoria and Albert Museum. Crown Copyright. London.

MacKenzie, I., 1987. British Prints. Antique Collectors' Club. Woodbridge.

Mallalieu, H., 1984. The Dictionary of British Watercolourists up to 1920. Antique Collector's Club. Woodbridge.

Rudling, D. (Ed). 2003. The Archaeology of Sussex to AD2000. King's Lynn: Heritage Marketing and Publications Ltd.

Russell, R.1969, Guide to British Topographical Prints. David & Charles. Newton Abbot.
Saunders, A. 1989. Fortress Britain. Liphook: Beaufort Publishing

SMP 2006. South Foreland to Beach Head Shoreline Management Plan. April 2006
Wood, C., 1978. The Dictionary of Victorian Painters. (2nd Edition). Antique Collector's Club. Woodbridge.

BBC News. 2014. Hastings Pier reconstruction: First decking planks laid. Available from: http://www.bbc.co.uk/news/uk-england-sussex-26435401 [Accessed May 2014].

The Defence of East Sussex Project. 2009. Defended localities - St. Leonards – Hastings. Available from: http://www.pillbox.org.uk/pillblogs/detail.asp?ID=256 [Accessed May 2014].

The Defence of East Sussex Project. 2009. Roadblocks - St. Leonards. Available from: http://www.pillbox.org.uk/pillblogs/detail.asp?ID=255 [Accessed May 2014].

1066 Online: Hastings and St Leonards. 2014. World War II. Available from: http://www.1066online.co.uk/hastings-history/ww2/world-war-2.htm [Accessed May 2014].

The Cinque Ports. 2014 Limbs – Past and Present. Available from: http://cinqueports.org/history/limbs [Accessed May 2014].

Hastings Chronicle. 2014. Hastings Pier. Available from: http://www.hastingschronicle.net/hastingsPier.html [Accessed May 2014].

Hastings Chronicle. 2014. St Leonards Pier. Available from: http://www.hastingschronicle.net/stLeonardsPier.html [Accessed May 2014].

National Piers Society. 2014. History of Hastings Pier. Available from: http://www.piers.org.uk/pierpages/NPShastings.html [Accessed May 2014].

National Piers Society. 2014. History of St Leonards Pier. Available from: http://www.piers.org.uk/pierpages/NPSstleonards.html [Accessed May 2014].

Open University. 2006. Beauport Park, East Sussex. Available from: http://www.open.edu/openlearn/history-the-arts/history/beauport-park-east-sussex [Accessed May 2014].

Wealden Iron Research Group. 2014. Database: Beauport Park. Available from: http://www.wirgdata.org/searchsites2.cgi [Accessed May 2014].

CASE STUDY 3D – SOLENT AND ISLE OF WIGHT, UK

Case Study Area: Solent and Isle of Wight, UK

Main geomorphological types: Soft chalk and weak sandstone clifflines, coastal landslide systems, shingle and sandy beaches, tidal estuaries, dunes, saltmarsh and mudflats

Main coastal change processes: Cliff erosion, coastal landsliding, beach erosion, sea flooding.

Primary resources used: Art, Archaeology, historic photographs, maps and charts.

Summary: The Solent and Isle of Wight coastlines are very varied and include exposed as well as sheltered frontages. They offer an excellent range of sites suitable in terms of illustrating historical coastal change processes. The area also has an extensive and unique archaeological and palaeoenvironmental record demonstrating these processes over the last 10,000 years.

Recommendations: Coastal managers should use these resources when predicting future rates of erosion, they provide thousands of years' worth of data to assist in the understanding of the rate and scale of change. Further work is required in order to model these changes across the region, combining the rich archaeological record with art, photographs and maps.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

The Solent and Isle of Wight is one of six UK case study areas for the Arch-Manche project. This case study report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented along with the results of the art, photos, and maps and charts studies. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented.

Within the Solent area the archaeological and palaeoenvironmental resource and the available art resource have been researched, scored and analysed. The extents of the detailed study areas are shown in Figure 3D1. The areas considered for archaeology and palaeoenvironment have been selected to provide a representative range of types of evidence across a range of periods spanning from the Palaeolithic through to more modern coastal heritage. The art, photograph and map and chart case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time.

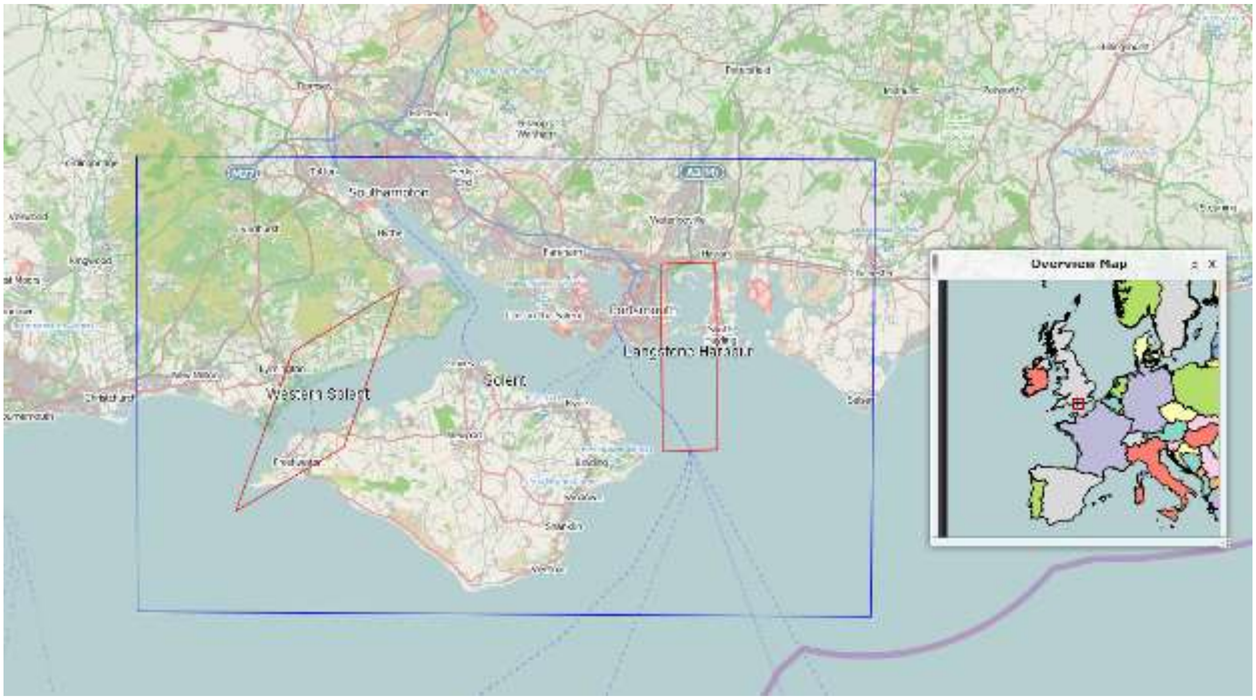

Figure 3D1: Map of the Solent and Isle of Wight Case Study Area. The art area is depicted in blue and the archaeology areas in red.

3D.1 Introduction to the Solent and Isle of Wight Study Area

The archaeological and palaeoenvironmental study areas cover the western Solent from the Needles to St Leonards, and Langstone Harbour. Both sites contain evidence of a changing landscape from the Palaeolithic to modern times.

The western Solent study area embraces the largest and best known of the two major spits in the Solent region, namely, Hurst Spit. The spit lies at the mouth of the western Solent where it projects some 2.1 km towards the Isle of Wight. The study area also encompasses the distinctive chalkland coastal topography at Alum Bay and the Needles.

This study area was chosen as a 'cross boundary' example where two administrative entities, on the opposite sides of a relatively narrow stretch of water, share a common interest in coastal behaviour. It is here that an array of archaeological and palaeoenvironmental features may help to define the nature, scale and pace of coastal processes that are still actively widening and deepening the seaway channel.

Langstone Harbour has been subject to detailed archaeological and palaeoenvironmental investigation, a large multi-disciplinary project was carried out over 5 years in the 1990's which sought an understanding of natural change and the course of human activity. The project revealed intermittent human activity commencing in the Mesolithic (Middle Stone Age) and adapting, at various times, to a rising sea-level. These changes were accompanied by a retreat of the shore from mudflats and saltmarsh. The area was selected in order to combine this data with recent studies to gain a more detailed picture of the changing landscape over time. As a result a 4D evolution model has been created and is presented below.

The three selected art study sites lie within the Hampshire Basin, at Portsmouth in Hampshire, and at Ventnor and Yarmouth on the Isle of Wight. The Hampshire coastline extends for a distance of approximately 30 miles (48km) along the central south coast of England and abuts the Solent; the Isle of Wight coastline extends to a total of 65 miles (110km). The study sites are Portsdown Hill overlooking Portsmouth Harbour in Hampshire, Ventnor on the south coast of the Isle of Wight and Yarmouth on its north-west coast. The particular geomorphological interest of the Solent and Isle of Wight study sites relate to understanding coastal evolution and coastal landsliding problems.

The study area coastline has a complex geological and geomorphological history with, as a result, a wide variety of landscape types. Although parts of the coastline are heavily developed, for example the great maritime ports of Southampton and Portsmouth, together with some of the seaside resorts and coastal towns bordering the eastern side of the Isle of Wight, much of the coastline is undeveloped and has been designated for its landscape, environmental and geological importance.

3D.1.1 Geology and Geomorphology

The coastlines of Hampshire and of the Isle of Wight lie within the Hampshire-Dieppe Basin; its geological structure arising from the Miocene Alpine mountain-building phase that took place approximately 30 million years ago. This resulted in a 'syncline' or downfold being created to form a Basin. The rocks on the Isle of Wight were uplifted, folded and compressed, and subsequently eroded and weathered. As a result of these structural movements, some of the strata now rest in a near vertical position, meaning that a wide variety of rock types, dating from the Cretaceous onwards, are exposed around its coastline. The steepest arm of the Isle of Wight monoclinal fold dips almost vertically to form the central downs, which cross the Island from west to east. The southern limb of the monoclinal fold dips gently from the central downs towards the south coast behind the town of Ventnor.

The ancient geological structural faults that first moulded the landscape were reactivated during the Tertiary to form the Hampshire Basin. These were overlain by the Lower Eocene London Clay which in turn were covered by groups of sands, gravels and clays laid through the Tertiary, in the Eocene and Oligocene. These formations have been moulded over the deep routed faulting bedrock and can be relatively easily reworked or eroded (Dix 2001, Bridgland 2001).

The eastern part of the Solent sits on a relict palaeo-channel that evolved during the Pleistocene. The Solent is the lower extent of a river system that drained the Hampshire Basin. The channels that emptied into the Solent were created over the last 2 million years and have been subject to repeated climate swings. A series of fluvial gravel deposits have been left behind, the youngest being close to the modern day coastline. As a result of the mountain-building phase, basement geological fractures and subsequent changes in sea level over the last 10,000 years, parts of the Hampshire and Isle of Wight coastlines are particularly susceptible to coastal instability problems promoted by erosion and high ground water levels.

3D.1.2 Summary of the Archaeology and History of the Study Area

Two areas were selected for archaeological and palaeoenvironmental investigation: the western Solent and Langstone Harbour. This section provides a summary of the archaeology and history of each area, the western Solent is presented first, followed by Langstone Harbour.

3D.1.2.1 Summary of the Archaeology and History of the Western Solent Study Area

The western Solent study area stretches from the Needles (on Isle of Wight) and Hurst Spit (in Hampshire) east to Hamstead (Isle of Wight) and the Beaulieu River (Hampshire). This study area was chosen as an example of where two coasts on the opposite sides of a relatively narrow strait share an array of archaeological and palaeoenvironmental features, which helps to define the nature, scale and pace of coastal processes that are still actively widening and deepening the stretch of water. The western Solent study area has been significantly affected by changing sea levels during and since the last glacial period. This has left a trail of gravel deposits along the shoulders of the Pleistocene river valleys of this region. The following text provides a historic context for the western Solent and identifies areas where future work could help understand the nature and scale of coastal change.

Early Prehistory (Palaeolithic and Mesolithic)

The earliest pertinent evidence of human activity comes from Pleistocene terrace gravels deposited at various altitudes along and below the upland boundaries of the western Solent lowland. Bridgland (2001, 16-19) cites four specific gravel terraces that may be dated by the presence of associated human artefacts. These deposits all rest on benches on the northern shoulder of the western Solent valley. These are the gravels of Setley Plain (*c*.42m OD); Old Milton (*c*. 35m OD); Taddiford Farm (*c*. 28m OD) and Stanswood Bay (*c*.22m OD).

Maps provided by Allen & Gibbard (1993) and Bridgland (2001) show the course of these elevated terrace gravels shadowing the northern coastline of the western Solent. Here they appear to conform to an ancient Pleistocene valley that long pre-dates the formation of the Solent seaway.

The highest and oldest of these gravels to yield datable human artefacts is the Setley Plain deposit. For this, Bridgland proffers a date of some 400,000 years BP (Oxygen isotope stage 11-10). This is based on implement typology and analogy. For implements in the Old Milton gravel, parity with oxygen isotope stage 8-7 is proposed. This would signify a date around 300,000BP. Implements within the Stanswood Bay gravel have yet to be assigned a conclusive date but a date within oxygen isotope stage 9/11 has been proposed (Bates, 2001).

The old terraces cutting through Dorset and Hampshire have proven to contain a rich source of Palaeolithic flint tools whereby reflecting the value of the waterways as routes for early waves of hominins. The youngest gravel lens is found across the north shores of the Solent, below the Pennington marshes between Lymington and Milford on Sea. It was laid down *c*.120,000 years ago towards the end of the Ipswichian (OIS 5e) and sits at a height that equates to current OD.

At lower levels within the western Solent valley, some palaeoenvironmental evidence is available from submerged contexts in the coastal zone. These resources include some deposits off the Isle of Wight coast at Newtown where elephant and bison remains have been recorded (Munt, 1987). Further palaeochannel deposits yielding interglacial fauna have been identified on the New Forest shore at Stone Point, Lepe (Brown *et al*, 1975).

It is the environmental changes of the early and mid Holocene that are of particular importance to the management and protection of the Solent coast. These events mark the genesis of the coastal processes that are still eroding and modifying the coastline today. The presence of Mesolithic habitation sites in the intertidal and sub-tidal zones offers a particularly valuable opportunity to establish the long term behavioural history of this shoreline. Current investigation into the submerged habitation site at Bouldnor has established a date of circa 8,000 BP for the existence of brackish conditions prior to the formation of the open sea-way. At this time habitation was still possible at a level of -11m OD.

Elsewhere on the floor of the western Solent, further evidence of Mesolithic activity can be detected. This evidence has been produced by fishermen recovering flint tools from the seabed, with recoveries from Pitts Deep and Pennington being particularly notable. These finds, and some associated deposits of peat, come from levels that are higher and arguably later than the dated occupation site identified at Bouldnor. This upward trail of submerged Mesolithic occupation sites now offers a valuable means of fixing and dating the retreat of the shoreline in the western Solent.

Later Prehistory (Neolithic, Bronze Age and Iron Age)
There is no doubt that the coastal landscape of the western Solent continued to submerge during the 3rd millennium BC. Explicit evidence comes from the mouth of Newtown harbour where a Neolithic wooden trackway was built across the coastal marshland, the feature has been dated by radiocarbon to 4160±70BP 2920-2500 *cal* BC (GU-5341). In the mouth of the Western Yar, another Neolithic trackway, laid in a similar environment, has been dated at 4220±60 BP 2920-2620 *cal* BC. Depths ranging from -2.9 to -1.6m OD place these structures well below current sea-level. If these structures were to extend further underwater their depth could provide further index points for change in sea level.

At Fawley, peat that had accumulated just above the tidal limit has been recorded at a level of -2.5mOD. This deposit has been dated approximately at 3600 BP. Other coastal Neolithic sites of potential value include the find-spots of flint artefacts at Newtown, Hamstead and Saltmead. At Colwell Bay, Bronze Age tools have been recovered from the intertidal zone but it is uncertain whether these were associated with a submerged landscape.

Towards the close of the 1st millennium BC, Iron Age activity developed within and around the hill fort at Buckland Rings near Lymington. This site overlooks the Lymington River at a point where an entrenched enclosure has been constructed on the river bank at Ampress. At present little is known of the date and function of the Ampress enclosure although it may be associated with Iron Age navigation of the river. Sediment archives occupying the margin between Iron Age occupation on the river bank and the accretion of river silts could offer particularly valuable information on past nature of this coastland and its contemporary sea level. At Exbury, on the east bank of the Beaulieu River, another defended enclosure offers similar potential.

Roman Period
At present, the nature of the Roman coastline of the western Solent is very poorly understood. Intertidal survey to pursue salt-working sites of this period would be particularly helpful in establishing the sea level of this period.

At Yarmouth Roads an anchorage of this period has been identified in a water depth of 9-16m (Tomalin 2006). A scatter of Roman pottery at this location suggests that very little change has taken place in the nature of this particular area of seabed during the past two millennia. Historic anchorages have also been identified at Lymington River and Hurst Roads.

Medieval Period (500AD – 1485AD)
Since the Middle Ages the Isle of Wight has been important from both a commercial and military standpoint. There has always been a strategic need to protect this offshore domain from the unwelcome interests of potential invaders. As a result, the coastline of the Solent has seen the construction of a succession of military defensive structures.

The medieval town and port of Newtown (Francheville) was critically damaged by French attack in the 14th century. It is thought that the town had developed an anchorage and waterfront within the confines of Newtown Harbour but after the French raid of 1377 it never recovered its prosperity. The sacked town diminished to a shrunken medieval settlement and it eventually ended its days a ‘rotten borough’, it status dismissed during the Parliamentary reforms of the 19th century.

The intertidal and sub-tidal archaeology at Newtown is of interest because it offers a very rare opportunity to examine an unbroken record of sediment accretion in a Solent creek. This is a location that has escaped all effects of navigational dredging. It has also escaped development interests since the 14th century. This location has the potential to offer a sediment archive covering several millennia.

Like Newtown, both Yarmouth and Lymington are medieval port towns. Both owe their development to the maritime aspirations of Anglo-Norman entrepreneurs. At both towns the nature of the medieval waterfront is not clearly understood although it is likely that the remains of the quays and jetties of this period now lie within areas that can be subject to reclamation, development or the construction of sea defences. Lymington also maintained a thriving medieval shipbuilding industry and this could bring a further array of helpful archaeological evidence to the low-water boundary of the contemporary shoreline.

Waterfront archaeology offers the potential of securing absolute dates for past shorelines. It can also reveal a wealth of information on the past coastal environment. Timbers of waterfront structures may offer tree-ring evidence of climate as well as dating. Navigational dredging is common at both Lymington and Yarmouth. Although destructive, these activities can offer opportunities to recover new evidence concerning the past environmental conditions that have accompanied the shoreline development of these historic towns.

Post-Medieval Period (1485AD – 1901AD)

During the post-medieval period the coast of the western Solent maintained its strategic importance. This is demonstrated by substantial fortifications at Hurst Castle, Yarmouth Castle, Fort Victoria and Fort Albert. The Tudor forts at Hurst and Calshot are sited on spits that are particularly vulnerable to changes brought on by coastal processes and sea level rise. By their very nature, these massive spits are subject to shifts in their configuration. These changes pose a threat to the cultural monuments on the spits and to a trail of leeward coastal habitats that depend on the spit's protection.

An important aspect of the 'built heritage' for the study of sea level change are the salterns. These were constructed at levels that related to the tidal cycle where rising seawater was allowed to enter through embanked enclosures. Salterns can offer further opportunities to examine the limits of past tidal regimes. In Hampshire the salt industry was particularly intense in the vicinity of Lymington and Pennington where many abandoned salterns still survive. Other historic structures of the coastland are chapels, houses and tidal mills. The latter may offer some evidence of past tidal levels.

A further potential source of environmental information may lie within each seabed 'footprint' provided by a contemporary shipwreck. The discovery of a 16th century Iberian merchant ship on the floor of Yarmouth Roads has revealed a preservative environment associated with the benign accretion of a protective blanket of sediment since its loss (believed to be) in 1567. This wreck was randomly discovered as a result of a specific archaeological survey. Its presence is now a reminder that a very substantial archaeological and palaeoenvironmental potential is still concealed within the vast area of the Solent floor that has escaped any kind of scientific examination.

Modern

Some of the most visible archaeological sites and remains from this period are defensive military structures such as pillboxes, gun emplacements and decoy sites. Current changes in the coastline have been observed at Hurst Spit where storm events have exposed and revealed ancient wooden structures associated with an earlier configuration of the spit (Figure 3D.2).

Figure 3D.2: Damage caused by the storms in January 2014

3D.1.2.2 Summary of the Archaeology and History of Langstone Harbour

Langstone Harbour today includes an area of around 1900 hectares, at low tide there are only 200 hectares of the harbour underwater, meaning that 1700 hectares of mud are exposed, demonstrating the shallow nature of the harbour.

Peats in the Broom Channel at a depth of between -10.5 and -12m below OD were discovered within cores related to a housing development (Mottershed 1976). But other than these the main evidence for the evolution and development of Langstone comes from work associated with the Langstone Harbour Archaeology project undertaken in the 1990s. During this project there were two dates gained from tree remains that were embedded within small peat deposits from Baker's Rithe and Russel's Lake areas. From the former a peat deposit from a depth of -1m OD provided a date of 2310 – 1950 Cal BC, and from the latter at a depth of -0.5m OD a date of 3350 – 2010 Cal BC. These Neolithic dates for peat deposits are evidence of the complex development of the harbour over time.

During auger work related to the excavation of the Langstone logboat in 2002 a substantial peat deposit was encountered at a depth of around – 2m OD off the north west coast of Long Island. This peat is currently undated, but its substantial thickness of up to 2m indicates this is likely to be a different peat to those identified during the Langstone Harbour Project (Allen & Gardiner 2000; Scaife 2003).

Langstone Harbour in Early Prehistory

During the interglacial periods of the Middle and Upper Pleistocene the climate was warm enough to accommodate early human settlers of the Lower and Middle Palaeolithic. Lithic evidence left by these peoples is not uncommon in Britain and the finds are predominately from reworked fluvial deposits displaced as landscapes were remoulded (Wenban-Smith & Hosfield 2001). The Solent region has been recorded as containing more Palaeolithic sites than anywhere else in the country (Wymer 1991). In Langstone Harbour flint tool finds from this period are recorded from Long Island and from the intertidal mud on the west side of Hayling Island.

The changes associated with the Holocene also correspond with the human re-colonisation of Britain around 13,000BP (11,000BC). During this period the marine landscape of the Solent was developing from one containing freshwater river systems running through incised valleys to increasing marine conditions caused by rising sea level. The area was also home to expanding Mesolithic populations.

Early Mesolithic sites are limited in numbers but increase as we move further into the Mesolithic. At Langstone Harbour there were fourteen areas of Mesolithic activity recorded in the intertidal zone but no evidence of any 'base camp' assemblages (Allen and Gardiner 2000,203-4). There are records of flint recoveries from each of the four islands in the harbour in addition to a cluster of finds from Farlington Marshes and others on the west coast of Hayling Island. These discoveries demonstrate a relatively limitied lithic 'tool kit', but they do provide an indication that former Mesolithic landsurfaces may be encountered within the harbour.

Later Prehistory (Neolithic, Bronze Age and Iron Age)
The slowing of the rise in sea level by the Neolithic saw water levels across the Solent region at around -6m OD. After this period the slower rises continued, with a further development of peat deposits in the Bronze Age which are around -4m OD. Associated archaeological and palaeoenvironmental deposits associated with buried prehistoric landsurfaces are found within the tidal river and estuaries of the Solent, including Langstone Harbour (Allen & Gardiner 2000; Long & Scaife 1996; West 1980).

Evidence from Langstone Harbour demonstrates that in the late Neolithic and Early Bronze Age the landscape had freshwater rivers existing within the former deeply incised channels. The area was now part of the coastal plain, and extensive peat blankets were formed in the valley flood plains.

With more permanent settlement the character of the archaeological record changes, in particular there is greater variety of finds, and importantly the presence of pottery and metal work remains. Evidence from the Neolithic period is dominated by flint tools and scatters related to their production, but by the Bronze Age levels of occupation are increasing and a wide range of evidence has been recovered from within the harbour.

During the mid to late Bronze Age Langstone Harbour had slow meandering streams running through low lying grassland with localised salt marsh. The maritime influence on the environment was growing. Artefacts from this period include metal work, a large flint collection and an extensive pottery assemblage. A number of the pottery vessels are believed to be related to cremation burials; pottery in the harbour is often found in association with small pits or hearths. Allen and Gardiner (2000) suggest that part of the harbour was used as an open flat cemetery with the cremation burials within it. However, further foreshore fieldwalking appears to be providing more evidence of hearths which could indicate more mixed use of the area.

The islands in the north of the Harbour are particularly rich in Bronze Age material, indicating this area of the harbour was dry land during this period. There is also material from Farlington Marshes and the west coast of Hayling Island. An interesting feature consisting of timber posts from the north coast of Hayling Island has been dated to the Bronze Age and may represent the remains of a trackway.

Environmental changes resulted in the harbour becoming wetter and more maritime by the Iron Age. The relatively small rises in sea level had greatly expanded the rivers, moving towards harbour conditions. Maritime trade and transport also developed significantly and by the Iron Age (800-700 BC) there was a comprehensive trade network between Britain and continental Europe. Pottery and coins from Europe have been discovered at a number of coastal settlements around the Solent (Trott and Tomalin 2003).

Most Iron Age evidence from the harbour is related to salt working, this includes briquetage and pottery. There are particular concentrations on the west coast of Hayling Island, North Binness Island and on the fringes of Farlington Marshes. There is a complete salt production site in Creek Field on Hayling Island which includes ‘boiling pits’ and flues. There is little other direct evidence of Iron Age activity within the harbour, however, on Hayling Island there is Tournebury Hill Fort in addition to an Iron Age Temple (King & Soffe 1994).

Roman Period

In the early Roman period it was neighbouring Chichester Harbour that was the most important of the three Solent harbours, with Fishbourne Roman Villa located at its head. However, there is evidence of a range of Roman occupation around Langstone Harbour demonstrated by villas, roads and saltworking.

Roman pottery finds from Langstone Harbour span all the main centuries of Roman occupation. The types of form and fabric are indicative of small scale rural farming communities, with only a small amount of imported pottery being discovered. While there has not been any evidence so far discovered for extensive settlement directly on Langstone Harbour, the material culture suggests that saltworking, brick or tile manufacture and oyster farming could all have been carried out. In particular saltworking appears to have been important with records from as early as AD410 which mention the superior quality of the salt from around the shores of Hayling Island (Allen & Gardiner, 2000: 217). Finds from around the harbour appear to demonstrate a continuity of salt making in locations that were used in the Iron Age.

Medieval Period

By the early fifth century the Roman Empire was in decline, trade between Britain and continental Europe had practically collapsed. From the mid-fifth century, groups of Germanic peoples began to arrive in southern and eastern England and contacts with the continent began to increase.

During this post Roman period it appears that the population returned to building methods which utilise timber, and hence do not generally leave such a visible archaeological record. However, there are a number of finds from Langstone Harbour which show continued use of the harbour throughout this period.

The Langstone logboat was excavated from the north west shore of Long Island in 2003 and has been radio carbon dated to AD500 (HWTMA 2003). The boat had been abandoned on salt marsh deposits; beneath the boat pieces of wood which had been split and some with tool marks were discovered, which demonstrates human activity in the marsh environment. Not far from the location of the boat several pieces of wattle work hurdle have been found with one of these dating to Cal AD 790-1030. Further organic remains dated to AD980 – 1180 were discovered protruding from the water at an extreme low tide, and subsequently investigated by divers. This was the Sinah Circle, which is believed to be related to oyster fishing activity.

The Domesday survey indicates Hayling Island was used extensively for agricultural activities in this period, while neighbouring Portsea island had few inhabitants. In Langstone Harbour Medieval activities were focused on fishing, oyster farming and saltworking. There are a large number of timber structures located on the west coast of Hayling Island which are thought to be related to fishing, although they have not been dated, they are assumed to be Post Medieval in date.

Post-Medieval Period
In terms of use of the inter tidal area in this period, Langstone does not witness large scale land reclamation between the 5th and 15th centuries which is often seen in other areas of the country (Galloway 2009; Fulford et al 1997:136). This may be due to the coastal saltmarshes being relatively narrow; it is not until the 17th Century that areas are reclaimed.

Saltworking continued to be a significant industry until the late 18th century when it went into decline. The industrialisation and urbanisation of Britain during the nineteenth century led to dependency on sea trade as never before. During this period the west side of Langstone Harbour was developed with housing and maritime facilities, although this was confined within Portsea Island. Within the harbour some saltworking was still undertaken. The need to develop a secure route for shipping from Portsmouth, via Chichester, to London saw the construction of a canal in 1822 which cut across the top of Hayling Island and entered Portsmouth via Milton Lock.

Modern
In Langstone Harbour large areas remain protected due to their environmental significance, this has ensured that development has not encroached on the harbour. The harbour is used for a range of recreational activities, but also maintains commercial shipping, particularly through aggregate wharves and associated vessels.

War related activity is reflected within the archaeological record which includes many pill boxes and decoy lighting sites, in addition to craters where bombs were dropped. Langstone was a centre for construction and diversion during the two World Wars. Mulberry harbours were built here; the remains of one remain to the north east of the harbour entrance. The islands in the harbour were used as air raid decoys to divert planes away from Portsmouth.

3D.1.3 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for the Project

A general overview of the Solent's history and archaeology is provided by The Book of the Solent – Solent Science (Drummond & McInnes 2001). This is supported by other general histories of the New Forest provided by the Forestry Commission and the New Forest National Park Authority that provide context for the north coast of the western Solent study area.

The Isle of Wight was one of the first areas in England to undertake detailed study of intertidal and coastal archaeology and in 1998 carried out a coastal audit. This resulted in the county Historic Environment Record (HER) containing large numbers of coastal sites and the potential and diversity of the coastal heritage resource being relatively well understood. The success of the IoW coastal audit led to an English Heritage supported program of Rapid Coastal Zone Assessments (RCZAs) in other areas of the country.

The western Solent has benefitted from a Rapid Coastal Zone Assessment (Wessex Archaeology 2010a and 2010b). The RCZA reviewed a wealth of existing literature and databases, before conducting fieldwork to identify more sites and better understand others. A wide range of smaller desk based assessments and archaeological reports also exist for the New Forest coastal area, providing valuable context for human activity and settlement in the area.

The main resources consulted during the Arch-Manche project for the western Solent area have been from the work carried out by the Maritime Archaeology Trust (MAT), particularly at the site of Bouldnor Cliff (Momber et al 2011). Work carried out by the MAT in Langstone Harbour has also been consulted alongside the 1990's Langstone Harbour Project (Allen & Gardiner, 2000).

On the northern shore of the Western Solent a substantial area of inter-tidal mudflat and salt marsh has accrued along a front approximately 10km long. Recent studies by have shown that these areas which were once sediment sinks are diminishing rapidly. Areas of mudflats are being lost by up to 5m per year (Ke and Collins 2002:422) and the Channel Coastal Observatory recorded an 83% loss since 1946 (Cope *et al* 2008).

Other resources consulted for the area are the Hampshire Field Club papers and occasional papers accessible at the University of Southampton and National Oceanography Centre libraries (Anderson, 1933; Draper 1968; Hack 1999; Bates 2001; Nichols & Clarke 1986) and PhD thesis' (Dyer 1969; Scaife 1980; Dean 1995). Archaeological data sources include English Heritage National Record of the Historic Environment (NRHE), county based HERs and various journals (Momber 2000; Long & Tooley 1995). The Solent - Thames Regional Research Framework contributory section for the Solent has an Upper Palaeolithic and Mesolithic resource assessment for the Isle of Wight (Loader 2007). Internet sources consulted including (West 2008; Cope et al 2008)

During the summer of 1997 the submerged forest that lay underwater in the Solent was subject to attention as part of the European Community L'Instrument Financier pour l'Environment (LIFE project entitled Coastal Change, Climate and Instability (Dix 2000; Scaife 2000a; Tomalin 2000a). This work was a particular relevant source of information as one of the main objectives of the project was to assess the value of archaeological and palaeoenvironmental evidence as a means of measuring the scale and pace of coastal change.

Historic sources include the numerous academics who have traced the evolution of the 'Solent River' back into the Pleistocene, during which river systems abraded a path through the southern part of the Hampshire Basin (Fox 1862; Everard 1954; Alley *et al* 1993). The primary source of information being the east-west-tending fluvial deposits laid down in close association with one another as the river migrated during successive glacial cycles. In more recent times seismic and coring investigations in Southampton Water and the Eastern Solent have helped to define a channel identified as the Solent River (Hodson and West 1972; Dyer 1975). The area is rich in gravel deposits and in peat formed during the preceding Flandrian Transgression, many of these deposits correspond with progressive inundation reflecting the Solent River's clearly defined geomorphological development as sea levels rose (Long and Tooley 1995).

Work by Velegrakis and the School of Ocean and Earth Sciences at the University of Southampton, identified a series of south-flowing palaeovalleys which had breached the old submerged chalk monocline prior to the Flandrian Transgression (Velegrakis *et al* 1999; Velegrakis 2000). This evidence refuted the notion of a Solent River passing from west to east to the north of the Isle of Wight during or following the last glacial epoch. The research showed that rather than there being a single river flowing east, there would have been a number of south-trending channels draining the lands to the north, forming separate waterways east and west of the island.

High-resolution multi-beam survey was conducted in the western Solent in conjunction with Submetrix/SEA Ltd in June 2001. The system was used was the Interferometric Seabed

Inspection Sonar (ISIS) 100 (Momber and Geen 2000). The georeferenced survey gave a highly accurate position and recorded a large expanse of elevated seabed which corresponded to the location of the peat deposits. Dive surveys were then able to integrate with the bathymetric model of the seabed and comparisons made. In the north east Solent, to the seaward end of Keyhaven Marshes around Hawker's Lake by Hurst Spit, not-withstanding the ongoing erosion witnessed on the seabed, comparison suggested that the submerged shelf upon which the peat sat mirrored the areas that had once supported mudflats only 200 years earlier.

3D.1.4 Art History of the Study Area

This section presents the background to artistic representations within the area including key schools and individual artists. This provides the background to the broader consideration of individual artworks within the study area.

The coastlines of Hampshire and Isle of Wight started to receive attention from artists and writers in the late eighteenth century who were visiting the region in search of picturesque scenery (Wyndham, 1793; Rowlandson, 1793; Tomkins, 1796; Pennant, 1801; Gilpin, 1804). The French Revolution and the Napoleonic Wars prevented travel in Europe and resulted in antiquarians and artists paying greater attention to the landscapes of the more remote parts British Isles such as this region.

One early writer and artist, William Bernard Cooke, having crossed to the Isle of Wight, described the Island in the following way: "the two sides of the Island present each a peculiar character, as distinct, and as strongly opposed as their aspects. The northern side is marked by all that is lovely, rich and picturesque; the southern side, commonly called 'the back of the Wight', abounds in bold wild rocks, precipitous projections, ravines, fearful chasms and other features of the opposing and even of the sublime. In parts it is true these opposite characters are greatly mingled – a circumstance that only adds to the effect produced upon the observer, and together with the constant alteration of marine and inland views contribute still more powerfully to distinguish the Isle of Wight as the 'Garden of England" (Cooke, 1808).

Gentry and other patrons of the arts living along the Hampshire and Isle of Wight shorelines became influenced by the 'Picturesque' style as exemplified by the works of such artists as Claude Lorrain, Nicholas Poussin and Salvator Rosa whose works they saw on the Grand Tour. They now increasingly purchased copies of finely illustrated topographical accounts of travels of their own region by such eminent authors and illustrators as Tomkins (1796), Pennant (1801), Gilpin (1804), Englefield (1816), Raye (1825), Rowe (1826), Brannon (from 1821) and Woodward (undated).

Mid-to-late eighteenth century landscape art in Hampshire and on the Isle of Wight is dominated by three important watercolour artists who were all painting here at about the same time, John Nixon, Thomas Rowlandson and, slightly later, Charles Tomkins. John Nixon was an amateur landscape painter and caricaturist who toured Britain, Ireland and the continent widely in the 1780s and 1790s often working with other important artists. He provided drawings for Thomas Pennant's 'Journey from London to the Isle of Wight' (Pennant, 1801) as well as for the European Magazine.

The leading artist of the Georgian period, Thomas Rowlandson visited Hampshire and the Isle of Wight in about 1784 with a colleague artist, Henry Wigstead, but returned in 1791 to undertake a more comprehensive tour producing numerous fine watercolour drawings.

'A Tour of the Isle of Wight' was published by Charles Tomkins in 1796 (Tomkins, 1796), the text being accompanied by eighty delicate sepia aquatints of coastal and inland views. The tour includes an extensive description of the journey from London to the Isle of Wight as well as interesting views along the central Hampshire coastline. Tomkins' aquatints compared favourably to the rather coarse copperplate engravings in Sir Richard Worsley's 'History of the Isle of Wight' (Worsley, 1781). A patron of the arts on the Isle of Wight, Earl Yarborough, commissioned Charles Tomkins to paint a further series of fifty-eight watercolour drawings of Isle of Wight scenery in 1809. Nearly all the watercolours from Tomkins' 1809 tour are illustrated elsewhere (McInnes, 1993). Together with the work of Rowlandson and Nixon the illustrations by Tomkins provide a unique insight into life in coastal Hampshire and on the Isle of Wight during the late eighteenth and early nineteenth centuries before the impact of the Victorian development.

The nineteenth century was a remarkable period for Hampshire and Isle of Wight art, with some nine hundred works being exhibited at the Royal Academy and other principal London exhibitions. A vast number of paintings and watercolours were produced in Queen Victoria's reign alone and for every fine painting that was exhibited there were perhaps one hundred that were not. Art and drawing was part of the upbringing at that time and thus there were hundreds of good paintings by Hampshire and Isle of Wight artists, as well as visiting artists, unlisted and unknown to exhibition catalogues.

During the early nineteenth century several fine sets of aquatints and engravings of works by such artists as John Dennis, Frederick Jukes, Richard Bankes Harraden, Barth and King, and Richard Livesay were published. As Hampshire and the Isle of Wight became more accessible, with improved rail communications, further fine books were published, illustrated with beautiful colour and black and white plates of both coastal and inland scenes including Charles Raye's 'Picturesque Tour of the Isle of Wight' (1825), Frederick Calvert's 'The Isle of Wight illustrated' (Calvert, 1846), William Westall's 'Views of Carisbrooke Castle and Environs' (Westall, 1839) and the three volume publication on 'Hampshire' by Mudie (Mudie, 1840).

Some of the finest views of Hampshire and the Isle of Wight coast were the ten aquatint engravings produced by William Daniell towards the end of his 'Voyage Round Great Britain' in 1825 (Daniell & Ayton,1814). By the time Daniell had toured the British Isles and reached the Solent he had perfected his style and his delicate views are some of the most important taken in that period. Whilst most of his views are of the Isle of Wight, his 'View from Portsdown Hill' and 'Distant view of the Needles and Hurst Castle' are particularly fine.

Many of England's most celebrated artists visited and painted the Hampshire shoreline including Thomas Rowlandson, Thomas Hearne, John Linnell, David Cox Snr and J. M. W. Turner. John Bullar completed his 'A companion in a tour of Southampton' with numerous views of the environs in 1819 (Bullar, 1819) later followed by 'Views of the Principal Seats and Marine and Landscape Scenery in the Vicinity of Lymington' by R. A. Grove in 1832 (Grove, 1832) and 'A Handbook for Lymington and the New Forest' by Richard King (King, 1845).

Between 1800 and 1820 wealthy families constructed marine villas in secluded locations around the Solent and South Wight shorelines or they improved earlier residences. Designs published by fashionable London architect Robert Lugar in his 'Villa Architecture' (Lugar, 1828) included a view of Puckaster Cottage, Niton, one of a number of cottages ornés constructed in this area. This style was encouraged by the prominent Regency architect, John Nash, who resided at East Cowes Castle. The owner of Puckaster Cottage was Mr James Vine, who commissioned a series of watercolour drawings from Joshua Cristall, first President of the Old Watercolour

Society. He was also host to J. M. W. Turner, Sir Edwin Landseer and many other artists. Two important visitors to the Island encouraged the development of its art. The first was Turner, who stayed on the Island on at least two occasions in 1795 and 1827. His first visit is recorded in the sketchbook number TBXX14 and contains numerous views of the Undercliff, Blackgang and Bonchurch.

The Isle of Wight artist, engraver and author, George Brannon, and his sons, Alfred and Philip, who worked on the Isle of Wight during the early and mid-nineteenth century, and are recognised as having made a significant contribution to Isle of Wight art and culture. The publication 'Vectis Scenery' (Brannon, 1821-1876), which was commenced by George Brannon in 1821, has provided us with an impression of the Island landscape through the eyes of a local resident over a period that spanned extraordinary changes in terms of the Island's landscape, coastal scenery and economy, particularly during the first half of the reign of Queen Victoria.

Brannon's 'Vectis Scenery' included, over its lifetime (Brannon, 1821-1876), a vast range of illustrations of Island towns, inland and coastal scenery as well as country houses and churches. In 1821 Brannon published the first complete volume of 'Vectis Scenery' and continued for almost forty years until his death in 1860. Alfred, his second son, took over the business at the age of forty-two, but within a few years sales of the book reduced dramatically, possibly due to the increased popularity of photography. Undoubtedly the most talented and versatile member of the Brannon family was Philip, one year younger than Alfred. He was a fine artist, engraver, teacher, a successful architect, civil engineer and inventon. 'Vectis Scenery' was just one of the publications by the Brannon family. Others included 'A Picture of the Isle of Wight' (Brannon, 1850a), 'Graphic Delineations of the Isle of Wight' (Brannon, 1841), 'Voyage round the Isle of Wight' (Brannon, c.1860) and the 'The Pleasure Visitor's Companion' (Brannon, 1850b). Philip Brannon also produced guides to Southampton, the New Forest and Bournemouth.

Both the Hampshire and Isle of Wight coastlines have a rich resource in terms of landscape paintings, watercolour drawings and engravings. On the Hampshire coast prolific artists included George Arnold ARA (fl. 1807-28), William Bellers (fl. 1762-73), George Chambers (fl. 1852-62) together with such well known names as J. C. Barrow, John and Robert Cleveley, Alfred Clint, James Francis Danby, A. V. Copley Fielding, Edwin Hayes, John Linnell, Dominic Serres, William Shayer and Alfred Vickers. In addition, a fine selection of albums of drawings, such as those of Philadelphia Mitford, exist in private collections or within the historic yacht clubs and local museums. Those artists with a coastal or Naval upbringing or training can be distinguished for the quality and accuracy of their works. These include, for example, E. W. Cooke and J. W. Carmichael. The Navy regarded drawing as an essential skill for officers; Richard Livesay was one of a number of drawing masters at the Royal Naval College, Portsmouth, having succeeded the eminent artist John Christian Schetky.

While Bonchurch developed in the east Wight, a similar writers and artist's circle was developing in the west Wight centred on Farringford, the Tennyson's home. Their neighbours included Julia Margaret Cameron, George Frederick Watts and Valentine Cameron Princep. Princep was the son of a distinguished Indian civil servant who lived at Holland Park in London, a noted gathering place for leading Victorian artists and writers. Princep was closely associated with G. F. Watts, Dante Gabriel Rossetti, Burne-Jones and others of the period.

The artist Helen Allingham, was introduced to Lord Tennyson through her husband William, a poet. Helen was also made aware of the beauties of the Island by an acquaintance, Thomas Carlyle, who had rented a villa at Ventnor for several seasons. Helen's interest in cottage architecture was fulfilled on the Isle of Wight where she painted over a hundred and ten watercolours on successive visits, mainly on the Farringford estate or in the vicinity of Freshwater. On several visits to Farringford she met the important Victorian watercolourist Myles Birket Foster and they painted together for a number of years. In February 1862 Birket Foster and his family moved to Bonchurch, renting Winterborne (now an hotel) for a period of recuperation from tuberculosis. Whilst living there, he produced at least ten fine watercolours of the cliffs and beach at Bonchurch or in The Landslip, and a number of these have been illustrated elsewhere (McInnes, 1989, 1999, 2004).

The natural landscape and in particular the sea cliffs of the south-east corner of the Isle of Wight were captured in detail by followers of the Pre-Raphaelite School, John Brett, John William Inchbold and Frederick Williamson. Brett took a house in Upper Bonchurch and produced views of the Undercliff scenery demonstrating the remarkable coastal geomorphology of the area in painstaking detail. He was, without doubt, the foremost landscape painter of the outer Pre-Raphaelite circle and he worked exclusively in watercolour until he was fifty but from then onwards turned solely to oils. The son of an army officer, he studied at the Royal Academy Schools before travelling abroad to Switzerland where he was deeply affected by the sight of the Alps. Here he met John W. Inchbold who was also a Pre-Raphaelite follower and who later worked on the Isle of Wight, painting a fine view of the Niton Undercliff in a style similar to that of Millals.

A further four artists who painted almost continuously in Hampshire and the Isle of Wight deserve special mention. Alfred Vickers was a Londoner, who exhibited views regularly between 1832 and 1869. His sketchy style of working in oil has been likened to that of the French artist, Eugene Boudin, and his exhibited Hampshire and Isle of Wight works numbered thirty-three in total. William Shayer also loved the scenery of the New Forest as well as crossing regularly from his native Southampton to paint coastal views or scenes of smuggling or gypsy folk. Julius Godet made an annual pilgrimage from London to the south coast from 1853 until 1879 with his work being accepted at the Royal Academy or Suffolk Street exhibitions in every one of those years. Finally, Miss Harriet Gouldsmith's works are worthy of note. Between 1826 and 1831 she was a prolific exhibitor of small oils of the coastal scenery and fisherfolk at Ventnor Bay and Luccombe, producing thirteen works for the Royal Academy and elsewhere over that period.

Marine painters including Charles John De Lacy, Thomas Sewell Robins, Edward Duncan, John Wilson Carmichael and George Chambers produced scenes of shipping and craft in the Solent waters. Charles and George Gregory, father and son, were also prolific local artists, although they did not exhibit regularly. Arthur Wellington Fowles painted yachting and regatta scenes off Cowes and Spithead in particular often depicted against the background of the Isle of Wight coastline. In 1850 he gave up his employment to concentrate on working as a marine painter, which he continued for the rest of his life. He painted a number of important scenes capturing races and regattas including important craft such as Cambria sailing off Ryde.

An increasing demand for visitor's guides to the Isle of Wight necessitated a change from the relatively expensive books by the Brannon family, Roscoe, Barber and others. These were replaced by cheaper guides, often illustrated with chromo-lithographs or woodcuts. Later, artists were commissioned to paint watercolours of local scenes for reproduction in the first colourplate guides and for picture postcards. This resulted in a wealth of attractive watercolours being produced at the end of the last century by Henry Wimbush, Alfred Robert Quinton, William Wells Quatremain, Alfred Heaton Cooper and Newport art teacher Fanny Mary Minns. The publishers A. & C. Black's pencil sketches series followed later with a delightful Island volume by Dorothy Woollard (Woollard, c.1915).

3.1.5 Art Resources Consulted for the Project

In order to investigate the art resources available to assist an understanding of long term coastal change a review has been made of works of art held by the principal national, local and private collections for the study area comprising the coastlines of Hampshire and the Isle of Wight. These collections are detailed in Section 2.1 .

As part of the research it was necessary to contact museum and gallery curators and search available publications, as well as undertaking research on the Internet, taking advantage of new resources including the Public Catalogue's Foundation volume (Ellis, 2004) and the BBC *Your Paintings* website.

In addition to searches of on-line databases and images held by national and local collections an assessment has been made of art from the study area contained in important publications and, in particular, catalogues of exhibitions at principal London galleries and also in the study area itself. The literature sources relating to works exhibited are comprehensive and comprise reviews of the artists and their works (e.g. Graves, 1901), together with catalogues and dictionaries published by the museums themselves and interested publishers (e.g. the Antique Collectors' Club). The published works of this kind do, therefore, represent a considerable resource of assistance to this study (Wood, 1978; Russell, 1969; Archibald, 1980; Lambourne *et al*., 1980; Mallalieu, 1984; MacKenzie, 1987).

More specifically in relation to local collections covering the Hampshire and Isle of Wight coastlines, the work of Dr Raymond Turley, formerly of Southampton University Library, is particularly relevant (Turley, 1975; Turley, 1977). With respect to the Isle of Wight coastline, an attempt was made to list both those artists that had exhibited works at the principal London exhibitions together with other artists who had exhibited locally or were active in the period 1770-1920 (McInnes, 1993); this list was updated substantially as part of The Crown Estate – Caird Fellowship 2008 (McInnes, 2008a).

A sample of historic photographs, maps and charts were assessed. These were obtained through online searches and several maps were provided by Professor Robin McInnes. The primary resources consulted for historic photographs were the Carisbrooke Castle Museum online library and the online collection from the Britain from Above project.

3D.2 Current Environmental Impacts, Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the Solent and Isle of Wight coastline and reviews the current coastal management issues and approaches.

3D.2.1 Review of Key Contributors to Coastal Change

The coastline of Hampshire and the Isle of Wight, facing the English Channel, are impacted upon by Atlantic storm waves from the south-west, as well as waves generated within the Channel itself and, indeed, within the Solent. This coastline has, historically, experienced rapid rates of coastal erosion resulting in instability problems, breaching and sea flooding. The coastline supports a high population density, with major cities, towns and smaller settlements, as well as important infrastructure located in vulnerable locations.

Climate change induced coastal change including sea level rise, will be likely to promote worsening conditions, particularly more rapid rates of coastal erosion and the reactivation of coastal landsliding, as well as increased flooding by the sea over the next decades. The low-lying coastlines of Hampshire are particularly vulnerable for flooding, for example the city of

Portsmouth, which is densely populated, as well as the towns of Cowes and Yarmouth on the north coast of the Isle of Wight.

Elsewhere, rising sea levels are inundating important salt marsh and mudflat habitats, which also form a natural type of coast protection for the creeks and estuaries bordering the Solent. Due to 'coastal squeeze' almost complete loss of saltmarsh is predicted on the Hampshire shore of the western Solent. Other natural and semi-natural habitats are associated with the gravel spits and the transitional margins of the higher (inner) saltmarsh and reed swamp areas. Some of these are essentially artificial, such as the saline lagoons within Pennington Marshes. These are the surviving relics of the Solent's historic salt-producing industry. Current rates of diminution are accelerating. This trend towards net loss almost certainly correlates with the commencement of erosion and the 'dieback' of *Spartina anglica*.

On the open coastline along the south of the Isle of Wight rapid rates of coastal erosion are being experienced, and these are expected to continue and increase, whilst, along the south coast of the Isle of Wight, the Undercliff, which is north-western Europe's largest coastal landslide complex, can be expected to face increasing challenges as a result of both coastal erosion and increased ground water levels as a result of changing weather patterns.

The archaeological study area of Langstone Harbour has a long history of submergence and coastal erosion, in particular to the mudflats caused by the die back of *Spartina* Grass. Relative sea-level rise will have a huge impact on the harbour given the high rate of downwarping in this region.

Similarly the western Solent archaeological study area is impacted by erosion. At Bouldnor cliff erosion is seen on land as high as 50m giving way to a slumping and retreating cliff-line where new and soft landslides are removed by the sea. On the other side of the Solent the saltmarsh around Lymington is being rapidly eroded and Hurst Spit, a cuspate shingle foreland protecting the entrance to the western Solent has witnessed notable changes due to an increased rate of transgression.

Cause and effect relationshops in this area are complex, this involves the consideration of sediment loading, sea level rise, the wave climate and hydraulic regime, as well as the impact of anthropogenic development and remodelling of the foreshore.

3D.2.2 Summary of Current Coastal Management Approach

To address the issues outlined above, shoreline management plans have been prepared for the whole of the study area coastlines, and an effective coastal monitoring programme has been in place for over ten years. Good communication between adjacent coast protection authorities, local authority planning departments, and other stakeholders is achieved through the Standing Conference on Problems Associated with the Coastline (SCOPAC), a coastal network, the Solent Forum and the Southern Coastal Group.

As noted above Hurst Spit is being affected by an increased rate of transgression, the site is important for coastal defence as it protects the western Solent and shelters the salt marsh to the north. After declining in volume the area is now being managed and maintained through regular shingle recycling. It is thought that coastal protection works from the 1940's in Christchurch Bay interrupted the movement of shingle which maintains the site's stability. This led to many breaches and as well as shingle replenishment and monitoring a rock breakwater and revetment were built in the late 1990's. Despite this, erosion is still impacting the site and the saltmarsh to the north are also eroding, the seaward edge is believed to be eroding by up to 2m/year (SMP).

3D.3 Archaeological and Palaeoenvironmental Scoring

This section outlines the results of the archaeological and palaeoenvironmental scoring from the study area, followed by a discussion of the results. The scoring methodology applied is detailed in Section 2.2.

3D.3.1 Results of the Archaeological and Palaeoenvironmental Scoring

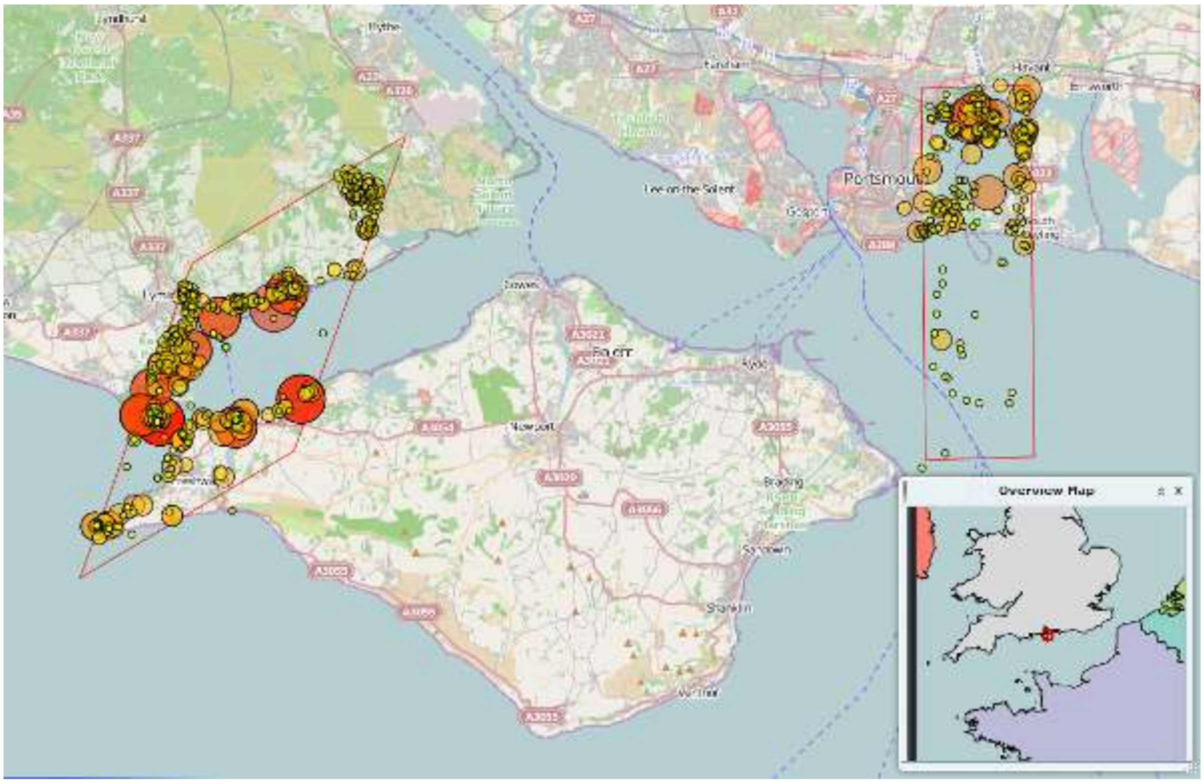

Figure 3D.3: Map showing the distribution of archaeological and palaeoenvironmental sites within the Study Areas

Within the study area data was obtained from the local Historic Environment Records (HERs), the National Record of the Historic Environment (NRHE), the United Kingdom Hydrographic Office (UKHO) and the English Heritage Peat Database. Where data from the HER indicated sites of particular interest, further research was in order to understand the full nature and extent of the site. Each data set went through a process of cleaning, in order to prevent the duplication of sites. A total of 817 sites and records were assessed.

The highest scoring sites are listed in the table below, the total score has been normalised to give each site a score out of 100.

APE uid	Site Name	Site Type	Period	Score – Sea Level	Score – Environ mental	Score – Temporal Continuity	Total Score	Coastal Context
600	PITTS DEEP - Submerged Peat Deposits	Submerged Landsurface	Prehistoric	High	High	High	100	Marine
707	BOULDNOR CLIFF	Submerged Landsurface	Mesolithic	High	High	High	100	Marine
604	HURST SPIT - Hurst Castle	Coastal Defence	Medieval	High	High	High	100	Above HW

324	RUSSELLS LAKE - Prehistoric Forest	Submerged Landsurface	Prehistoric	High	High	High	100	Marine
339	BAKERS RITHE - Prehistoric Forest	Submerged Landsurface	Prehistoric	High	High	High	100	Marine
712	HAWKERS LAKE - Submerged Peat	Submerged Landsurface	Unknown	High	High	Medium	88	Marine
714	OXEY MARSH - Submerged Forest	Submerged Landsurface	Unknown	High	High	Medium	88	Marine
716	PENNINGTON MARSHES - Peat	Submerged Landsurface	Unknown	High	High	Medium	88	Marine
717	PYLEWELL LAKE - Peat	Submerged Landsurface	Unknown	High	High	Medium	88	Marine
718	RIVER YAR - Peat	Submerged Landsurface	Unknown	High	High	Medium	88	Estuary
719	TANNERS HARD - Submerged Forest	Submerged Landsurface	Unknown	High	High	Medium	88	Marine
705	HURST CASTLE SPIT - Core Samples	Other	Prehistoric	Medium	High	High	88	Sandy foreshor e
265	WRECK - Long Island Logboat	Wreck	Early Medieval	Medium	High	Medium	77	Inter-tidal
271	LANGSTONE HARBOUR - Sinah Circle	Marine installation	Early Medieval	High	Medium	Medium	77	Marine

Table 3D.1: Highest ranking archaeological and palaeoenvironmental sites within the Solent study area.

Figure 3D.4: Map showing distribution of highest ranking archaeological and palaeoenvironmental sites within the Solent study area.

Scores for sea level change

	High	Medium	Low
Number of sites	13	179	625

Scores for environmental change

	High	Medium	Low
Number of sites	13	20	784

Scores for temporal continuity

	High	Medium	Low
Number of sites	6	197	614

Table 3D.2: Detail of the ranking across archaeological and palaeoenvironmental categories for the Solent case study

3D.3.2 Discussion of the Scoring Results

The western Solent area includes a wide range of archaeological and palaeoenvironmental site types. Of particular interest are the number of prehistoric finds, sites and peat deposits.

A relatively large number of sites have been recognised for their ‘medium’ potential for providing information on past sea level. Submerged landsurfaces feature heavily in the higher scores. These include multiple finds from the Bouldnor area where stratified Mesolithic material has been found underwater at a height relevant to a contemporary sea level. Stratified organic material can be used to date sea-level at particular periods. This is illustrated by the dated peat deposits in a submerged landscape at Bouldnor as well as evidence of dated submerged forests off the islands of Langstone Harbour.

Some features of later date also score highly. This includes the medieval castle at Hurst Spit. The interpretation of these sites in relation to sea level can provide information on the use and the development of the marine zone and on human responses to changes in sea level or specific natural events. The Hurst Spit site also has the potential to inform on environmental changes as it contains datable palaeoenvironmental evidence.

A large number of submerged landsurfaces and peat deposits scored highly, in particular for the evidence they provide on environmental change, this reflects the often long and helpful timescale offered by these sediment archives. The high scores awarded to submerged landscapes and palaeoenvironmental deposits reflect their particular value in helping to inform on past sea levels and coastal change.

3D.4 Archaeological Fieldwork

The main archaeological and palaeoenvironmental fieldwork was carried out in the western Solent and in Langstone Harbour. Smaller surveys were also carried out on the Hamble River, Burrow Island (Portsmouth Harbour) and East Winner Bank wreck (eastern Solent). This section outlines the field studies undertaken and the main results. The western Solent will be presented first, followed by Langstone Harbour and then the smaller studies.

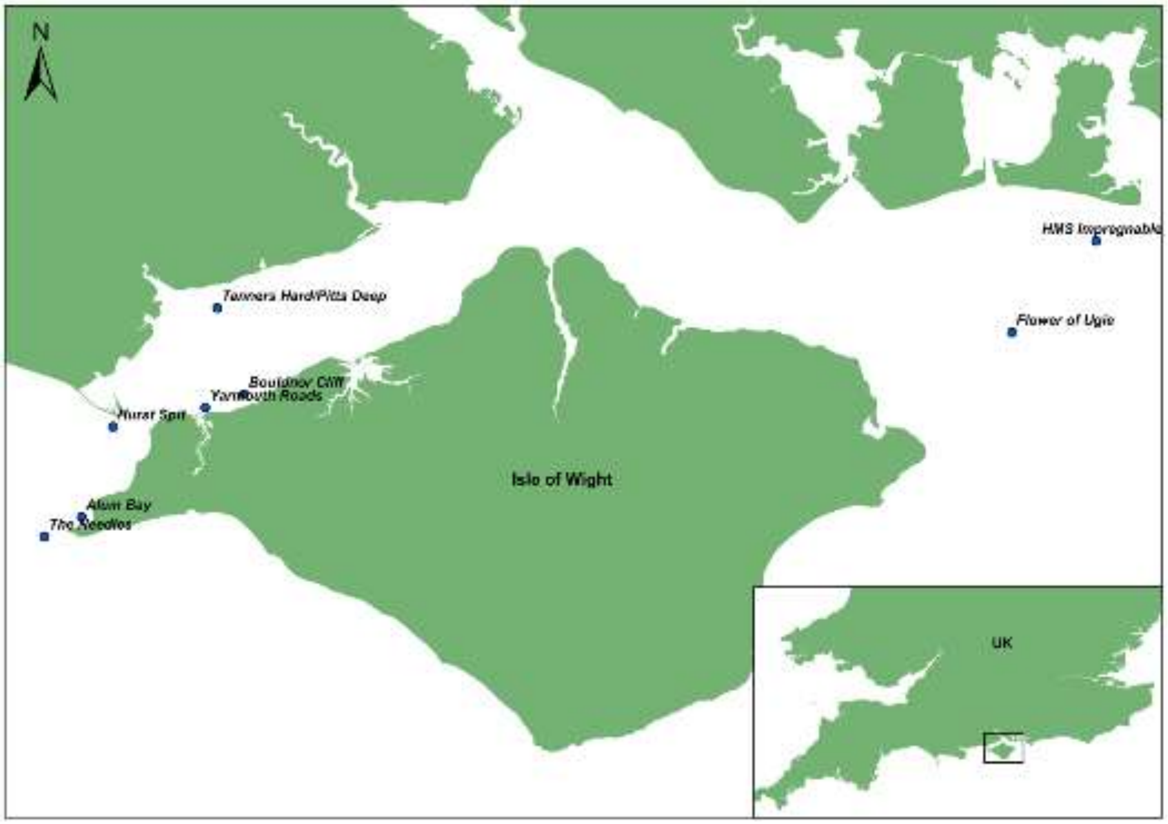

Figure 3D.5: Location of dive sites in the Solent, UK

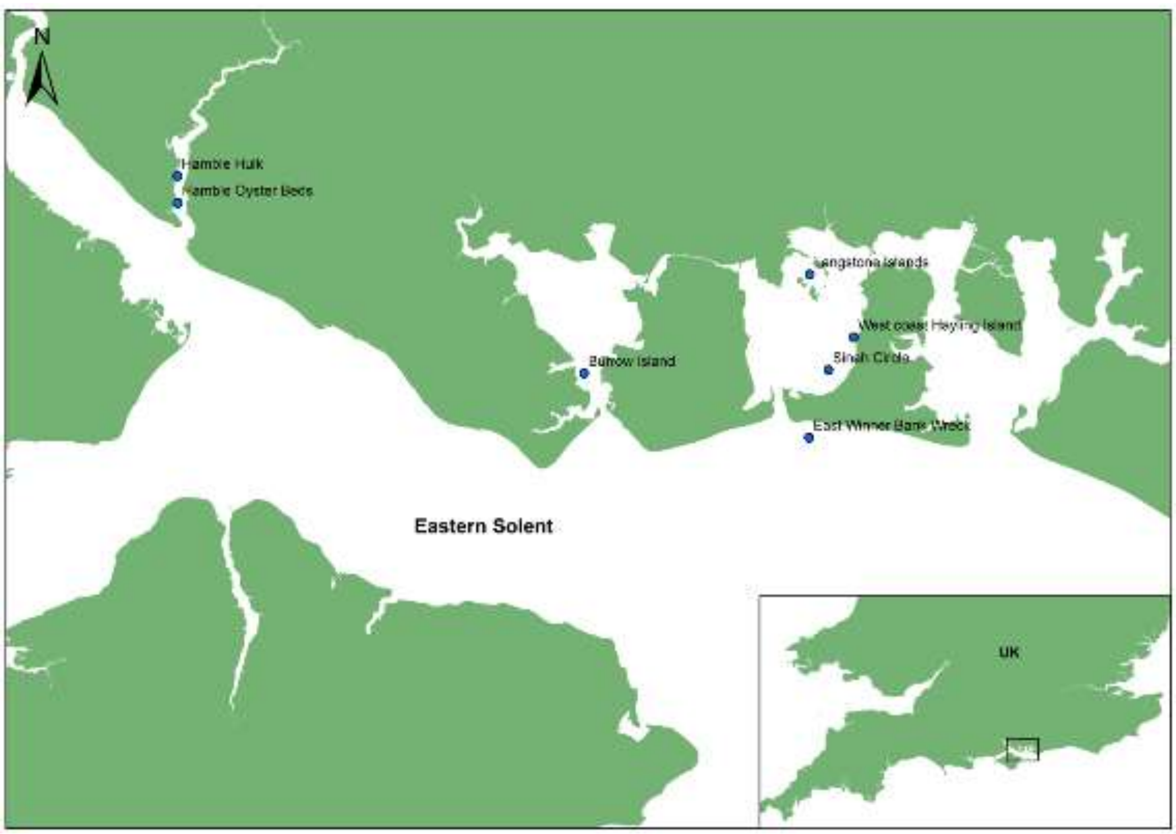

Figure 3D.6: Location of intertidal sites in the UK

3D.4.1 Western Solent

The western Solent is an interesting coastline to study as it has been completely reconfigured over the last 8,000 years during the rise of sea level. The process has not finished and a stable equilibrium has yet to be reached. It demonstrates how the long term evolution of a coastline can influence future patterns of change with important implications for ongoing management policies.

The underlying geological controls have been outlined in 3D.1.1 above. Dominant features along the coastal fringes are the Cretaceous Chalk structures. These have been folded to form rolling downs and sea cliffs which run from the Isle of Wight to Dorset in the west and extend below sea level to the east (Figure 3D.7). North of the chalk ridge the rocks dip gently towards the Solent. Here, the sedimentary sequences are younger and generally less consolidated than the chalk thereby succumbing more readily to weathering (Moore *et al* 2010). However, undulations in the landscape are also the result of geological factors where deep-rooted basement faults cause moulding of the plastic Mesozoic and Tertiary strata (Nowell 1995, Melville & Freshney 1982). This causes irregular rates of uplift and down-warping over relatively short distances. Some of the faulting has manifested itself as an anticline that runs along a northwest axis across the Solent from Newtown Creek to the New Forest while to its west there is a syncline or basin below what is now Yarmouth Roads. Hard limestone outcrops are in concordance with the anticline while the syncline is dominated by soft Eocene clays. The reshaping of the surface morphology along the western Solent coastline has been controlled by these varying geological features with different susceptibilities to erosion.

Figure 3D.7: White chalk cliffs on the south west side of the Isle of Wight

Key Research Questions

Palaeoenvironmental and archaeological remains can be used as indicators to record the scale and pace of past change within coastal units as a result of sea level and environmental fluctuations. The archaeological fieldwork and geomorphological studies conducted in the western Solent aimed to gather data that could answer the following research questions:

- What are the long term patterns of geopmorphological adaptation along the coastline as a result of sea level change?
- What are the current coastal and submarine processes?
- What can the palaeoenvironmental data collected from the western Solent tell us about the past environment?

- What can the archaeological data collected from the western Solent tell us about human adaptation to change and provide lessens from the past?
- Can monitoring discreet areas of the seabed show rates of erosion?
- How can this information be used in conjunction with previous survey work to inform on the changing landscape over time?

The fieldwork aimed to collect data from key areas of the western Solent that could build on past research to show current change and vulnerabilities. Work was focused on the prehistoric and landscape features at Bouldnor Cliff, Tanners Hard and Hurst Spit, while the wreck sites within Alum Bay reveal data on more recent seabed changes. These sites provided data on the north, south and west of the western Solent. The formation of the Solent has removed most prehistoric landscape evidence from the east of the study area.

The key aim of the fieldwork was to gather information on sites, finds and deposits which can inform on the changing landscape over time. The key objectives were to:

- Establish whether the submerged landscapes off Tanners Hard in the Solent were continuing to erode.
- Establish whether the submerged landscapes off Bouldnor Cliff in the Solent were continuing to erode.
- Sample palaeo-environmental material from the seabed to ascertain the date and process of past environmental change.
- Sample palaeo-environmental material from the seabed to aid understanding of the formation of the Solent and consequential impact on coastal processes.
- Monitor seabed changes around the wreck sites of Alum Bay to provide data on micro-scale changes occurring with the bay.

Long term patterns of geopmorphological adaptation along the coastline as a result of sea level change

The Holocene began when the Younger Dryas came to an end c.11,500 years ago and the climate warmed. The sea was 30-40m below current levels. Analysis of ice core GISP2 from Greenland shows a rise in temperature of 5º to 10º C in just a few tens of years (Taylor *et al* 1997; Alley 2000; Alley *et al* 1993). This increase in temperature caused relatively quick melting of the permafrost and ice sheets.

The millennia that followed the Younger Dryas were formative years for the western Solent basin (Momber, 2004). About 8,500 years ago sea level was around 15-18 m below Ordnance Datum (OD) and the Isle of Wight was part of mainland Britain. The Solent River ran down Southampton Water and veered east at Calshot. Tributaries from Beaulieu and Newtown plus waterways running through Portsmouth and Langstone Harbours joined the river as it headed south to the Channel. The area around Yarmouth Roads remained separated from the Solent River system by elevated land that mirrored the geological anticline running north-west through Newtown Creek. To the west there was another shoulder of land that ran along the line of Hurst Spit to Sconce Point. The Lymington River drained south between Hurst and Newtown, passing along the course of the Western Yar to Freshwater on the further side of the Isle of Wight (Figure 3D.8). The area of the western Solent formed a basin around the river floodplain with fresh water lakes and mires (Momber 2011a; Tomalin 2000b).

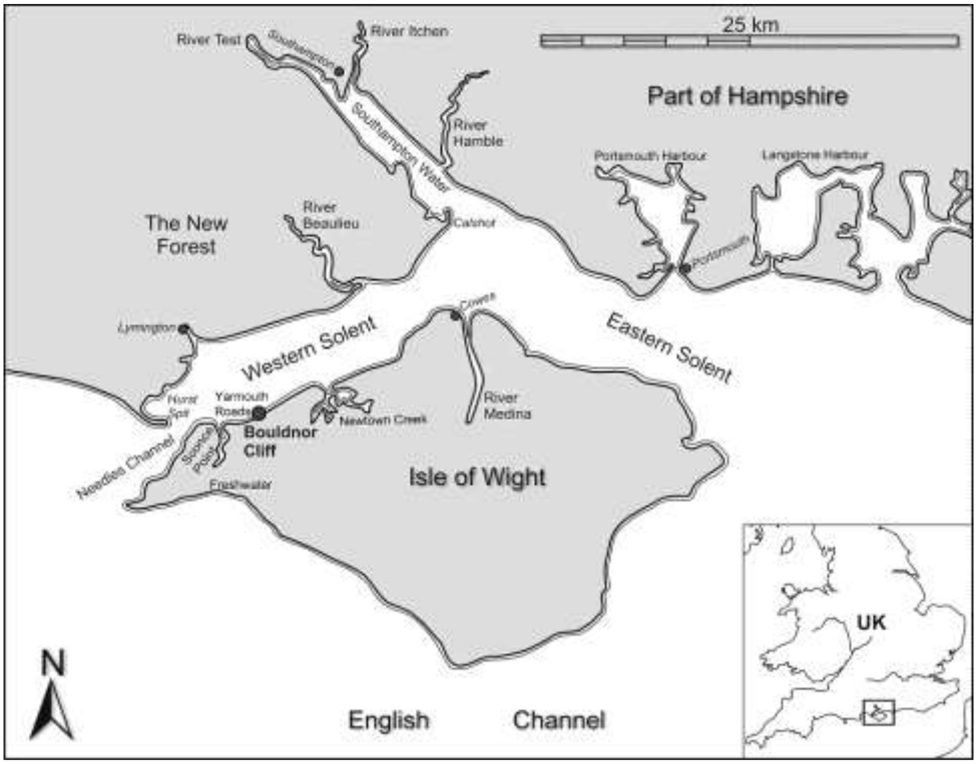

Figure 3D.8: Map of the study area showing the places mentioned in the text.

Five hundred years later, at 8,000BP the sea level had risen to 10.7m below Ordnance Datum (Momber et al 2011 p32). This had now flooded the west Solent basin and a wet fen environment was developing around an estuarine lagoon. The transition between a 'well watered' freshwater fenland to a brackish environment took a quite a few decades. The pollen record shows how it was accompanied by an increase of alder and grasses, ultimately resulting in colonisation by saline tolerant plants and the formation of saltmarsh.

As the sea water continued to flood into the Solent there is a strong presence of deep water planktonic and continental shelf foraminifera. Arrival at the site could be due to a sea level surge or reworking of older deposits. This also coincides with an expansion of the diatom *Paralia sulcata* that arrived with deeper water following a flooding event (Scaife 2011). The saltmarsh soon gave way to the formation of mudflat. Over the next 2,000 years the sea level rose a further five and a half meters during which time the mudflats continued to deepen (Momber *et al*. 2011). By the time water levels had reached 5m below OD, the flooded basin overtopped the land to the east and the Lymington River joined the Solent estuary.

The new expanded estuary continued to develop for the next 300 years or so laying down another metre of mudflat sediment. This deposit was then colonised by saltmarsh; evidence for which has been found along the north and south of the modern Solent, and on the Christcurch Bay side of Hurst Spit. At that time, around 6,000 years ago, the rate of sea level rise was slowing but the estuarine conditions in the western Solent prevailed. Studies conducted through the University of Southampton looking at the morphodynamics and evolution of the saltmarshes have concluded that these peats formed within an inner estuarine or bayhead deposit in the western Solent (Ke & Collins 2002, 435). Furthermore, a date has been speculated for the final submergence of the peat and the opening of the Solent to Christchurch Bay at somewhere before 2500 years BP. The figure is based on the assessment of dated peat samples from similar heights in the region (Devoy 1982; Dean 1995; Hampshire County Council 2014). 3,800 year old samples from peat deposits 2.5 metres below Ordnance Datum have subsequently been recovered from the south of the Needles Channel, east of Hurst Spit that show fully marine conditions were not introduced into the Solent until after this time (Momber 2011b). This means the area had not been overtopped and the western Solent waterway had yet to form (Figure 3d.9).

Until the Solent managed to break through its western end, the coastal zone between the New Forest and the Isle of Wight was sheltered and formed a sedimentary sink. It was an area dominated by mudflats and saltmarsh. This provided protection for the coastline and preserved the buried landscapes beneath it. When the Solent finally became an open channel new currents were introduced that started to remove the sediment and the protection it afforded the coastline. This new process has, and is still having, a very erosive impact above and below water. The fieldwork conducted as part of the Arch-Manche project has helped us to understand the rate and scale of erosion as well as contributing to our understanding of the geomorphological processes.

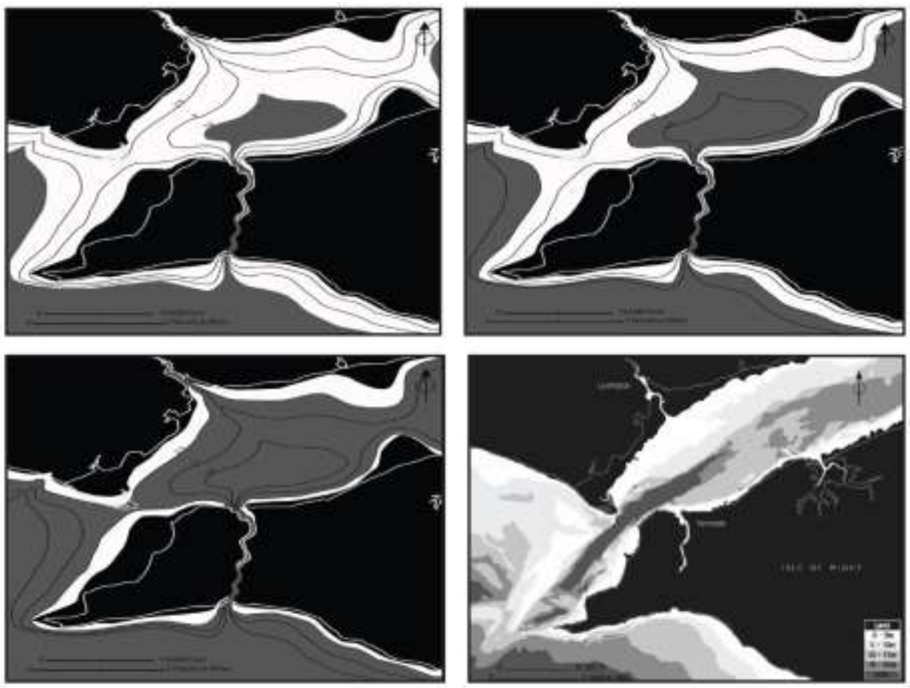

Figure 3D.9: Images showing the development of the western Solent. About 3,500 years ago, the breaching of the final land link to the island transformed a salt marsh into a channel that would eventually extend over 10km long and up to 60m deep. The strong tidal currents introduced when the channel was formed continue to erode the Solent shoreline today.

Current coastal and submarine processes

One of the most striking consequences of the new western arm of the Solent was the Hurst Deep. This is a furrow that has been excavated to almost 60m below OD off the reverse end of Hurst Spit. It runs for around 5 km towards the Needles in the south-west. Tracking 5km beyond the Hurst narrows in the opposite direction, the seabed quickly shallows again rising to less than 20m below OD off Bouldnor Cliff. It can therefore be seen that the central point off Hurst spit is roughly equidistant with shallow water to its east and west. The Deep is very localised and occurs where the currents are strongest. It would appear the channel off Hurst is controlled by the morphology of the spit which forces the water into a confined space causing scour (Dyer 1975). Consequently, its formation can be attributed to recent marine tidal attrition.

It is probable that the erosion around the Hurst Deep will be amplified as the sea level rises and the amount of water through the channel increases. The enlarged volume of water will add to the forces through the narrows. The Spit itself is now being defended with artificial recharge following storms by the sea defences and castle at its tip, therefore, it is protected from the forces. This is not the case for the other side of the Hurst narrows which is only 1.2km to the south east (Figure 3D.10). Here the Eocene clays and fine sands of the Headon Hill Formation at Fort Victoria Country Park are being washed away by the sea (Figure 3D.11). This area is likely to see an acceleration in erosion as the sea level rises.

Prior to coastal erosion, the hill would have extended further into the Solent. Before the breach it would have joined with the submerged land that still remains underwater to the north where it has been protected by the shelter of Hurst Spit. However, once that first bit of land was breached and the channel was opened, tidal scour has widened and deepened the water course at an exponential rate.

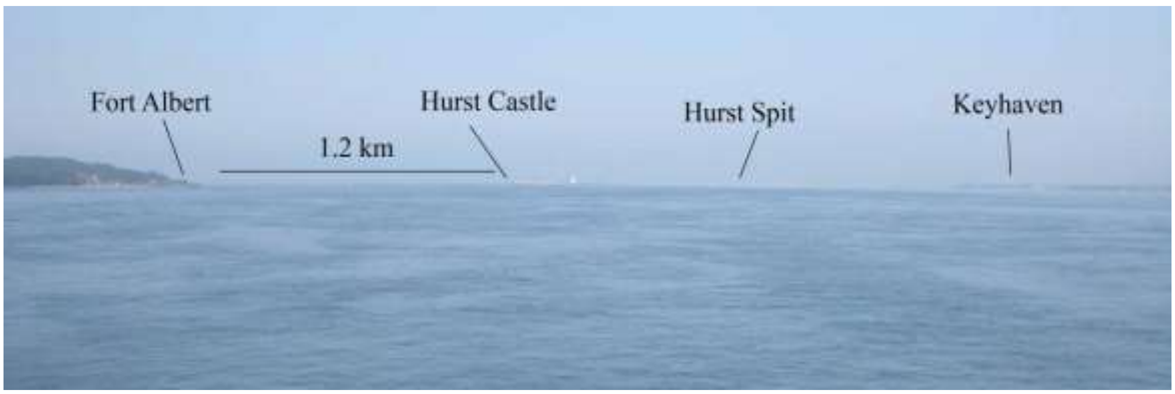

Figure 3D.10: A 3,800 year old palaeo-landsurface lying just 0.5m below Chart Datum remains protected on the east side of Hurst Spit (this side of the Spit in the image). The hill at Victoria Country Park, adjacent to fort Albert is receding. The width of the channel is only 1.2m while the depth is close to 60m. The spit and hill have protected the land causing the tidal forces to scour the 60m Hurst Deep. The forces acting in the channel will increase as sea level rises increasing threats to the coastline.

Figure 3D.11: Active erosion and rotational sliding forming a cliff along the north edge of Victoria Country Park.

Another significant geological soft spot is the 60m high cliff at Bouldnor which is the northwest face of a truncated hill a little over two 2km east of Yarmouth. The hill is composed of soft Oligocene Marls forming an angle of repose in the order of 15° to 20°. It is being steadily trimmed by the Solent and resulting in rotational sliding as indicated by fallen trees lying on the beach and expanses of bare rock face caused by mudslides (Figure 3D.12). The hill would have previously extended further northwest across the Solent towards the New Forest. Reduction of the current cliff at Bouldnor is clearly visible and rapid. This will have been accelerating as sea levels rose and it is also worth noting that the highest point on the hill at Bouldnor lies at the top of the cliff. This shows that the hill is still rising at the point where it is severed by erosion inferring that the pre-eroded hill would have been higher. The notion of a prominent hill extending across the western Solent valley towards the mainland before being eroded by the sea is unavoidable.

Figure 3D.12: Fallen trees below Bouldnor Hill resulting from cliff erosion

A record of recent movement of coastal features has been collected by historic chart comparison studies covering the last 200 years and the monitoring of the salt marsh over the last 50 years. This has shown a distinct regression of the coastline and declining saltmarsh along the north west Solent (Figure 3D.13) (source data from: http://www.channelcoast.org and New Forest District Coastal Group, 2007).

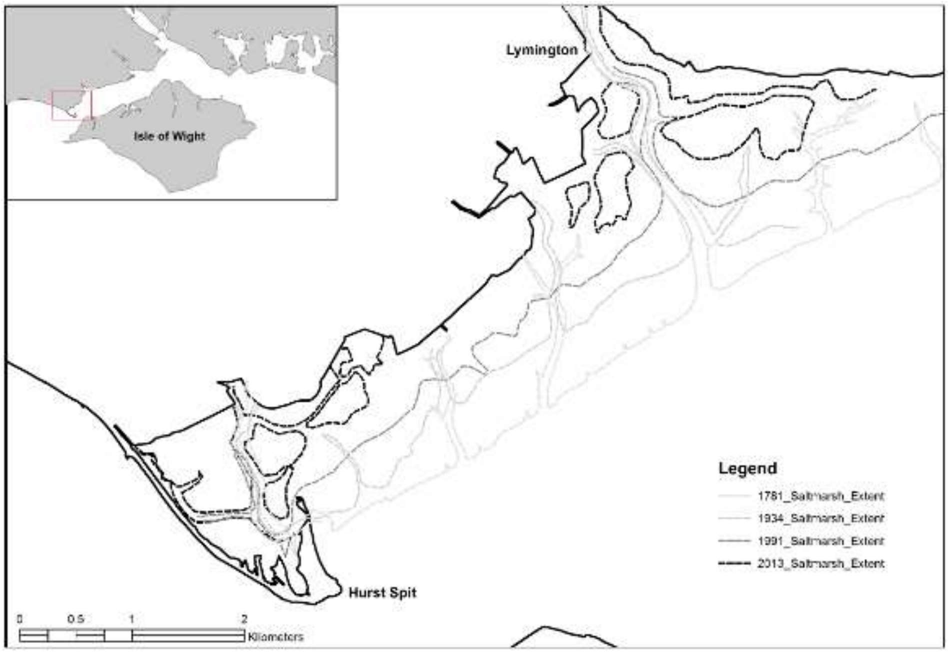

Figure 3D.13: Saltmarsh and mudflat regression from 1781, 1934, 1991 and 2013 based on the analysis of historic maps (see section 3D.7 below).

The removal of the mudflats has revealed a widespread deposit of peat and trees underwater at 2.5-4m below OD. These deposits have dates ranging from around 4,000 to 6,300 years BP. Much of the older deposit in 4m of water is very well preserved, however, now that it is uncovered it is eroding fast and subject to virulent degradation by crabs and wood boring organisms (Figure 3D.14). The landscape represents a shallow submerged bench that absorbs wave energy before it reaches the shore. The fresh, but aggressive loss of material testifies the long term stability of the submerged land surface inferring that it has been uncovered for the first time. This in turn implies that the mud flats have been stable for 6,000 years and the current regression is a modern phenomena that is invariably a result of human actions in the last 200 years. The loss of the mudflats and underlying land surface is increasing the threat to the coastline. Similar recorded submerged landscapes are seen along the southern shores of the eastern Solent (Tomalin *et al* 2012).

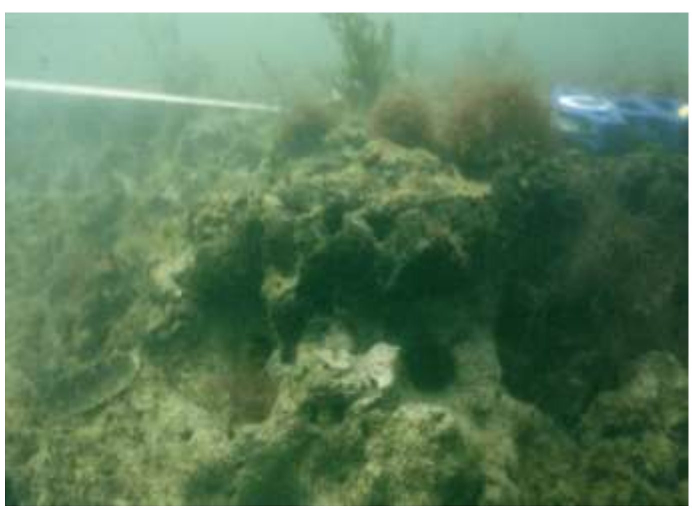

Figure 3D.14: Erosion and degradation accentuated by marine boring is evident within the relatively recently exposed submerged landscapes in the north-west Solent.

On the opposite side of the Solent, below Bouldnor Cliff, the relict landscape is less expansive due to the impact of the tidal channel that has scoured a linear 8-9m high cliff (Figures 3D.15 and 3D.16). It runs for around 1km below the water, parallel with the shore and the main channel at around 3-400m offshore. The top of the cliff reaches 4m below OD. This area has survived because it lies in a bay within the lee of Yarmouth, however, it continues to erode and as it does so, it both reduces protection for the coastline and exposes the palaeolandsurface that is eroding from the base of the cliff. This area has been monitored during the course of Arch-Manche fieldwork.

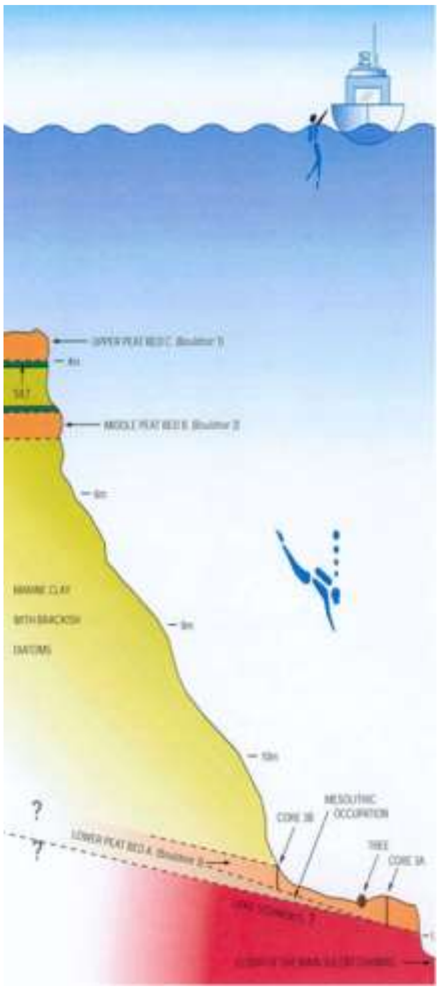

Figure 3D. 15 (left): Schematic across Bouldnor Cliff showing the sediment layers and relict submerged land-surface at the base of the cliff (Courtesy of Isle of Wight Coastal centre).
Figure 3D.16: (right) The 8-9m high submerged cliff at Bouldnor runs for 1km along the edge of the Solent channel parallel with the shore.

The investigations in the Solent have shown that by characterising areas of long term erosion, coastlines under ongoing stress can be identified. To improve our understanding of the changes there is a need to calibrate the rate and scale of erosion in the long and short term if we wish to anticipate future scenarios. The long term issues have been considered above while short and medium term changes have been addressed by the diving fieldwork conducted in the western Solent during 2012 and 2013.

3D4.1.1 Fieldwork Methodology

The fieldwork was conducted to monitor the seabed and collect samples that would address the key research questions outlined above. The fieldwork included:

Diver survey - The diving fieldwork involved the use of professional divers and suitably qualified volunteers over fieldwork seasons 2012 and 2013. All diving was conducted to UK HSE diving standards. The diving took place at Bouldnor Cliff, Tanner's Hard, Hurst Spit and Alum Bay from the certified dive vessel *Wight Spirit.*

Monitoring landscapes – On the prehistoric landscape sites the objective was to relocate the historic datum points and monitoring pins to calibrate rates of erosion over the past 10 to 15 years. When the datum pins were relocated, baselines were run between them and offset measurements were taken between the pins and well defined points on the cliff edge and to trees routed to the land surface. The measurements were taken at set distances along the baseline and the monitoring pins to replicate previous survey.

Monitoring also utilised bathymetric survey. A survey conducted in 2003 defined the lines of the submerged cliff and highlighted areas susceptible to erosion by marine boring crustaceans where reworked archaeological artefacts had been found on the seabed (Figure 3D.17).

A further survey was conducted at BC-V where the original survey grid was re-established with baselines and offset measurements were made to the eroding edge of the palaeo-landsurface in 11m of water.

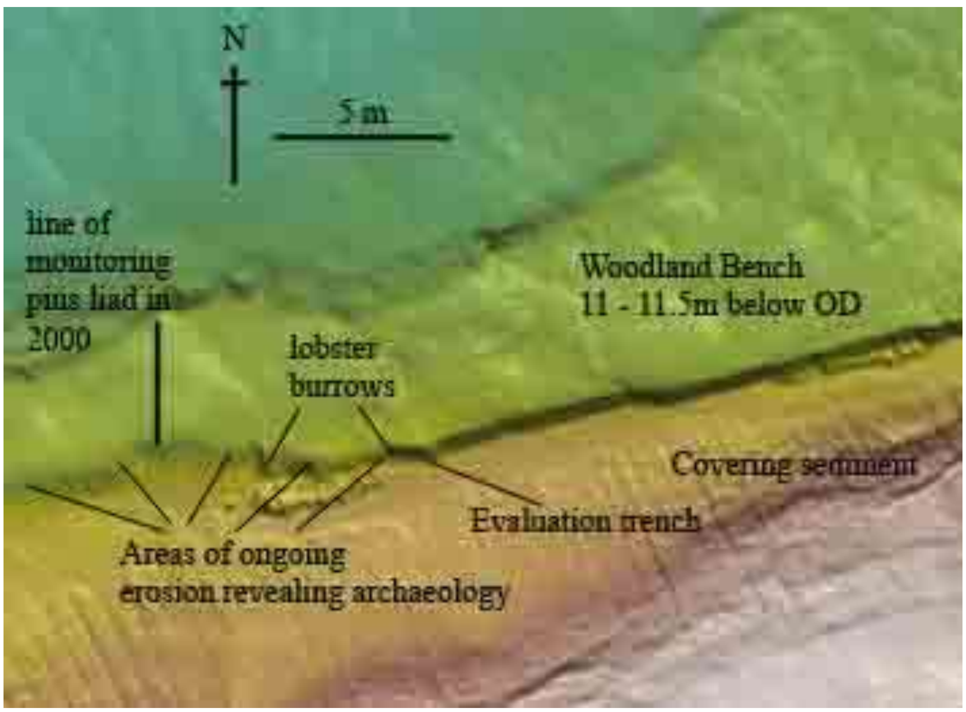

Figure 3D.17: Annotated bathymetric survey conducted in 2003.

Sampling landscapes – Sediment samples were collected from Bouldnor Cliff and Hurst Spit to assess palaeoenviromental changes and for radiocarbon dating. The samples were collected by divers using marine grade stainless steel monolith tins on Bouldnor Cliff and by taking cohesive bulk samples on Hurst Spit. Hand saws were employed to help remove the tins from the outlying sediment and the samples were protected by being wrapped in industrial-strength cling film at the point of extraction. These tin sizes are manageable for divers to handle but large enough to retain a cohesive sample (Figure 3D.18). Bulk samples were also removed from an evaluation trench at BCII following clearing of the alluvial clay to access the sandy clay archaeological layer beneath. Sandbags were filled upon completion and packed into the trench to backfill it to protect the surrounding seabed.

Figure 3D.18: Sample being recovered by divers from prehistoric landscape site.

The samples brought to the surface during diving fieldwork in 2012 and 2013 were processed once on shore by experienced staff or they were kept in cold storage at 6 degrees centigrade at the British Ocean Sediment Core Research Facility (BOSCORF) where they were sub-sampled by specialists to determine their suitability for palaeoenvironmental analysis. Selected samples were subject to radiocarbon dating.

Excavation – an evaluation trench measuring 1m by 2m was created by removing a slab of clay from an eroding section of the submerged landscape. The area below was sub-sectioned into 0.25 by 0.5 m areas and lithic material was recovered from individual sections. Sampling in the trench was limited to a single 30cm spit within the sandy silt deposit.

The excavation trench was also extended at BC-V. Here, the covering peat and humic sediment was removed from above timber that was vulnerable to erosion and loss. Conventional trowels and brushes were used to clear the sediment and work around the artefact before recovery.

Rescue artefacts – Artefacts which have been exposed through erosion of their protective sediments were recovered from the seabed before they were lost. The location of the finds were plotted with reference to the site grid.

Monitoring shipwrecks – diver survey of the Alum Bay 1 and 2 shipwrecks consisted of direct measured survey of areas of exposed wreckage in relation to established datum points. Additional evidence was gathered through photographic and video survey of the sites.

3D4.1.2 Results of work at Bouldnor Cliff II (BC-II)

Monitoring

Inspection of the seabed in 2012, 10m to the west from the evaluation trench excavated in 2003 revealed a large area of scour that extended into the base of the cliff. Previous survey had recorded a fallen oak tree at this location but it was now gone (Figure 3D.19). It would have been removed by the strong tides or been snagged and pulled from the bank by fishing gear. The underlying palaeolandsurface was now exposed (Figure 3D.20). This consisted of a sandy silt deposit that was covered by a horizon of peat, which, in turn was covered by a layer of estuarine mudflat deposit. This sequence of horizons was recorded in 2003 as part of an English Heritage project and dated by radiocarbon dating to around 8,000 years old. The base of the peat and sandy silt deposit contained archaeological material.

Figure 3D.19: 60 cm wide, eight thousand year old, oak tree on seabed at BC-II recorded in 2003. It is now gone and the area has become more vulnerable to erosion.

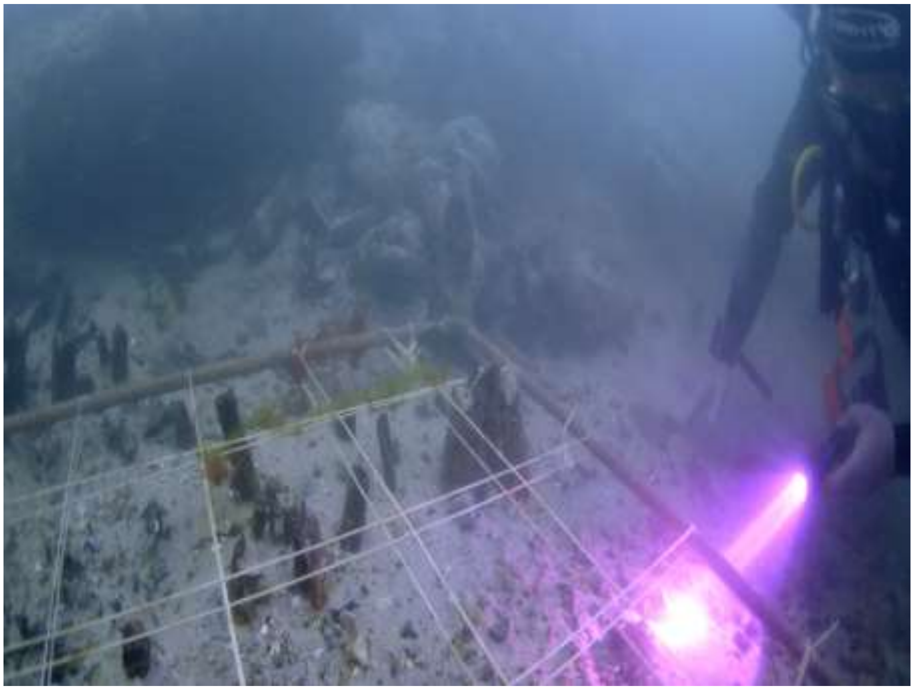

Figure 3D.20: *Area of seabed inspected and surveyed at BCII. This has become exposed since previous survey in 2003. Tree roots and flints can be seen in planning frame. The surface is now 11m below OD and is 8,000 years old.*

To determine the extent of erosion, the area was re-recorded and compared to the 2003 survey (completed in 2004). A number of the original datum points were relocated and the survey grid was re-established. Comparative measurements were taken from the survey baselines to the base of the cliff (Figure 3D.21). The erosion was recorded at around 3 m in 10 years although it should be noted that this was the location where a tree had since been removed.

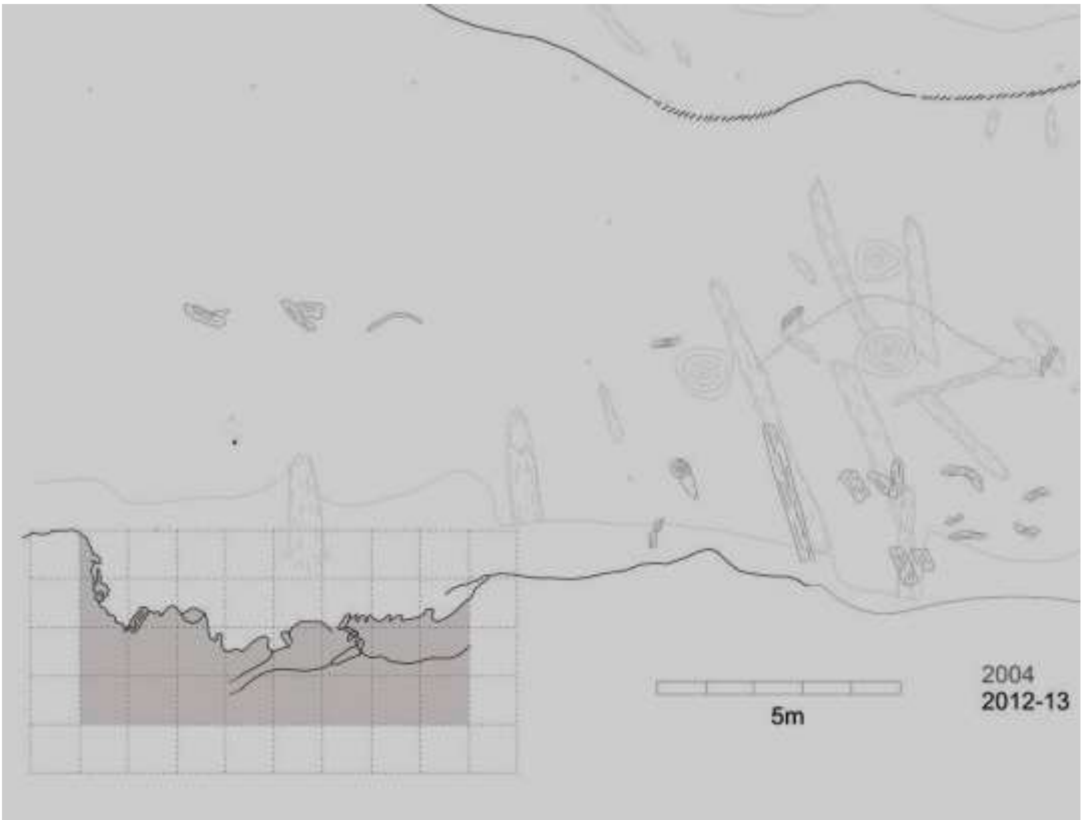

Figure 3D.21: The darkened area within the survey grid had been subject to greatest erosion since 2003/4. Erosion of 3-4m was recorded.

A main cause of the receding submerged cliff line is scouring and collapse. The fine sandy silt deposit that lies under the peat is easily winnowed away by the tide and is attractive for crustaceans who burrow into it. Once the sandy silt is removed, the peat and silt above is undermined. It soon breaks and collapses, falling onto the seabed in front of the cliff. From here, it is steadily washed away by the tides. Comparison of bathymetric surveys conducted in 2003 and 2013 can be seen in Figure 3D.22. It shows that the area investigated was already beginning to fracture and separate from the cliff in 2003.

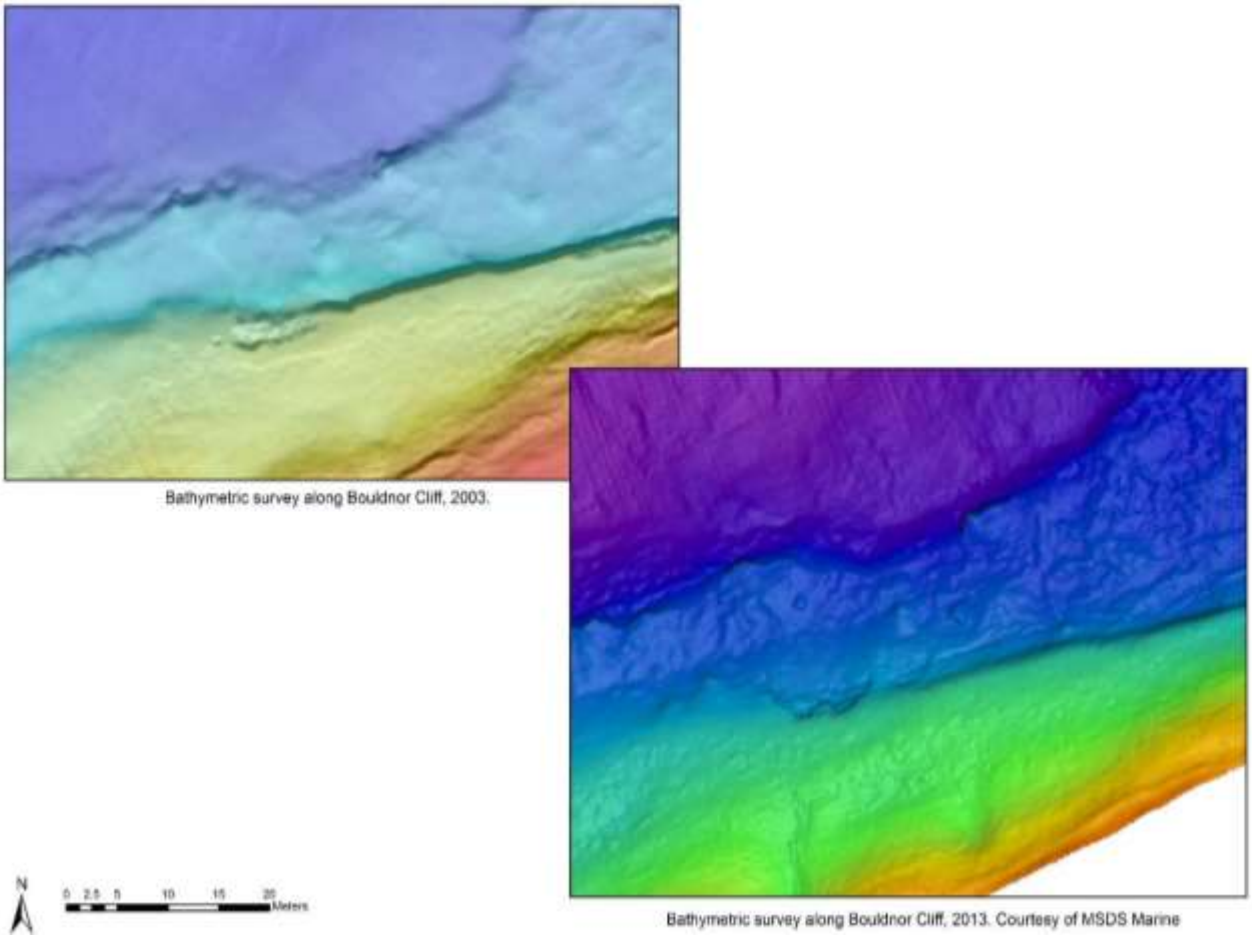

Figure 3D.22: Two bathymetric surveys conducted of the same area show plans 10 years apart. The different colours represent different depths. The colours change at 1m intervals although the hues differ between the two survey images. In the 2003 survey, the light blue area running from left to right in the centre of the image is the 11m deep submerged land surface. It is covered with trees inlaid within a matted peat deposit. The same layer is dark blue in the 2013 survey. The colours to the south, at the bottom of the image, represent the sediment within the covering cliff; the trees and peat extend underneath the cliff to the south. Here, the water gets shallower as the cliff gets higher. The area surveyed by divers is located at the bottom of the cliff and along the southern end of the submerged land surface: in the lower middle left of the images. The mottling evident in the yellow level on the 2003 survey is the area that has since collapsed. The loss of material can be seen when compared to the cliff edge at the same location in the 2013 survey.

Sampling at BC-II

Inspection of the seabed during the first dives on the site in 2012 resulted in the discovery of 43 pieces of worked or burnt flint. These were found in 11m of water at the foot of the cliff. The ensuing survey pinpointed their position to an 8m long section in the area where erosion was greatest (see Figure 3D.21). Here, the freshly exposed sandy silt horizon was being scoured by lobsters and the tidal currents. At the western end of the exposure, a deeply scoured undercut contained several flints (Figure 3D.23), although the concentration of discoveries was greatest 2m to the east (Figure 3D. 24).


Figure 3D.23 (left): An undercut running 1.1m beneath the peat cover. It is located at the western end of the survey area.
Figure 3D.24 (right): Loose worked flints recovered by divers following their discovery on the seafloor at Bouldnor Cliff. A limited amount of marine growth demonstrated that they had not been exposed for long.

Palaeoenvironmental evidence including, pollen, diatoms and foraminifera was also extracted from the site to characterise the changing climate and ingress of marine conditions at the time of human occupation. Pollen and diatom analysis was conducted by Rob Scaife. Pollen was extracted using standard pollen extraction techniques (Moore and Webb 1978; Moore *et al* 1991) on samples 2ml in volume, diatoms were prepared by digestion of humic/organic material using hydrogen peroxide, then drying on microscope cover-slips, mounting, then subject to examination at high-power magnification. Samples for foraminifera evidence were processed and analysed by Jan Gillespie after a process of soaking in Calgon 10%, washing, drying and examining at high-power maginification.

The results from the deposits at BCII showed a clear palaeoenvironmental sequence. Mesolithic activity, including flint working and the processing of hazelnuts in oak/hazel/alder woodland alongside a stream, the deposition of flint gravel, the development of alder-dominated fen woodland, its replacement (probably as a result of rising water level) by an alluvial reedswamp and, finally a full marine transgression. The samples from along the cliff at site BCV identified 3 local pollen sequences. Overall oak and hazel are the most important constituents throughout with only small numbers of birch and pine.

Other trees include elm, holly, ash and yew though taxa are less well represented in the pollen spectra and may have been relatively important constituents of the local woodland. There then comes a poorly developed palaeosoil and old land surface which was sealed by development of the overlying peat. Oak and hazel woodland prevailed on drier soils adjacent to a wet fen or slow-flowing river and lime was starting to colonise the habitat with a peaty humic soil developing. Increasing rainfall/humidity and increasing relative sea level during the early Atlantic period (Chromozone II) resulted in destruction of the on-site and near-local woodland. Rising sea level caused conditions suited to peat formation through the raised groundwater table, but this was ceased by the final marine/brackish transgression. Change to the marine conditions is also supported by evidence in the diatom and foraminifera record. The samples which came from the context are shown to be detrital fen peat and did not contain foraminifera or diatoms, this is followed by a salt-marsh deposit that developed following gradually wetter conditions and is evidenced by a foraminifera assemblage consisting of a typical mudflat fauna (*Haynesina germanica, Ammonia beccarii and Elphidiu? Excavatum). Trochammina* was recorded below this level indicating a transition from marsh to mudflat.

Excavation and artefact recovery at BC-II
The initial phase of diver survey identified an area where the covering clay had separated from the submerged cliff and was in the process of collapse. This was adjacent to an area where the concentration of archaeological discoveries was greatest so it was removed for the next phase of investigation.

The second phase of fieldwork in 2012 and 2013 was an evaluation trench, excavated to confirm that the flints were coming from within the cliff. A section that had been exposed by erosion was identified and cleaned (Figure 3D.25). The face was then protected from collapse with sand bags. This allowed the 2m wide capping of alluvial/mudflat clay to be removed without destabilising the deposit below. It was removed with ease as it had already broken away from the bottom of the sloping cliff. The clay was removed to reveal a layer of wood rich peat. The peat layer was divided into sections then carefully removed in 30cmx20cm blocks, flints were noted in the base of the peat. The peat samples were recovered in zip lock bags that could be carried to the surface by the divers in safety. The surface below the peat consisted of a fine sandy silt deposit with inclusions of vegetation and flint lithics.

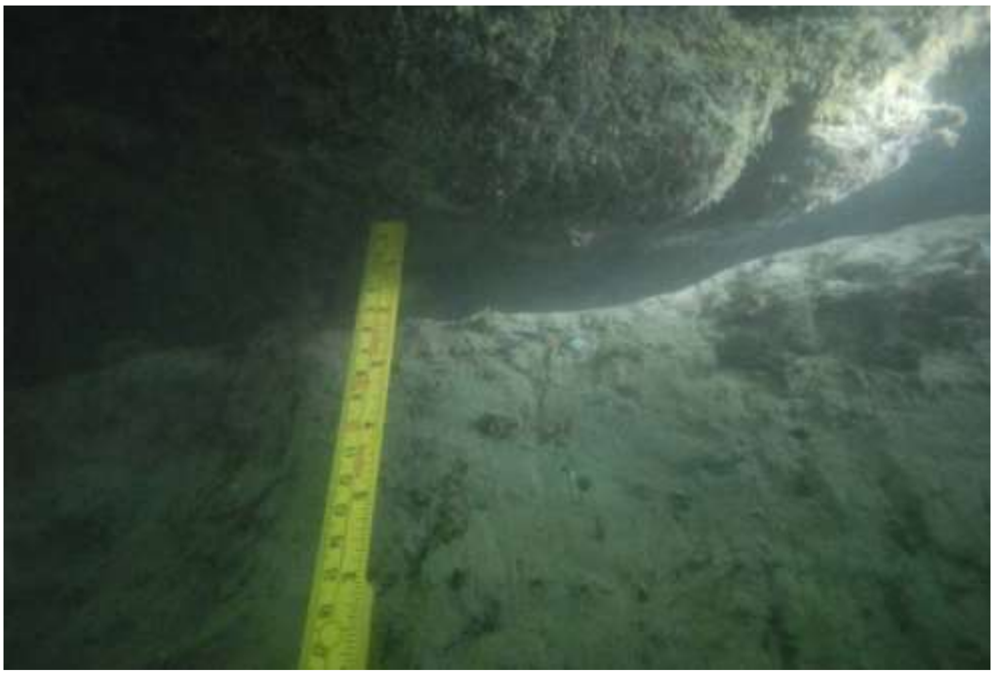

Figure 3D.25: Interface between the peat deposit and the underlying fine sandy silt. The sandy silt deposit is the main source of worked flints.

A 1m x 2m, east – west orientated surface was cleared below the peat. It was sub-sectioned into 0.5x.25m units and the surface deposits were slowly cleared by hand-fanning, towelling and brushing. Lithics that became exposed were recorded then recovered (Figure 3D.26).

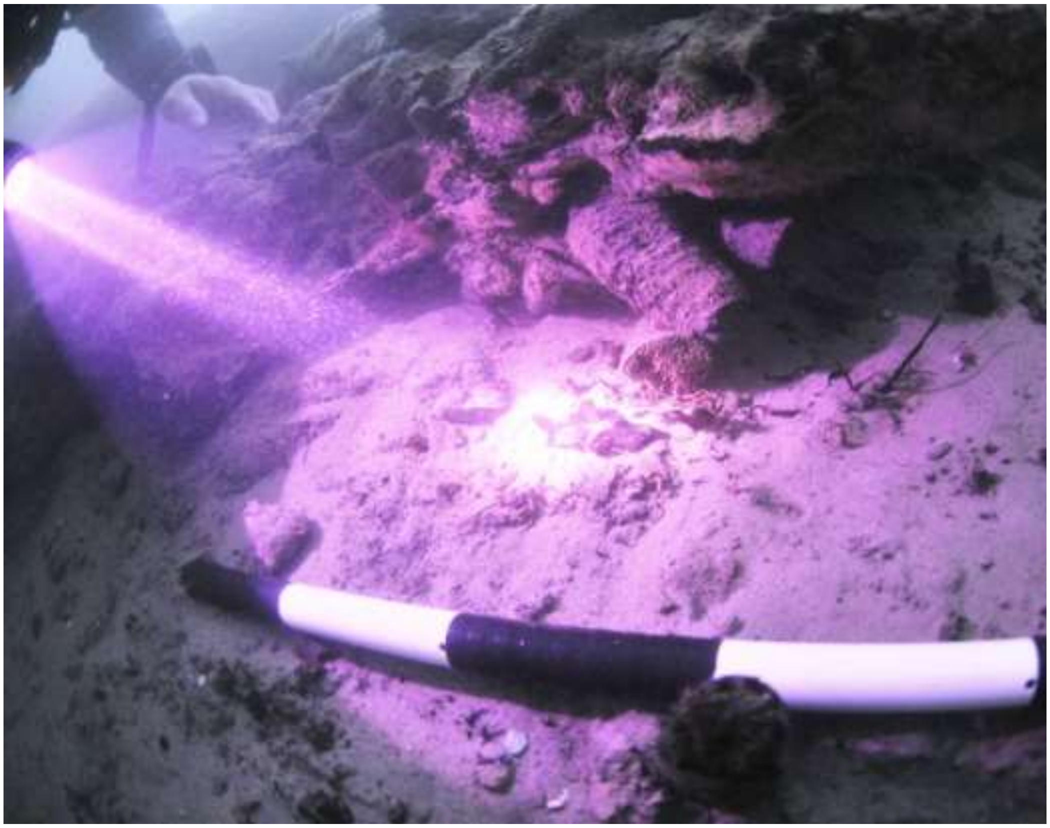

Figure 3D.26: The surface of the fine sandy silt matrix shown shortly after it was exposed but before sampling and excavation. The torch light is illuminating an oak leaf found in-situ and a black flint flake is visible immediately to the left of the beam.

The sediment was excavated to reveal worked and burnt flints. The flints were distributed fairly evenly across and within the sandy silt. Studies from 2003 identified the sandy silt layer as a sand bar deposit that built up adjacent to a fresh watercourse over the course of a few years or decades. This had undergone periods of stability that would have enabled activity on its surface. The flints could have been deposited during these periods. They might have also been subject to an amount bioturbation although the distribution is fairly even and the pattern is widespread across the deposit. In addition, the time period between deposition, development of peat and then burial under mudflat deposits following inundation would have restricted the window of opportunity for too much movement.

The deposit appeared homogenous and was excavated for 30cm which brought it close to the seabed level at the foot of the cliff. Here, more flints were recorded but this time there were several distinct clusters (Figure 3D.27). These flints would probably have been deposited on the land-surface before it was covered by the sandbar. The clusters were not large and could have gathered together naturally. There is a need to understand the wider context before we can qualify the relationship between the flints, however, the extensive vertical distribution through the sandy silt and into the peat demonstrates continual activity on the site during a period of marked environmental change.

Following the excavation, the site was backfilled with sand bags and re-covered with the capping alluvial clay that had been removed at the outset.

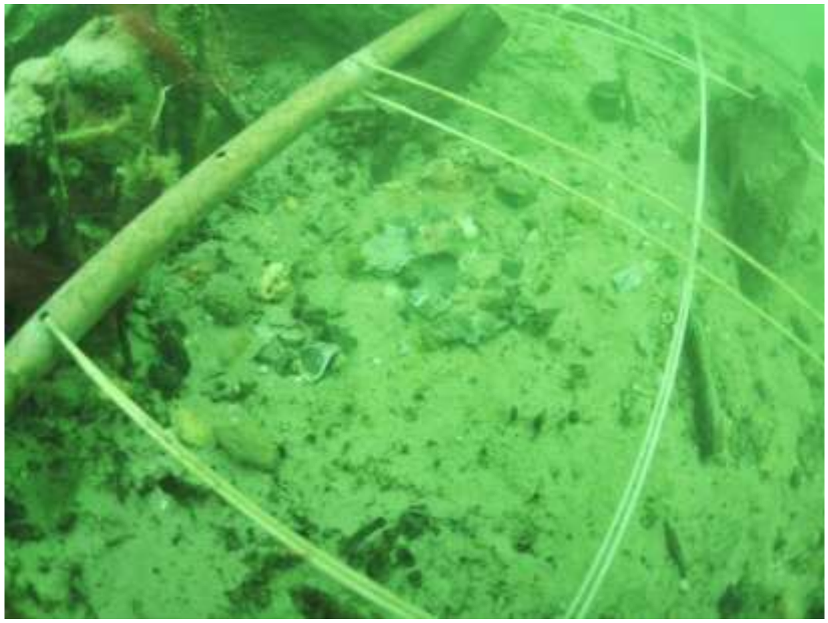

Figure 3D.27: Three clusters of flints were noted at the base of the evaluation trench. The cluster shown at the centre of this figure was located along the southern edge of the trench.

Artefacts

In total, 124 flints were recovered during the excavation (Figures 3D.28 and 3D.29). These were largely burnt flints, flakes, bladelets and cores. The struck flints were in very good condition and showed no signs of abrasion. The collection is comparable to that recovered in 2003 (Tomalin 2011), but it has yet to be fully analysed.

Figure 3D.28 (left): A selection of flakes and bladelets recovered during the fieldwork in 2012/13.
Figure 3D.29 (right): A selection of cores recovered during the fieldwork in 2012/13.

In addition to the 43 pieces of worked or burnt flints recovered from the seabed and 124 flints recorded in the evaluation trench in 2012, a further 35 flints pieces were identified and brought to the surface in 2013. Furthermore, a bovine trichlea/ankle bone was discovered within the depression scoured beneath the peat outcrop to the west of the site (see Figure 3D.30). The trichlea was found out of context but it was too large to belong to a modern cow, but the right size for an auroch. Collagen from the bone was dated to 6220 - 6020 Cal BC; 2 Sigma calibrated result, 95% probability (Beta-366541). During preparation it was noted that the collagen levels were low which could be caused by heating. If the auroch have been heated and possibly cooked, this would not contradict the archaeological findings to-date, however, signs of burning have not been detected on the bone, nor have cut marks. Either way, the discovery of the single bone indicates that there could be a great deal more evidence within the eroding cliff. Further investigation would be needed to answer these questions.

Figure 3D.30: Caudal view of the Auroch trichlae that was recovered from the eroded landscape at Bouldnor Cliff-II.

3D4.1.3 Bouldnor Cliff V (BC-V)

Bouldnor Cliff V lies 400m to the west of BC-II. It is a location that contains worked wood and is believed to be a site of wood working activity that could have included boat building. It lies on the northern edge of the peat platform where a cliff in the order of 1.5 m drops to the floor of the seabed and then dips gently into the Solent. The edge is subject to ongoing erosion by the tide and by crustaceans that burrow into it and destabilise the softer sediments. The site was revisited to record evidence of continued degradation and to look for further exposures of archaeological material.

Monitoring

A site grid was set up at BC-V in 2007 and west-east running baselines were laid between 1m long galvanised steel datum points. A 25m baseline was used to gather baseline data between the grid and the edge of the cliff to the north.

In 2012, the grid was re-established and offset measurement were repeated along the baseline. The rate of erosion along the cliff edge varied from negligible to 2m. The areas subject to the greatest amounts of erosion were in the east and west (Figure 3D.31). These were also the areas where most of the archaeological material had been identified.

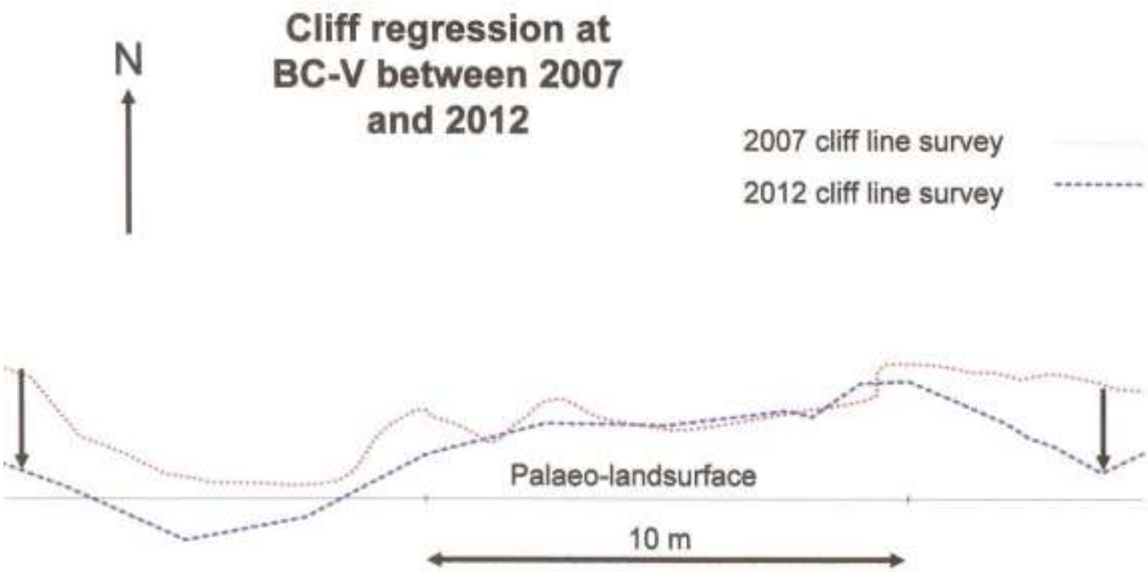

Figure 3D.31: Erosion monitoring plan of BC-V. Losses of 2m of sediment were recorded in the east and the west although the site was relatively stable in the middle.

Sampling

Sample collection at BC-V was limited. Material that is eroded from the northern edge of the shelf is quickly lost into the Solent allowing very limited opportunities for its rescue and recovery. However, during diver inspection in 2014, a new exposure of worked timber within a matted peat horizon associated with the archaeological horizon was recorded. It was eroding from the eastern end of the site, 18m west of the postulated wood working site. Pieces of protruding timber were recovered for recording and assessment (Figures 3D.32 and 3D.33).

Figure 3D.32: Undersides of split and worked timber from BC-V. The samples recovered in 2014 are at the top of the picture.

Figure 3D.33: Opposite side of the two split timbers recovered in 2014. The flat side is down.

Excavation and Artefact Recovery at BC-V

Approximately three square metres of seabed were excavated between 2007 and 2001. The site of excavation was 2m back from the edge of the cliff. This was an area where the palaeo-landsurface of peat was sitting above a humic surface that contained archaeological material. 25 pieces of archaeological timber were recovered from this area. Amongst these timbers was one large timber which proved to be a plank which had been tangentially split, the technique was, and still is, used for boat building and other structural woodworking and has been observed in assemblages of timber from the Neolithic to the Bronze Age but is unknown in the Mesolithic. It is not known if further material exists although exposures of similar worked wood have been found within 20m of the location.

In 2012, inspection of the excavated trench revealed the area in the south was receding and a timber feature was becoming exposed (Figure 3D.34). The timber was excavated and recovered (Figures 3D.35 and 3D.36). A smaller piece of worked timber was also identified in the base of the archaeological horizon, 0.5m to the north. This was also recovered (Figure 3D.37).

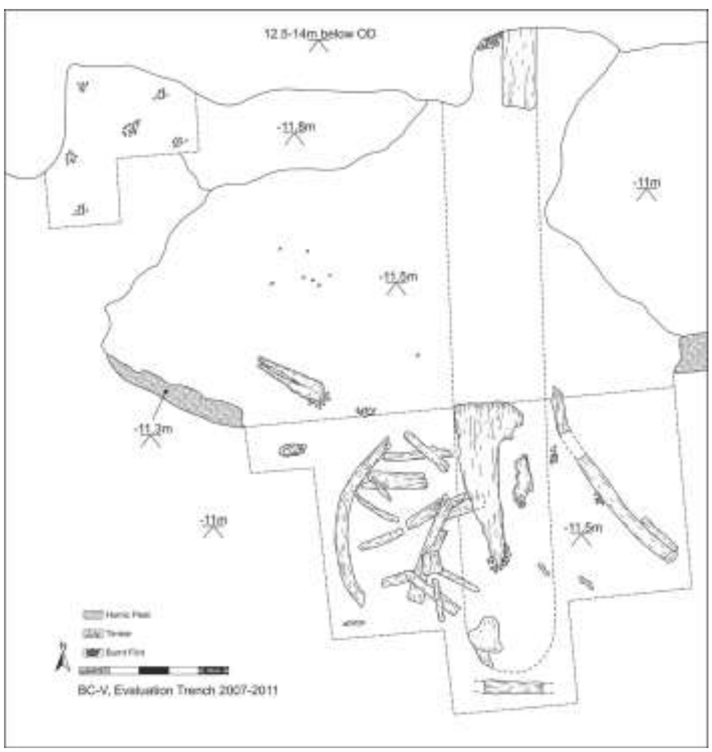

Figure 3D.34: Plan of the wood working site at BC-V. The exposed timber recovered in 2012 was first noted in 2011. It is recorded on the above plan as the southernmost piece of timber.

The timber rescued in 2012 was recorded in-situ then carefully recovered to the boat. The timber was chopped from the roots and was found laid on its side perpendicular to the line of the proposed log boat that was being worked on site. Four such pieces of timber that had been cut down in this way have been found at the site. They are of varying size and two are shown with the 2012 recovery in Figure 3D.35. The timber measured 1.1m long and had a distinctive cut, 0.7m from its base (Figure 3D.36).

Figure 3D.35: The 1.1m long timber recovered in 2012 was found lying perpendicular to the hypothesised log boat where it would have provided support at its southern end. The smaller pieces of timber, were harvested by Mesolithic people in a similar way. They were found in the same assemblage of timbers at BC-V.

Figure 3D.36 (left): Close up of the distinctive cut o.7m from the base of the recovered timber.
Figure 3D.37 (right): A smaller piece of fashioned and worked timber was recovered from the floor of the trench extended in 2012. It contains well defined cut marks but its function is yet to be determined.

3D4.1.4 Pitts Deep and Tanners Hard

The terrestrial landscape at Bouldnor once extended across the valley floor into the New Forest (Figure 3D.38). Tracts of submerged prehistoric landscape still remain in the north west Solent. The area has been a source of many prehistoric artefacts and is an integral part of the old Solent cultural landscape.

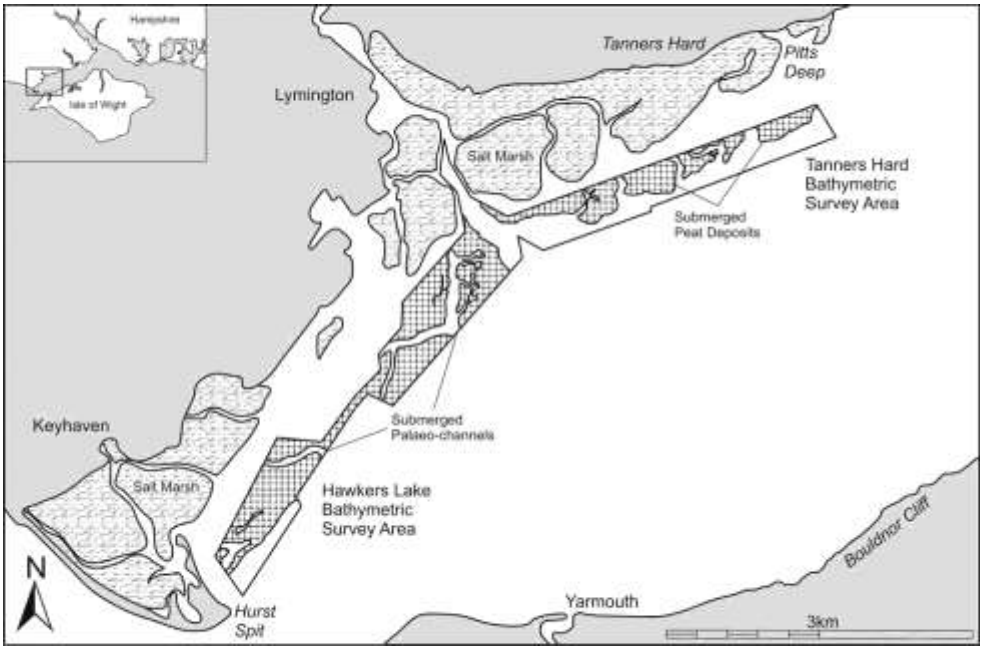

Figure 3D.38: Peat deposits in north west Solent are signified by the hashed boxes. The data was collected by Bathymetric survey.

Monolith samples taken from Tanners Hard in 2000 were subject to palaeo-environmental analysis and radio carbon dated. The samples were taken from a well-defined section along the submerged cliff. The base of the upper peat platform which sat at a depth of -4m OD was dated to 5510 +/- 70 BP (2 sig cal BC 4470 to 4240) (cal BP 6420-6190) (Beta-166477) (Figure 3D.39). The lower peat, beneath the silt at a depth of -7.7m, provided a date of 6170 +/- 60BP (2 sig cal BC 5290-4940) (cal BP 7240-6890) (Beta-166478).

Figure 3D.39: Section at the top of the 1.5m high cliff off Tanners hard. The peat deposit is 0.2m thick.

Monitoring survey at Tanners Hard

In 2000 a grid was set up on the edge of a 1.5m high cliff 1.5km south of Tanners Hard on the New Forest coast of the north west Solent. A key datum was a railway wheel laid 5m south of the cliff edge (Figure 3D.40). The peat deposit was 0.2m thick all the way to the edge of the cliff. The cliff at this point dropped vertically for a distance of 9m. Its angle of repose reduced to the east and west of the vertical section.

Figure 3D.40: The railway wheel that is used as a sinker and monitoring point for cliff erosion.

The 2012 inspection and survey was conducted at the same spot. The large circular sinker positioned 5m south of the north facing cliff edge in 2000 was relocated and its position relative to the cliff edge was recorded. The measurement was taken from the centre of the wheel, as it was in 2000, and recorded as 3m. This demonstrated erosion of 3m. However, the erosion was greatest along the edge of the cliff. The vertical drop recorded in 2000 had now been reduced to a slope of about 45 degrees and the peat along the cliff edge has thinned with patches of silt showing through. The erosion could be natural but the evidence suggests it has been trimmed by fishing activity where lines scrape along the edges of the cliffs.

The baseline was relocated and the measurements concurred with the direct distances recorded from the railway wheel. Monitoring pins were placed to the west of the sinker in a new survey area at Pitts deep at 7m offset from the cliff edge. Offset measurements were taken to two peat edges north of the cliff.

The loss of the mud flats along the north west Solent are having a direct impact on the coast line. A visit to Pitts Deep, which lies 1 km to the east of Tanners Hard, following the storms in January 2014 revealed extensive erosion of harbour structures that date back to the 16th century. Material had been removed for the first time since the harbour was built (Figures 3D.41 and 3D.42). This level of destruction will be ongoing if the saltmash continues to erode. The submerged landscape provides a shallow water breakwater that reduces the energy of the waves. Once it is gone, the erosive forces along the shore will increase.

Figure 3D.41: The loss of mudflats from the north west Solent have reduced protection for the coastline. Erosion of infill deposits from this post medieval jetty at Pitt's Deep during the winter of 2014 now make the cultural site and the shoreline much more vulnerable.

Figure 3D.42: Layers of wattle that would have been laid beneath the jetty infill are now exposed and eroding. These probably date to the 18th century although Pitt's Deep was known as a harbour when the first charts were drawn up of the area in the Elizabethan Period (17th century).

3D4.1.5 Hurst Spit

Hurst Spit is situated at the entrance to the Solent. There is a distance of 1.2km between the tip of the spit and the soft eroding cliffs behind Fort Victoria Country Park where the seabed plunges into the 60m depths of Hurst Narrow (see section - *Current coastal and submarine processes* – above). Where Hurst Spit reaches out in the mouth of the western Solent it has protected a palaeo-landsurface that bridges over half the distance between the mainland and the Isle of Wight.

Diving survey in 2012 identified a submerged peat deposit to the west of Hurst Spit. This is an area that is exposed to the predominant westerly storms. The spit has migrated to the east across this palaeo-landsurface so the date and character of the land can provide information that can inform the processes of change that led to the current geomorphological configuration of the spit and formation of the Solent. In 2012 and 2014 the peat deposit to the west of the spit was inspected and samples were collected for palaeo-environmental analysis and dating.

Sampling

A peat sample was located 0.5 km from the end of the spit (50º 42' 26"N, 01º 33' 38" W), from an outcrop of submerged land on the western side from the shingle spit at c.4m below OD. A section of the protruding deposit was recovered with a hand saw (HS01). Its orientation was labelled, it was sealed in a zip lock bag and recovered to the surface for further analysis and sub-sampling. Two samples were taken; one from near the base of the peat and the other from near the top. Unfortunately, the covering sediment was missing and the amount of the surface lost by erosion was unknown. This compromised the accuracy of the dates as an index points for sea level rise, however, when complemented with palaeo-environmental analysis of pollen, diatoms and foraminifera, the relationship to sea level rise within the changing environment could be resolved.

Results

The sediment samples raised from the submerged land off Hurst spit were subject to palaeolenvironmental investigation and radio carbon dating. Well preserved pollen and spores where recovered from the sample (HS01) which gave two radiocarbon dates of 3690+/-30BP (2190 to 1980 Cal BC) (*Beta*-366543) and 3780+/-40BP, (2290 to 2140 Cal BC) (*Beta*-366542). The pollen report, produced by Dr Rob Scaife, concluded that the area the sample had been recovered from was once wooded, and the dominance of hazel pollen suggests that the on-site vegetation comprised relatively dry woodland with sufficient moisture to enable humic accumulation. Oak is present and would certainly have been growing within the overall hazel woodland. It is possible that ash and lime may also have been growing on nearby well drained soils as they are generally poorly represented in pollen assemblages unless the sample site is in close proximity to their growth (Andersen 1970, 1973). A very limited herb pollen flora is attributed to the ground cover of the site, especially enchanter's nightshade and sedges (Figure 3D.43). Evidence of acid heathland communities was nearby and a wet *sphagnum* mire community is seen to develop in the upper levels of the peat. Interestingly this acid plant community reflects the sand Tertiary lithology lying north of the chalk ridge and is comparable with the heathland of adjacent Headon Warren on the Isle of Wight. Samples taken from three submerged peat beds at Bouldnor Cliff also demonstrated the expansion of Sphagnum in the western Solent in the uppermost of the peat beds (Scaife 2011) where there is a similar change to a more acidophilous *Sphagnum* community. A late prehistoric radiocarbon date of 5580+/-60BP (4525-4330 Cal BC), (Beta-140102) from underlying sediments demonstrates that this change occurred during the late-prehistoric period. *Sphagnum* may have developed over quite a substantial area of the low lying and now submerged western Solent as demonstrated at these two sites with similar ages. Other than a single record of Chenopodiacea in the upper level of the sample it is concluded that there are no indications of impending saline conditions although transgression must have taken place at a later date. Analysis showed that the sample did not contain any diatoms or foraminifera, which is indicative of a terrestrial land surface without a maritime influence.

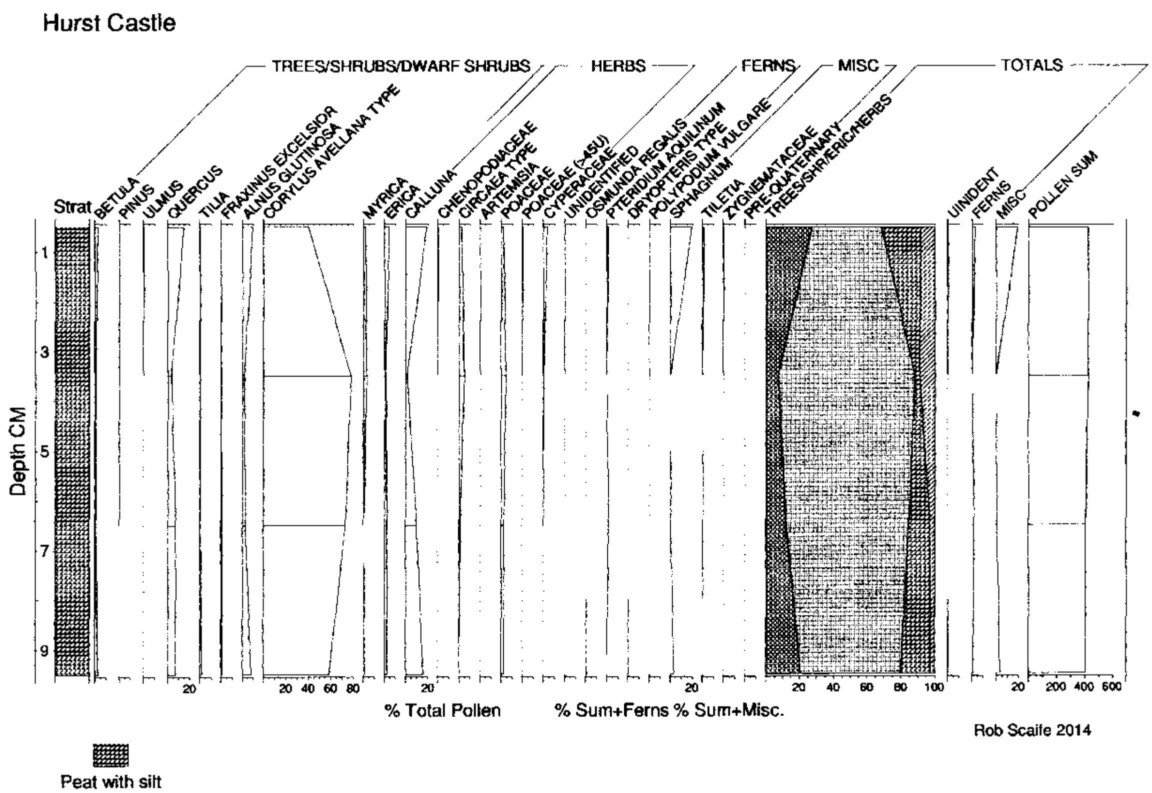

Figure 3D.43: Pollen diagram from Sample HS01, off Hurst Spit, Hampshire.

Interpretation

The sample was recovered from immediately to the west of the spit and represents a landscape without the immediate influence of marine conditions. The environmental characteristics compare favourably to the changes seen in the upper peat deposits within the western Solent. These were formed on top of an earlier mud flat and prior to further inundation, however, they occurred a couple of thousand years later. The sites from within the Solent were recovered from a depth of -4.1m below OD off Bouldnor Cliff with a date of 4525-4330 Cal BC (Beta 140102) and in -4.0m below OD in Tanners Hard dating to 4470-4240 Cal BC (Beta166477).

The sample from Hurst Spit (HS01) is from a similar depth to those in the Solent which is unusual as it was dated to over 2,000 years later. It was formed during a period when sea level was rising, so, when compared with the western Solent sea level curve, it should have been inundated. However, it was dry land. Another sample from the east of Hurst Spit (HSE1) was dated to 1900–1690 Cal BC (Beta-270797), which was only 2-300 years later. It came from a landscape that was 2.5 m below Ordnance Datum (OD). The difference in heights could be accounted for by a fall in sea level between 4,000 and 2,000 BC (which is contrary to the sea level curves along southern Britain), or compaction (that is probable and could contribute to it being in a deeper depth, but the sample was recovered from next to a tree bowl that was round rather than oval, whereby suggesting compaction was limited), or it could be caused by a larger tidal range in the Solent caused by funnelling along the Estuary. Today, the funnelling effect of the Solent and Southampton Water on the tide between the open sea and Southampton, which lies towards the top of the estuary, is around 0.6m. If the high tides were 0.6m higher in the Solent 4,000 years ago, the saltmarsh or mudflat would have developed at a similarly elevated height. If the western Solent was still an estuary when the land on the east side of the modern-day Hurst Spit was formed, as dated by sample HSE1 to 1900–1690 Cal BC (Beta-270797), the funnelling effect would explain the relatively high salt marshes in the Solent. If the Solent was an open waterway, this discrepancy would not exist. This infers that the Isle of Wight was still connected to the mainland at this location around 3,800 years ago.

The evidence from the relative dates and depths of the earlier land surfaces is significant enough to hypothesise a late formation of the Solent, but it would still be beneficial to calculate the extent of compaction to refine our understanding of relative sea level. This is also important to the assessment of coastal stability along the spit. The issue of stability relates to the migration of the spit over underlying landscapes. If a spit or beach is being forced uphill, it will invariably meet more resistance and travel more slowly. However, if it is pushed along a flat surface or downhill, it will be less stable and be more vulnerable.

Diving fieldwork in 2014 included a further inspection of the peat deposits along the west of Hurst Spit, 900m from the reverse end (50º 42’ 28”N, 01º 33’ 50” W). At this location, a wide expanse of peat was evident. This was inlaid with tress and vegetation. The deposit was at a depth of 5.5 to 6m below OD. The peat overlays soft clay sediment that is at least 1.3m thick. Following ground-truthing by divers, the peat deposit was identified on bathymetric data supplied by the Channel Coastal Observatory (Figure 3D.44). The peat deposit is truncated in the west along a cliff that mirrors the line of the spit and continues towards the spit in the east (Figure 3D.45). The spit is known to have migrated to the east in historic times. As it has moved, it would uncover land to the west that was once protected. Hordle Parish Saltern, which was shown on the east side of the spit on the Murdoch MacKenzie chart of 1781, appeared on the west side of the spit following a large storm in 1989. This meant the spit moved around 100m in 200 years. Therefore, it is probable that the spit migrated east away from the peat deposits that are now exposed underwater. It should also be noted that the peat creates a dipping seabed which travels steadily upslope towards the current beach at a gradient of approximately 1:10. It is possible that the peat has suffered greater erosion to the west, although, long term horizontal erosion has formed a submarine cliff. If this does represent a slope, it means the beach complex including the spit has ascended to the crest of the relict hill.

The evolution of Hurst Spit has been dependent on the long term geomorphological processes that formed the western Solent. This has dictated its past response to maritime forces and it is influencing its response to current and future storm events. This information is fundamental when assessing the long term management of the spit.

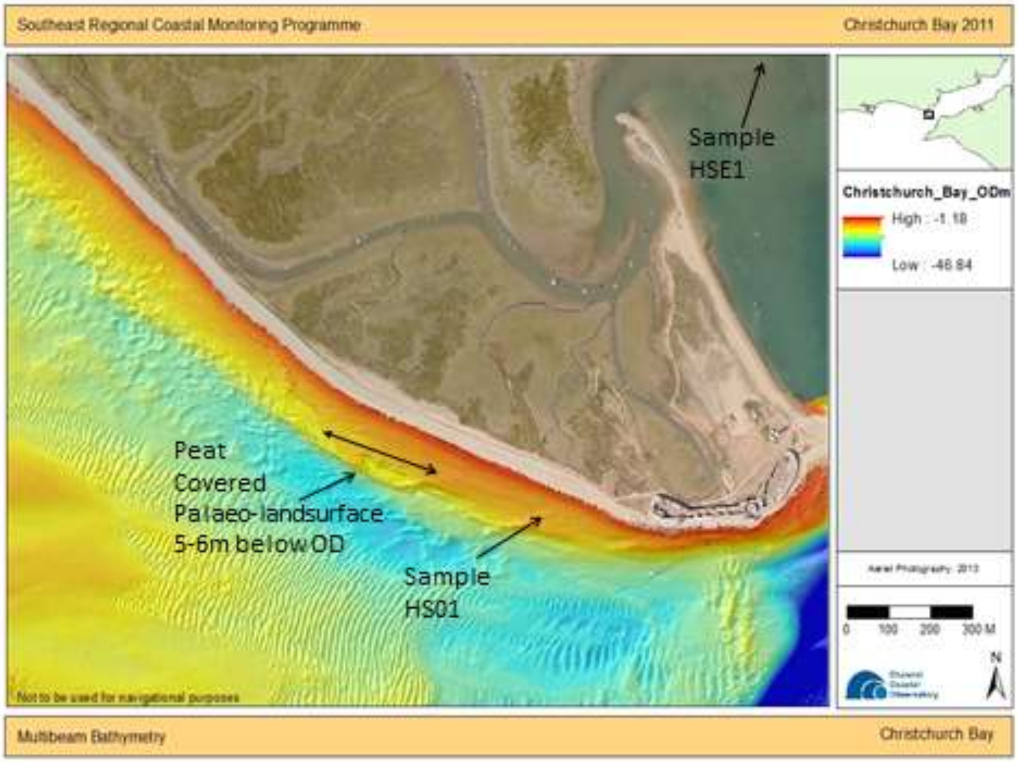

Figure 3D.44: Bathymetric data showing the seabed west of Hurst Spit. Image kindly provided by the Channel Coastal Observatory.

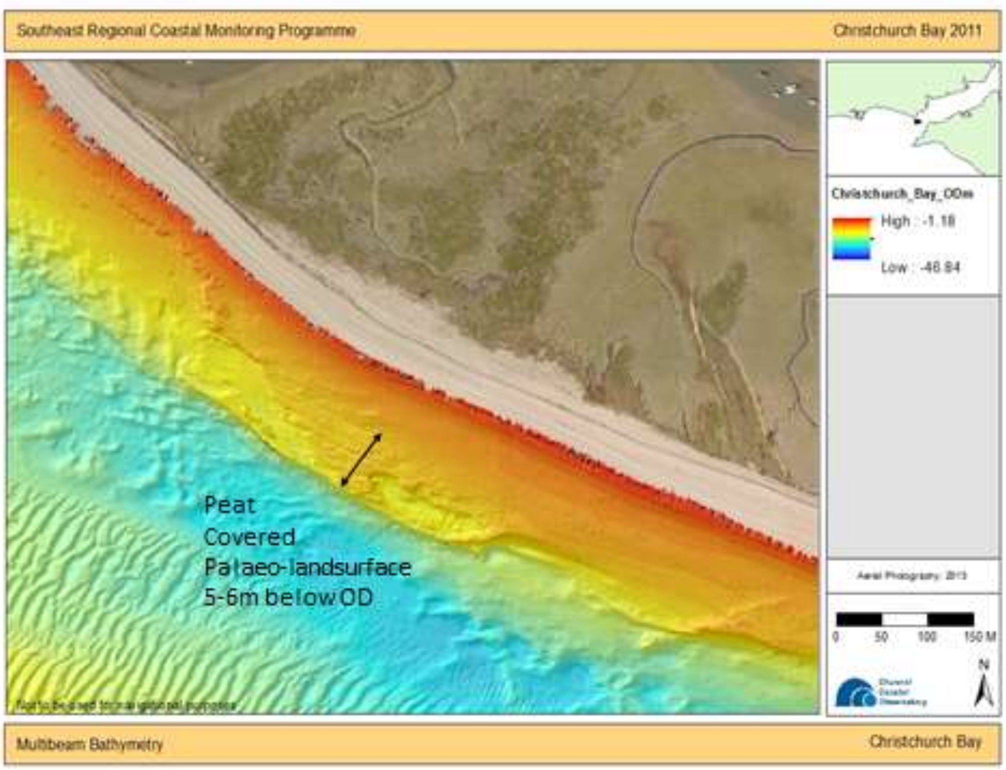

Figure 3D.45: Close up of the bathymetric data highlighting the peat deposit on the seabed west of Hurst Spit. The peat forms a slope from east to west. Image kindly provided by the Channel Coastal Observatory.

3D4.1.6 Wrecks of Alum Bay

Alum Bay itself is located on the north west coast of the Isle of Wight (Figure 3D.46). Needles Point and its famous surrounding rocks are the most westerly point of the island and are located at the extreme western end of Alum Bay. The coastline of the bay forms steady curve, bounded by high chalk cliffs prone to rock-falls and landslips along the southern edge with bands of coloured rock along the eastern side. Alum Bay is bordered to the north-west by the Needles Channel.

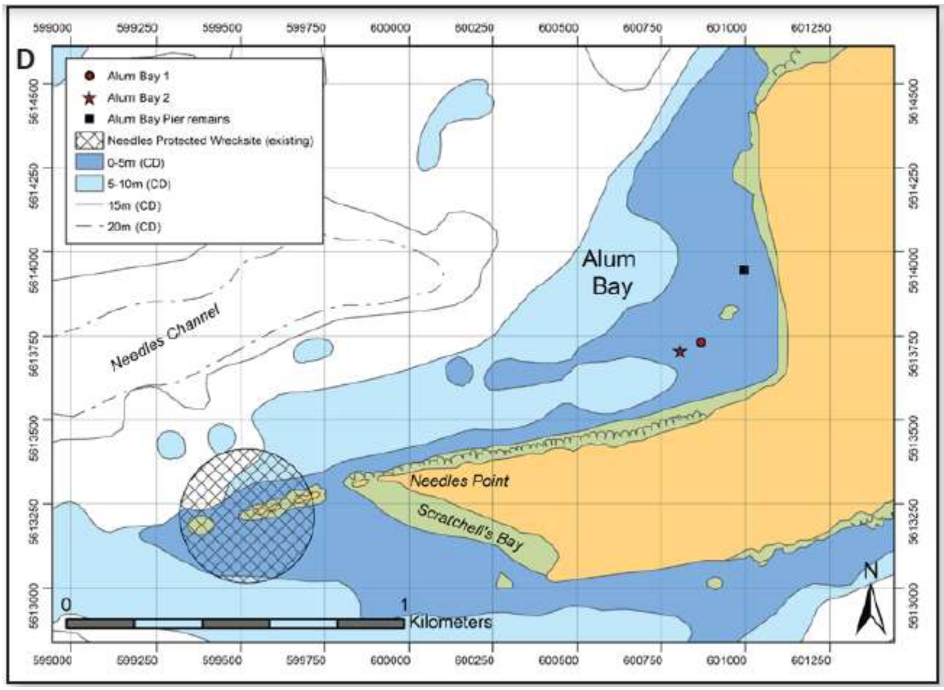

Figure 3D.46. The location of the wrecks within Alum Bay

3.1.1 Geology and Seabed

Alum Bay lies within the Greater Poole and Christchurch Bay region as defined by the South Coast Regional Environment Characterisation (SCREC). Christchurch Bay is a relatively shallow embayment, defined by Hengistbury Head in the west and Hurst Spit and The Needles in the East. The underlying geology of the area is of Wealdon Beds to the south of a line running between The Needles and Purbeck, a thin strip of Lower Greensand/Gault and Upper Greensand lies to the north of this. The remainder of the area to the north is comprised of Bracklesham Beds, Barton Group and Solent Group (cf. Velegrakis, 2000: 23-25 & Figure. 3D.47). Alum Bay lies just at the intersection of these and the chalk outcrop that traverses the centre of the Isle of Wight (Figure 3D.47). This has resulted in the famous coloured rocks along the eastern cliff of Alum Bay and the notable contrast between those and the chalk cliffs and stacks of the southern edge of the Bay and the Needles proper (Figure 3D.48).

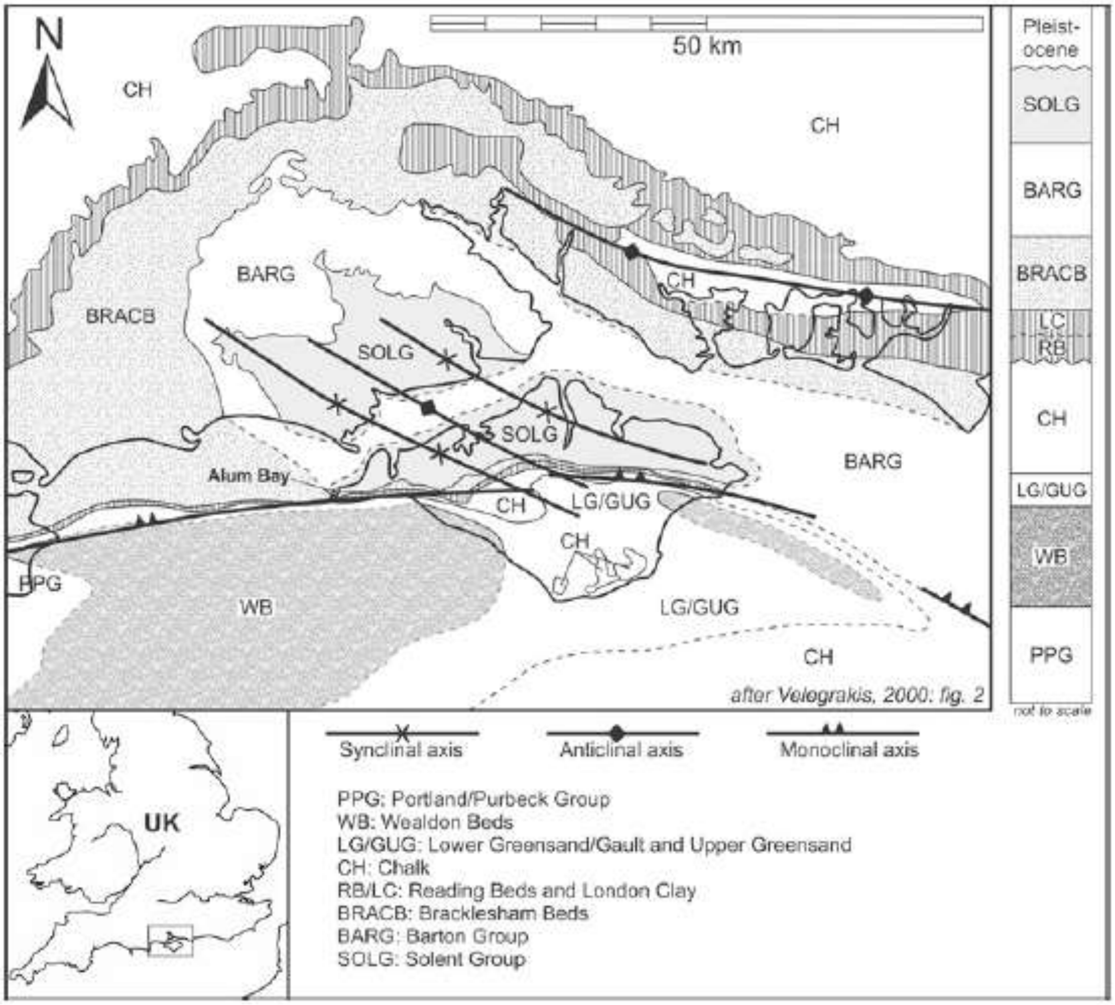

Figure 3D.47: The geological context of Alum Bay (after Veligrakis, 2000).

Figure 3D.48: The Needles, Needles Point and Alum Bay looking east from the Needles Channel. The inner reaches of Alum Bay can be seen where the cliff geology changes from white chalk to coloured sands.

In the south of Alum Bay, the Reading Beds and London Clay dip steeply (SCOPAC: Western Solent, E5&6) and all strata in Alum Bay are soft and easily eroded, comprising clays, sandstones and occasional grit and pebble horizons. There is ongoing erosion of the high chalk cliffs that line Alum Bay, although little quantitative work has been undertaken on the scale and pace of change (SCOPAC: Western Solent, E5&6). Erosion occurs as the cliffs are undercut and destabilised through marine erosion, leading to infrequent, localised rock falls, depositing debris on the cliff base and beach, which is then gradually removed by marine processes before the cycle is repeated (Figure 3D.49). The erosion of these cliffs has been cited as being an important source of gravel and course sands for local beaches while finer sands, silts and clays derived from the cliffs are thought to be susceptible to rapid suspended transport offshore. The seabed in the area is a thin layer of sandy-gravel, overlaying bedrock. Within the SCREC, the seabed at Alum Bay is described as 40-50% gravel and 50-60% sand, this comprises poorly-sorted granules with a mean diameter of 2-4mm.

Figure 3D.49: High chalk cliffs characterise the shoreline along the southern side of Alum Bay and are subject to on-going erosion resulting in significant landslips (Photo: Ine Demerre)

Observation during fieldwork within Alum Bay indicates that the seabed around the two wreck sites consists of sandy silt which overlies the bedrock. A seabed sample was taken from the area of Trench 3 during the 2010 fieldwork, prior to the excavation and removal of sediment from this area. The sample extended between two of the vessel's frames to the depth of the outer hull planking. As such, the sample encompasses the sediment overlying the wreckage following its deposition.

Assessment of the sediment has identified four distinct layers all comprised of sand. Each of these layers is c.25mm thick and very distinct in nature. From top to bottom these layers are described as follows:

1. Upper mobile yellow sand.
2. Beige sand.
3. Very dark-grey sand.
4. Mid-grey sand.

It has been possible to correlate the assessment of the recovered seabed sample from AB1 with existing diver observation of the sediment composition made during survey and excavation of AB1 and survey of AB2. This indicates that sediment disposition, prior to any excavation or disturbance has been broadly similar across both sites, resulting in a thin layer of sediment covering both sites.

Tidal and Sediment Regime

Alum Bay is exposed to tidal currents and modified open sea, including swell and waves. Maximum significant wave heights of up to 2.3m might occur at a 1 in 50 or 1 in 100 frequency. The general tidal patterns in the Solent are complex (see Bruce, 2008) and the relationship between the tidal streams in Alum Bay and those in the western Solent and Needles Channel no less so. In the Needles Channel, north-easterly tidal flow peaks at 3.7 knots, 5 hours prior to high water (Portsmouth) springs (Bruce, 2008: 10) and the south-westerly tidal flow at 3.3 knots, 3 hours after high water (Bruce, 2008: 26).

The sediment regime in the surroundings of Alum Bay is twofold. Offshore, the over-riding regime is one of the south-westerly transport of sediment from the western Solent and Hurst Spit along Hurst Channel and the Needles Channel. This is partly related to the tidal regime in the area. Tidal flow is broadly asymmetric, with a concentration of the ebb tide into a shorter time period than the flood tide, with a correspondingly higher potential for sediment transport in a seaward direction. The potential for sediment transport against this general regime has also been noted and in the case of coarse sediment transport this is seemingly the result of high wave energy coupled with a storm surge (SCOPAC: Western Solent, F1). Meanwhile, fine sediment may be transported in a north-easterly direction during the longer flood tide. Inshore, within Alum Bay, there is a net littoral drift from southwest to northeast leading to the transport of flints, sand and gravel from Alum Bay towards Totland (SCOPAC: Western Solent, LT4) and net offshore loss of fine sand in Alum Bay has been suggested (Brampton *et al*., 1998).

In comparison to the rest of the Isle of Wight, Alum Bay has received far less study and is correspondingly less well understood. Survey, monitoring and reporting of beach profiles to advise on sediment erosion/accretion has taken place around the Isle of Wight as part of the Southeast Strategic Regional Coastal Monitoring Programme (see Crocombe, 2008; Case, 2009a; 2009b). However, the Totland 1 cell (containing the western half of Alum Bay) has either not been included in the topographic survey so far undertaken through this programme (Crocombe, 2008: 12) or the survey has been delayed (Case, 2009a: 21; 2009b: 18). Some data is available for the Totland 2 cell (containing the eastern half of Alum Bay). Where monitoring of beach material has taken place, it has revealed an overall loss of material between 1996 and 2002 (Bradbury *et al*., 2003). Analysis of the northern half of Alum Bay between 2003-2004 illustrates an accretion in the cross-sectional area of the beach caused by a steepening of the profile (Crocombe, 2008: 19, 150-2). The northern half of Alum Bay has been classified as being in 'retreat' at the mean high and low water marks with a classified *foreshore change parameter* of -6 (Crowcombe, 2008: 19). It has been suggested within the context of the work of SCOPAC that future increases in rates of sea-level rise and winter rainfall would have the potential to accelerate the landslides on the cliffs within Alum Bay, with an increase in the supply of sediments to the sediment transport system just outlined, as a result.

On-site Sediment Levels

As part of the Arch-Manche project diver survey was undertaken to record sediment levels in the vicinity of the two areas of historic shipwreck (Alum Bay 1 and Alum Bay 2). Observation since 1993 on Alum Bay 1 and 2001 on Alum Bay 2 suggests that the level of sediment has changed at either site, in different ways and that any observed changes tend to be quite localised in nature. In general, it may be stated that the levels of sediment at both sites have remained relatively stable over the last decade or so, although there has been an observed reduction in sediment, and associated exposure of wooden structure, at the site of Alum Bay 1. However, there has been no dramatic exposures of ‘fresh’ structure or significant accumulations of sediment.

At the site of Alum Bay 1, there has been a slight reduction in sediment cover over the archaeological remains, this is more pronounced around the hawse-hole structure that protrudes from the seabed at the northern end of the site (Figure 3D.50). There, the hawse pipes have become far more visible than in previous decades and wooden material has become exposed and degraded away. Meanwhile, the photographic archive from Alum Bay 2, located slightly further towards the Needles Channel, suggests that sediment has accumulated on the site since 2001, obscuring the exposed framing timbers at the northern end of the site (Figure 3D.51). It may also be noted that the low laying nature of Alum Bay 2 means that it has been particularly prone to changes in sediment levels, with small increases greatly obscuring the site.

This general observation seems at odds with the overall sediment regime model for Alum Bay and the surrounding areas (above), which indicates that there should be net sediment loss within Alum Bay, rather than the relatively stable levels of sediment that seem to be present over the last decade or so. A possible explanation might be that while fine sediment is being transported in a generally north-east direction from Alum Bay towards Totland, similar sediment is accumulating around some areas of the two wreck structures as a result of sediment movement from the south-western end of Alum Bay within the overall north-easterly trend. The reef that lies to the north of both sites may be having an impact within this process by reducing sediment transport to the north. It should also be noted here, that the period of archaeological diver observation on the two sites has taken place over a much longer time frame than the limited investigation into sediment movement within Alum Bay itself. Broadly speaking, Alum Bay 2 appears to be better protected, at the time of writing, than Alum Bay 1; the former being subjected to slowly increasing levels of sediment, while the latter is seemingly subject to slow reductions in sediment levels.

Figure 3D.50: Changes to sediment levels at the site of Alum Bay 1 in the area of the hawse holes. Top: 1993, Middle: 2001, Bottom: 2003 (photo Roland Brooks). Overall sediment levels seem to be gradually falling in this area of the site, leading to the exposure and subsequent destruction of wooden structural material.

Figure 3D.51: Changes to sediment levels at the site of Alum Bay 2 wreck in the northern area of the site where framing timbers are most exposed. Top: 2003, Middle: 2003, Bottom: 2013 (photo Roland Brooks). Overall sediment levels seem to be gradually increasing in this area of the site, affording the wooden remains protection from marine organisms and erosion.

3D.4.2 Langstone Harbour

Fieldwork was carried out in Langstone Harbour in September 2012 and June 2013. A large archaeological project was carried out in the harbour in the 1990's with further work carried out by the MAT in 2002-2004. This work demonstrated the rich archaeological resource of the area and how modern erosion is exposing more material off islands located in the north of the harbour over time. Work as part of the Arch-Manche project aimed to re-survey some of the areas previously investigated and undertake further intertidal survey and sampling.

Key Research Questions

The archaeology ranking criteria demonstrated that archaeological and palaeoenvironmental remains can inform on past coastal change through the information they contain on past environments, or their location relative to changes to the coastline. The fieldwork conducted in Langstone Harbour over the two seasons of investigation aimed to gather information to answer the following research questions:

- What can the archaeological and palaeoenvironmental data collected from Langstone Harbour tell us about the past environment?
- How can this information be used in conjunction with previous survey work to inform on the changing landscape of the harbour over time?

The fieldwork aimed to collect a variety of different types of data from key areas of the harbour that had been identified as important by previous studies. These included the islands present in the north of the harbour, which are known to be the last vestiges of the prehistoric landscape prior to inundation; the west coast of Hayling Island, where numerous finds and wooden features have been identified; the channels of the harbour itself; and the location of the Sinah Circle.

The key objectives of the fieldwork were to:

- Establish whether further sites, features, deposits or finds of archaeological interest currently lie exposed off the coasts of Long Island, North Binness Island and Bakers Island;
- To gather detailed survey data on archaeological exposures to aid understanding of the landscape over time;
- To further investigate a palaeochannel and associated peat deposits which had been identified through augering off the west coast of Long Island;
- Determine whether other palaeochannel features lie buried below the current foreshore levels;
- Locate and investigate 'flint walled building' and associated complex of banks on Bakers Island; and
- Recover material for analysis and dating where it has the potential to add to understanding of coastal change.

Fieldwork Methodology

The following methods were used;

Walkover surveys – these were carried out in order to identify sites, features and finds which may have eroded or been exposed at the fieldwork sites. Positions were taken using a Real Time Kinematic (RTK) GPS along with a photograph. Artefacts were recovered if at risk of loss and archaeologically significant.

Monitoring of previously recorded sites – sites recorded during the 1990's Langstone Harbour Project and the 2002-2004 survey work were revisited to determine whether they were still in-situ or had been eroded. Positions were recorded with the RTK GPS system and photographs taken.

Landscape survey – the RTK GPS system was also used to survey the current edge of two islands in Langstone Harbour, focussing on the base of the small cliff which marks the extent of erosion.

Photographic survey – Photographs were taken of all the sites in Langstone Harbour, these and the associated index sheets are stored on the MAT servers.

Sampling – samples were recovered from the timber structures off Hayling Island and sent for radiocarbon dating along with samples from the auger survey.

Positioning - A Leica 1200 Real-Time Kinematic (RTK) GPS system was used to record the precise position of sites and areas of landscape. The RTK system provides accuracy to within +/- 15mm. Data collected can be imported into GIS for further processing, management and analysis. For archiving purposes, all basic data is retained in the form of a simple .txt file to ensure full future access to the original data collected during the survey.

Auger Survey - This was carried out off the west coast of Long Island with the aim to track the buried palaeochannel identified during previous excavations in the area. The survey was carried out using hand augers, both a gouge and dutch head were used (Figure 3D.52). Samples were assessed on site, with examples being recovered for further analysis and dating. The relative depths of the different soil types were noted when analysing the samples, so as to build a geological/stratigraphical sequence of the sediments.

Figure 3D.52: Auger Survey off Long Island, Langstone Harbour

Marine Seismic Investigations - As on land, reflection seismic measurements at sea involve the use of a sound source, towed behind a vessel or mounted to the hull, to generate acoustic waves that travel through the soil. Part of the acoustic signal is reflected from the seafloor but the remainder penetrates the seafloor and is reflected when it encounters boundaries between layers with different elastic properties. The recorded reflected acoustic waves result in a continuous record of the sub-seafloor stratigraphy.

Several physical parameters (frequency, output power, pulse length) determine the capability of the chosen technique. High frequencies provide higher resolution, but are limited in amount of penetration below the seafloor whereas lower frequencies provide lower resolutions but better penetration. Increasing output power allows for greater penetration but in the case of a hard seabed or very shallow water this will yield strong multiple reflections (i.e. seafloor echo) and lower signal to noise ratio. Finally, long pulse lengths yield more energy and result in greater penetration but will decrease the resolution. Shorter pulses correspond to broader bandwidth frequency response, thus increasing the resolution.

Figure 3D.53: Marine Seismic survey in Langstone Harbour. Upper left: Installation of the transducer pole onto the RIB. The pole is attached to a tilting system that fits over the inflatable hull. Upper right: transducer pole tilted horizontally during transit; GPS and motion sensor are on the right. Lower left: Data acquisition on board the RIB in Langstone Harbour. Lower right: close-up of the SES acquisition unit.

In Langstone Harbour a parametric echosounder was used. This source, which is mounted onto a pole attached to the side of the boat emits two signals with a different frequency (Figure 3D.53). The high-frequency signal (100 kHz) allows a very detailed image of the sea floor. The lower-frequency signal (between 6 and 14 kHz) penetrates deeper, resulting in an image of the underlying structure. The fast pulse rate (20-25 pulses per second) resulted in a high lateral coverage. During the measurements the echosounder was attached on a long iron pole fastened to the side of the ship. A motion sensor was used to filter out the wave movement. Positioning was done using a DGPS antenna with an accuracy of ±1 m.

Fieldwork Results

The map below (Figure 3D.54) presents the main areas targeted by fieldwork.

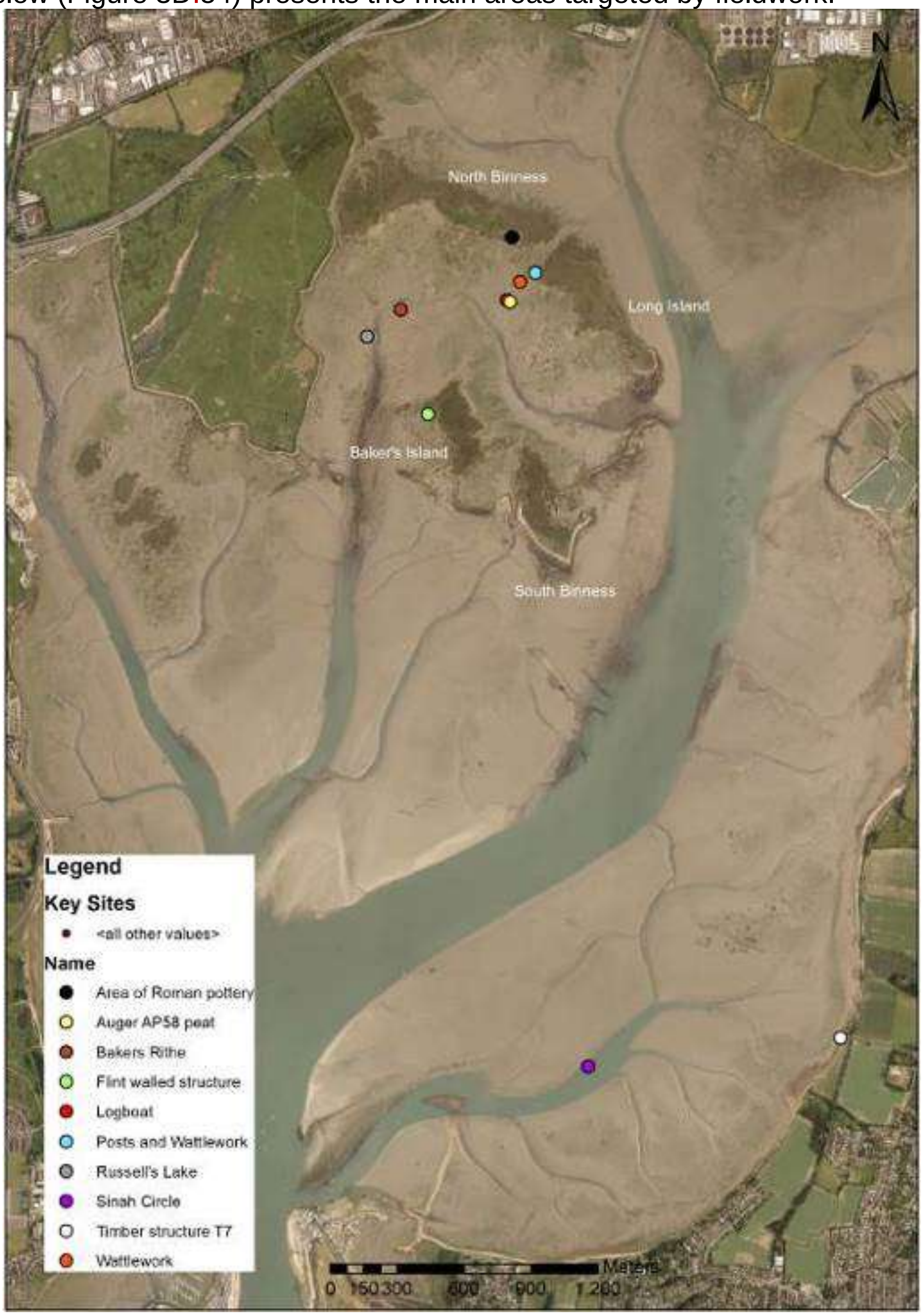

Figure 3D.54: Location of key fieldwork sites in Langstone harbour.

Walkover Survey and Monitoring Previously Recorded Sites

Walkover survey was carried out on the west coast of Hayling Island and around the four islands in the north of the harbour. Any sites and finds were photographed and the position was recorded using the RTK GPS system.

On the west coast of Hayling Island the focus of the fieldwork was on several timber structures identified through the 1990's Langstone Harbour Project. These were thought to be fish traps, which if dated could provide important information on relative sea level at the time of construction.

With the help of students from the University of Southampton, one site, T7, was selected for detailed investigation and dating. This site was thought to be a fish trap with a possible medieval date (Allen & Gardner, 2000:80). The site was planned and two samples recovered for dating. Radiocarbon results gave a date of AD cal 1650-present. This alongside other historical evidence including historic maps suggest that this structure and the other similar structures along the west coast of Hayling Island are extensions of the field boundaries into the intertidal area of the harbour. It was common practice to graze livestock in a saltmarsh environment.

Even though these structures are more modern field boundaries, they are able to provide detailed information on coastal change. Analysis in combination with historic maps and photos, demonstrates that there has been a rapid loss of salt marsh environment with areas where livestock would have grazed becoming mudflats. These structures can therefore provide information on the changing environment of Langstone Harbour over the last 300 years.

Figure 3D.55: Location of site T7 on the west coast of Hayling Island, the aerial photo (courtesy of the CCO) has been overlaid with a 1st edition OS map. The site corresponds with the field boundaries.

Sites off Long Island were also re-visited. This included an area of wattlework discovered in 2002 which was dated to 790-1030 Cal AD. Searches around the area were not successful in finding any of these remains, these may have since been eroded. Slightly further north and closer to Long Island another area of wattlework and timber posts recorded in 2002 were re-located (Figure 3D.56).

This area of four posts and wattlework lies on the very edge of Long Island. This feature consists of four posts arranged in a square with an area of wattle work on the northern side. There is also an area of flint nodules to the east of the structure which may be associated.

Figure 3D.56: The four post structure and wattlework off Long Island.

The timbers appear to be square in section, indicating they are likely to have been worked or sawn into shape. Two timbers are larger, these are on the eastern side of the feature, the western timbers are smaller. The south east timber measures 20cm x 10cm in section, the height above the foreshore was 0.30m, the north east timber is 10cm x 10cm and 0.29m high, with the western timbers measuring around 8cm square, the SW being 0.24m high and the NW 0.21m. The wattle remains lie less than 2 metres to the north of the timber posts. The western edge of the structure lies at 0.65m OD, with the eastern edge slightly lower at 0.61m OD.

The areas where wattlework has been discovered are now predominantly mudflats, suggesting that in the early Medieval period this area may have been a much different environment, possibly saltmarsh for grazing livestock. Another site further south in the harbour dates to a similar period, the Sinah Circle. Both sites can provide information on the late Saxon/early Medieval environment.

The Sinah Circle is a circular timber feature located within Sinah Lake in the south east corner of the harbour. The site is submerged other than on exceptionally low tides, one of which was experienced in March 1993, when the site was first noticed by local fisherman Mr Arthur Mack who indicated the tide was the lowest he had seen for 40 years. The waterlogged environment has aided the preservation of the site which consists of upright wooden posts with wattle woven in between in a circular form measuring 6 metres diameter.

Sinah Circle is important in terms of the information it can provide on coastal change. If the structure was related to oyster farming as is the current interpretation, then its position in relation to high and low water as well as accessibility would have been important. Based on later oyster beds from the 19th Century, such structures are generally located in the intertidal zone, they are positioned so that they retain a small amount of water at low tide to keep the oysters alive, but can still be accessible.

The last time the site was exposed was during an extreme low tide in 1993. This would indicate that mean sea level has risen since the Sinah Circle's construction. Mean high water springs in Langstone Harbour are 4.8m above Chart Datum/2.1m above Ordnance Datum (OD), Mean Low Water Springs are 0.8m above Chart Datum/-1.9m OD. Sinah Circle is located at -2.7 to -3m OD (Figure 3D.57). This indicates that generally at low water there is still at least 0.8m of water above the structure. Allen & Gardiner (2000:202) suggest that Langstone became a harbour by the Late Iron Age, and that the location of the Sinah Circle at -2.7 to -3m OD suggests that it is a marine structure as opposed to being built at a time of lower sea level. If it is related to oyster farming as suggested in the publication, then with at least 0.8m of water above the site during low water springs would make it difficult to access, therefore suggesting that there has been a small rise in sea level since this time.

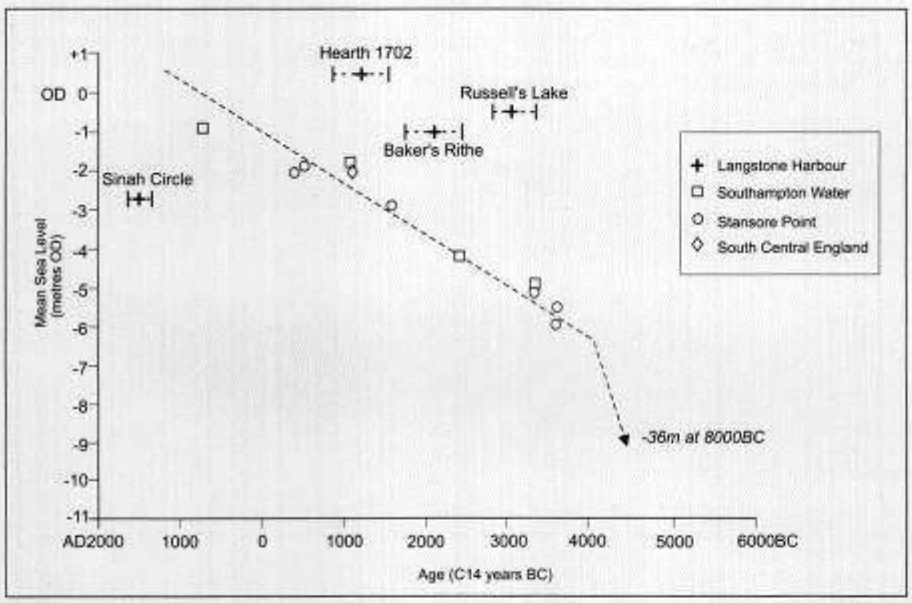

Figure 61 Mean sea-level changes (after Long and Scaife 1996, fig 17) with data from Southampton Water (Long and Scaife 1996) and Stansore Point (Long and Tooley 1995), and central southern England (Devoy 1982; 1987b, and Tooley 1990), and Langstone Harbour (this volume). Age errors of c ± 100 years and altitude errors of ± 0.5m should be assumed for each index point. Drawn by S E James

Figure 3D.57: Mean Sea Level Changes (Allen & Gardiner, 2000:202)

Further work is required in order to establish the function of the structure. If it is related to oyster farming then its position in relation to mean low water suggests that the structure can reveal more detail of the rise in sea level over the last 1000 years.

Another site which was re-visited was a small flint walled structure on Baker's Island. The island also contains the remains of WWII decoy structures which are now being affected by erosion. The islands were used as air raid decoys to divert planes away from Portsmouth.

Figure 3D.58: WWII decoy structures on Baker's Island. Structure on the beach are now being eroded.

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The flint walled structure is marked on 19th century maps as 'old walls' and lies at the south west end of an elongated enclosure formed of a bank and ditch (Figure 3D.59). The building and 'field system' complex has been interpreted as either oyster beds or salterns, with an assumed Post Medieval date. As this site is potentially closely linked to activities which can demonstrate sea level change it was subject to more detailed survey in 2012.

Figure 3D.59: The remains of the flint walled building are highlighted in red, the associated banks can also be seen. Aerial photo courtesy of the CCO 2013.

Although the site was surveyed more detailed analysis is required in order to determine the date and nature of this site. Arthur Mack, a local fisherman informed us that historic records describe three families who lived on the island grazing sheep, the records also mention masonry buildings dated to the 16th Century AD. It is possible that this relates to the remains found on Bakers Island however, the oldest maps found of the area which date to the 18th Century, prior to the reclamation of Farlington Marshes, do not depict any structures on the islands.

Landscape Survey

The RTK GPS was used to record the edge of the small cliffs off Hayling Island and on Long Island. This data can be used to monitor erosion of the area over the coming years. In order to understand past changes it has been possible to compare the current high water mark with that recorded on the 1st Edition OS Map of Langstone Harbour from 1878 (Figure 3D.60). There has been up to 50m of erosion off Long Island and notable change on Bakers Island, however in some places there seems to be sediment accumulation, such as the northern edge of North Binness Island. There has been some work carried out by the landowners (RSPB) to build up the shoreline of the islands for nesting birds, further work is required to understand the nature and extent of this work.

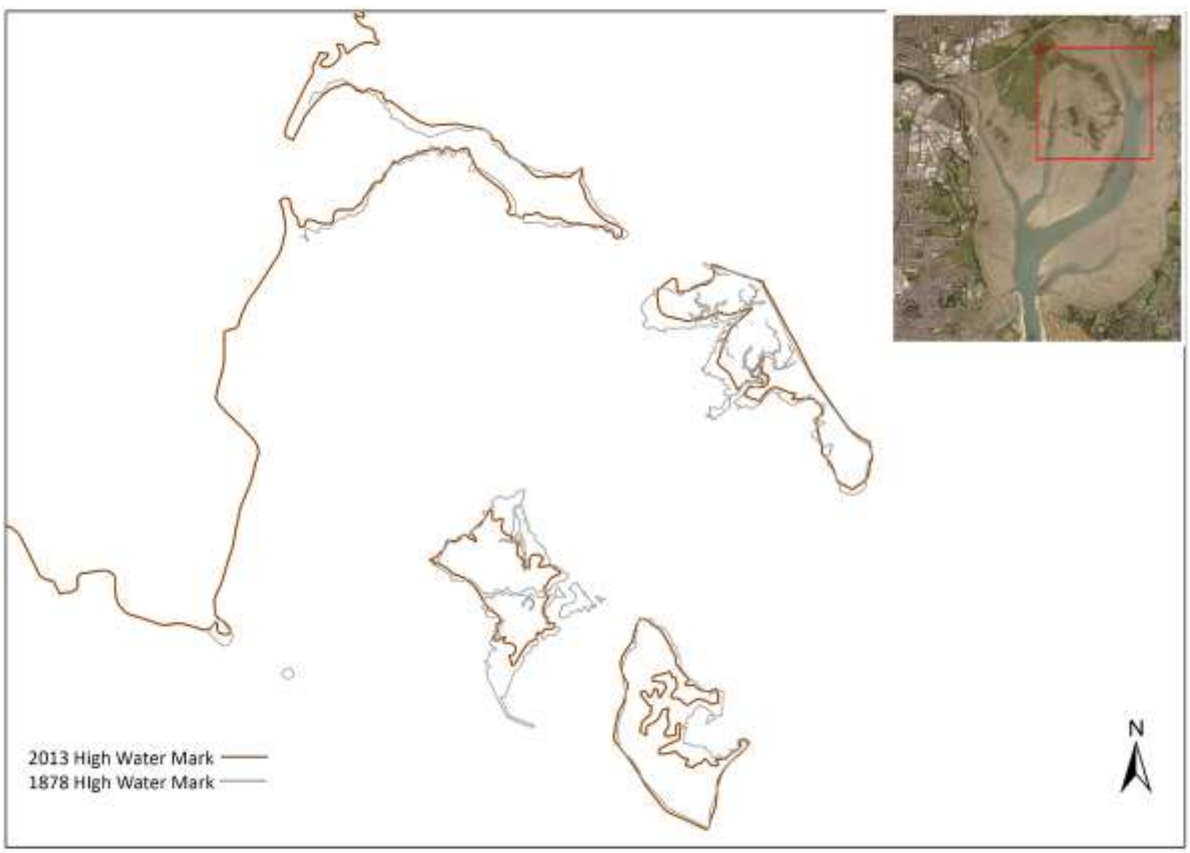


Figure 3D.60: High water mark from 1878 to 2013 around the islands, Langstone Harbour.

As well as assessing the change in the high water mark, it has also been possible to look at changes in the extent of saltmarsh in the harbour. A study in 2007 analysing saltmarsh change in central Southern England, demonstrated that between 1956 and 2001 around 71% of saltmarsh was lost from Langstone harbour (Baily and Pearson, 2007). It therefore seems likely that the harbour would have contained substantially more saltmarsh when structures like the wattlework and the Sinah Circle were built, meaning that it is likely to have been accessible at low water. The rapid reduction in salt marsh is demonstrated in Figure 3D.61. The extent of saltmarsh in 1946 and earlier would have made these sites more accessible by foot during low tide, today they are in a predominantly mudflat environment.

Figure 3D.61: The black lines show the extent of saltmarsh in 1946, the white shows the extent in 2005. Data courtesy of the CCO.

The precise cause of this rapid loss of saltmarsh over the last fifty years is unknown, dieback of Spartina is thought to have caused much of the saltmarsh loss in the Solent. Sea level rise, eutrophication and dredging may also play a part (Langstone Harbour Board 2009).

Auger Survey

The auger survey that was conducted off the coast of Long Island (Figure 3D.62) was able to re-locate the palaeochannel from the approximate area of the log boat survey which had been recorded in previous investigations. This palaeochannel was detected in four separate cores, and several of the other cores had potentially associated deposits relating to the development of the palaeochannel. Unfortunately, the penetration of the cores only reached 2.3m and although 14 cores were taken, the location of these cores were not able to capture high resolution detail on the path of the palaeochannel and there was little time to revisit the site in order to extend the survey area.

Figure 3D.62: Location of the Auger Survey, Langstone Harbour

The underlying geology of the area in the northern part of Langstone Harbour, where the survey took place, is chalk (Allen & Gardiner, 2000, 9), and although none of the auger cores went deep enough to reach this bedrock, it is not surprising that the base deposits contained chalk inclusions. The interpretation sequence is therefore based on deposits that lie on top of this geology; this sequence is as follows:

Unit 1: Base Deposit – The base deposit is a grey, silty clay that contains chalk inclusions from the bedrock. This deposit was recognised during the Langstone Harbour Project, and is thought to be either periglacial or post-glacial (Allen & Gardiner, 2000, 53).
Unit 2: Silty Clay – The next unit is composed of blackish, silty clay. It could well represent the bottom of the channel or the deposits that were formed prior to the channel being formed. It is likely to be Holocene in date, as a similar deposit is mentioned in the Langstone Harbour project, an alluvial, organic-rich, silty clay (Allen & Gardiner, 2000, 11).
Unit 3: Peat – The peat unit represents the Palaeochannel that was found during the survey. It is one of many that are known to have existed in the area, although their exact locations are not entirely known.
Unit 4: Sandy Clay – This unit is a sandy alluvial clay that could represent deposits on the edge of the palaeochannel. It was found close to, but not necessarily on top of the peat.
Unit 5: Greenish Black Clay – The greenish black clay is a post-channel alluvial deposit, probably from after the Harbour was inundated and no longer a coastal plain but a large intertidal basin.
Unit 6: Yellow Clay – The yellow clay unit is the archaeological horizon that is only found on the islands, and is known from the Langstone Harbour Project. It represents the last remnants of the

land surface (known to contain archaeological material particularly from the Mesolithic to the Bronze Age and later) that is being eroded away as the islands are subjected to coastal erosion. This is the layer in which archaeological artefacts might be found.
Unit 7: Silty Clay – This silty clay unit has shell inclusions, and sits under the top soil; it is most likely from modern fluvial actions.
Unit 8: Silty Clay – The top surface of the survey was a water logged silty clay that is undoubtedly modern and formed by current fluvial actions.

The auger survey did encounter a palaeochannel, which shows up as a peat horizon in samples AP02, AP06, AP58, and AP 57. The surrounding deposits, therefore, mostly likely represent the clay alluvial deposits laid down prior to the channel formation, silty clays afterwards, and sandy deposits from the edge of the channel. The palaeochannel would have been active after the last ice age but before the Harbour was inundated. No archaeological artefacts were found within the sample.

The sample that was taken from core AP58 at a depth of 76-81cm, was radiocarbon dated to-1500 Cal BC (Bronze Age). This ties into the period where the rise in sea level saw systematic flooding of the harbour area apart from the main channels that still exist today. The discovery of this palaeochannel lead to the second season of fieldwork using geophysical survey in order to try and detect further palaeochannels across the harbour as a whole.

Marine Seismic Investigations
The results from the geophysical survey of Langstone Harbour conducted in June 2013 are presented below. The survey was divided into five areas:

Baker's Island:
The geophysical survey recorded a dense network of 45 east-west, 7 north west-south east, and 38 north-south profiles in order to investigate the suspected area of submerged forest near Baker's Island (Russell's Lake and Baker's Rithe). These profiles revealed in high detail a network of channels of varying size present in the area. The data also showed a number of small, but marked surface features, some of which could have related to tree stump and timber remains. These remains were not located in the submerged forest area, suggesting that the 'forest' area could be much more widespread than originally presumed. The interpretation of the data was severely affected by the presence of shallow gas across the area. This meant that the palaeochannels identified could not be mapped in a coherent way.

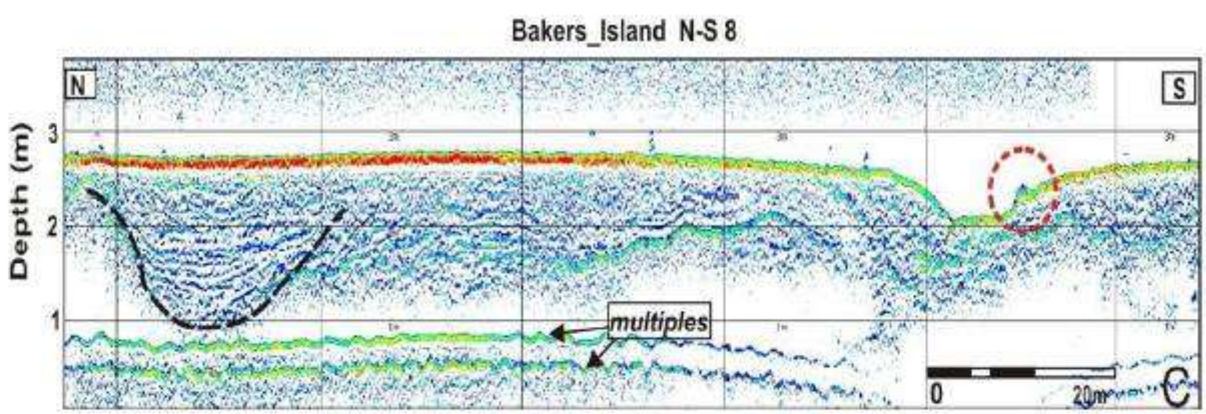


Figure 3D.63: Seismic profile showing a surficial feature on the seabed (red dashed circle), possibly related to a seabed channel. A small buried palaeochannel is also observed (black dotted line).

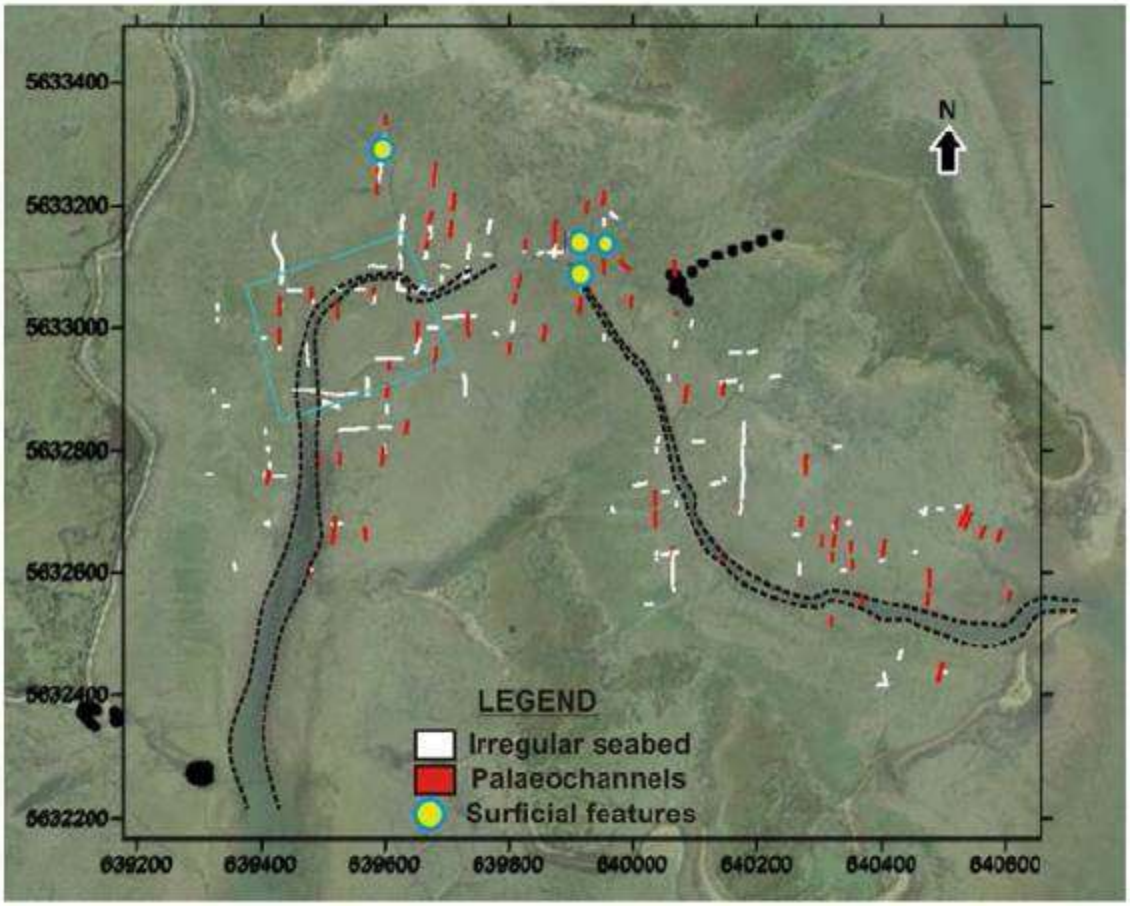


Figure 3D.64: Spatial distribution of irregular seabed, buried palaeochannels and marked surficial seabed features observed near Baker's Island. The blue rectangle marks the submerged forest area observed from previous investigations. The black dots in the northeast and southwest represent shallow core sites (it was not possible to reach the latter by boat).

<u>Langstone Channel:</u>
A small network of 8 north-south profiles and 11 east-west profiles were recorded in the Langstone Channel over the approximate location of the anomaly recorded in the 1996 Chirp survey of the harbour (Allen & Gardiner, 2000).

Again the survey was affected by the presence of shallow gas pockets, but a good penetration was achieved in the deeper part of the channel. Some large palaeochannels were observed at this location in high detail, though a coherent map of the buried palaeochannels was not possible because of the gas. The survey also potentially relocated the anomaly from the 1996 survey.

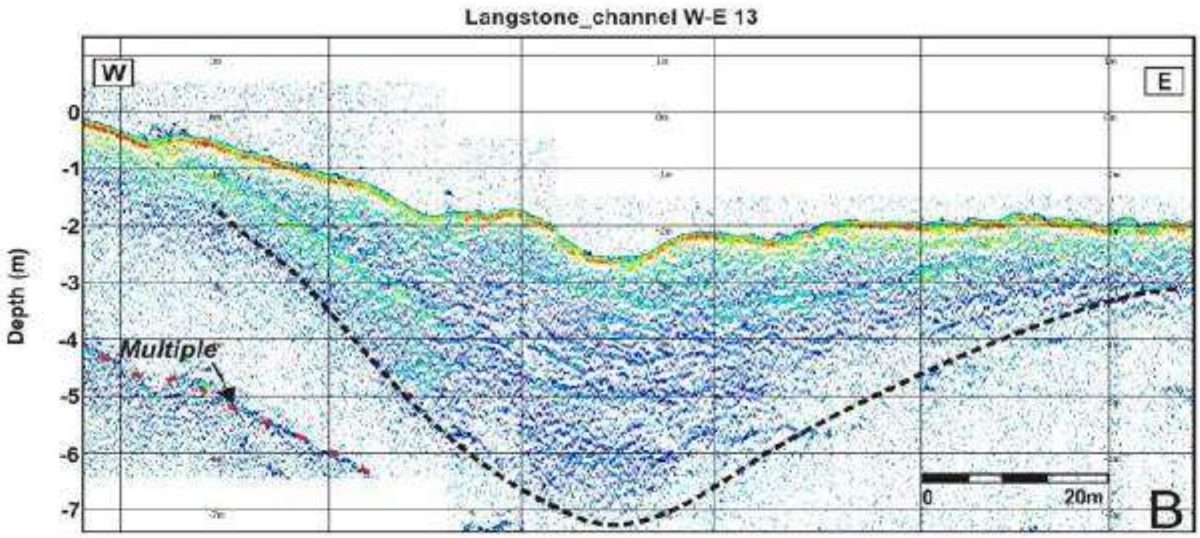


Figure 3D.65: Seismic profile in Langstone Channel showing a large buried palaeochannel and scour-related bottom features.

Mesolithic Spot:

The survey recorded 8 north-south and 13 east-west profiles over the approximate location of an area of Mesolithic finds identified in an earlier survey. The shallow gas pockets that are present throughout the harbour again affected the survey, in this case only allowing for one small palaeochannel to be observed in the data. Despite these problems, the survey was also able to identify a number of small features on the seabed, in the region of 10-40cm high. However, the identity and origin of these features is unknown.

Feature T2:

The feature T2 was identified during the Langstone Harbour Project and was covered by 14 north-south and 10 east-west profiles during this survey. Whilst again, being hindered by gas pockets, the survey did identify some locally buried palaeochannels, as well as the gently dipping Tertiary strata of the underlying geology. Unfortunately, the timber remains of T2 could not be clearly identified in the data.

Sinah Circle:

The approximate location of the Sinah Circle was covered with 10 north west-south east and 12 south east-north west profiles. Whilst again the survey was hindered by the presence of gas pockets, several palaeochannels, three distinct superficial features, and the Tertiary strata were identified in the profiles. The superficial structures are likely to represent timbers, and hence could prove that the Sinah Circle is still extant on the seabed.

The geophysical survey enabled the identification of numerous palaeochannels, and other features, across several different areas of the harbour. Unfortunately, the presence of shallow gas deposits across the areas surveyed means that these channels cannot be coherently mapped. However, the information about the location and the depth of the channels identified has been used with the other results and the work carried out in the 1990's in order to develop the 4D model demonstrating the evolution of the harbour from the Mesolithic to the present day, see Section 3D.7 below.

3D.4.3 Hamble River Survey

After the exposure of a series of wooden posts on the foreshore on the lower part of the River Hamble in 2011 a survey was carried out. Initial survey and desk based assessment established that the site represented a former oyster pond, the assessment was carried out with the use of historical mapping and aerial photographs, demonstrating the value of combining these resources. The site was selected as a case study site for Arch-Manche as the remains could provide information about the changing sediment levels on the River Hamble and the site was re-visited in 2012 to assess potential change.

Key Research Questions

The aim of the survey was to identify the extent of the features and structures on the foreshore and to create a site plan. This could then be compared with historical maps and monitored in future in order to understand the scale and rate of potential sediment change on the foreshore of the River Hamble.

Fieldwork Methodology

Fieldwork was carried out in spring and summer in 2011 and the site was re-visited again in 2012, some elements of the site are a relatively long way down the foreshore and can only be accessed for a period of two hours either side of low tide. Although the intertidal zone of the River Hamble is generally comprised of estuarine mudflats, the area immediately surrounding and including the site is relatively firm. Consequently, access to the site is safe and straightforward with none of the problems of sinking into the mud associated with other intertidal sites on the river. This allowed the maximum use to be made of the limited time on site accorded by the tidal regime.

GPS Survey

A rapid survey of the extant structural features of the site was conducted using a *Leica 1200* SmartNet GPS system. Use of this system allowed structural features such as posts and plank shuttering to be positioned to with +/- 1cm accuracy within the British National Grid. The rapid nature of this survey technique allowed the entire site to be surveyed by two people within the period of a single tidal window. The centre point of each post was recorded, in addition to its shape and extent. The extent and arrangement of any associated plank shuttering was also recorded. In addition to this, a topographic survey of the area of the wooden structure and the foreshore in the immediate vicinity was recorded to provide a benchmark record of foreshore mud levels for subsequent surveys. Finally, the edge of the slipway that runs along the northern side of the oyster pit was also recorded to allow future geo-referencing.

In May 2012 a repeat topographic survey of the site was conducted. This survey was again undertaken with a *Leica 1200* SmartNet GPS system with the intention of establishing if there had been any change in the levels of foreshore sediment at the site since the initial survey in March 2011.

Measured Surface Survey

A traditional, measured survey of the features visible on the surface of the site was completed. This allowed detailed recording of individual structural elements, particularly those along the southern side of the site. Additionally, searches were conducted along the southern edge of the site and in the vicinity of the single post located to the north of the slipway, during the GPS survey, to establish if any other structural features were visible. These areas had been identified during the GPS survey as being highly likely to contain additional structure. Where such features were visible, a small area around them was cleaned in order to allow them to be fully surveyed. Due to tidal restrictions, no survey work was conducted at the most eastern, riverward end of the site.

In addition to the offset survey, three 1m square areas for targeted detailed survey were established along the southern edge of the site around three the post tops. This allowed these features and any associated structure to be recorded in more detail than had been possible during the rapid GPS survey. These areas were surveyed with offsets from the edges of the areas, in addition to the use of planning frames. A further 1m area was established around the solitary post to the north of the slipway.

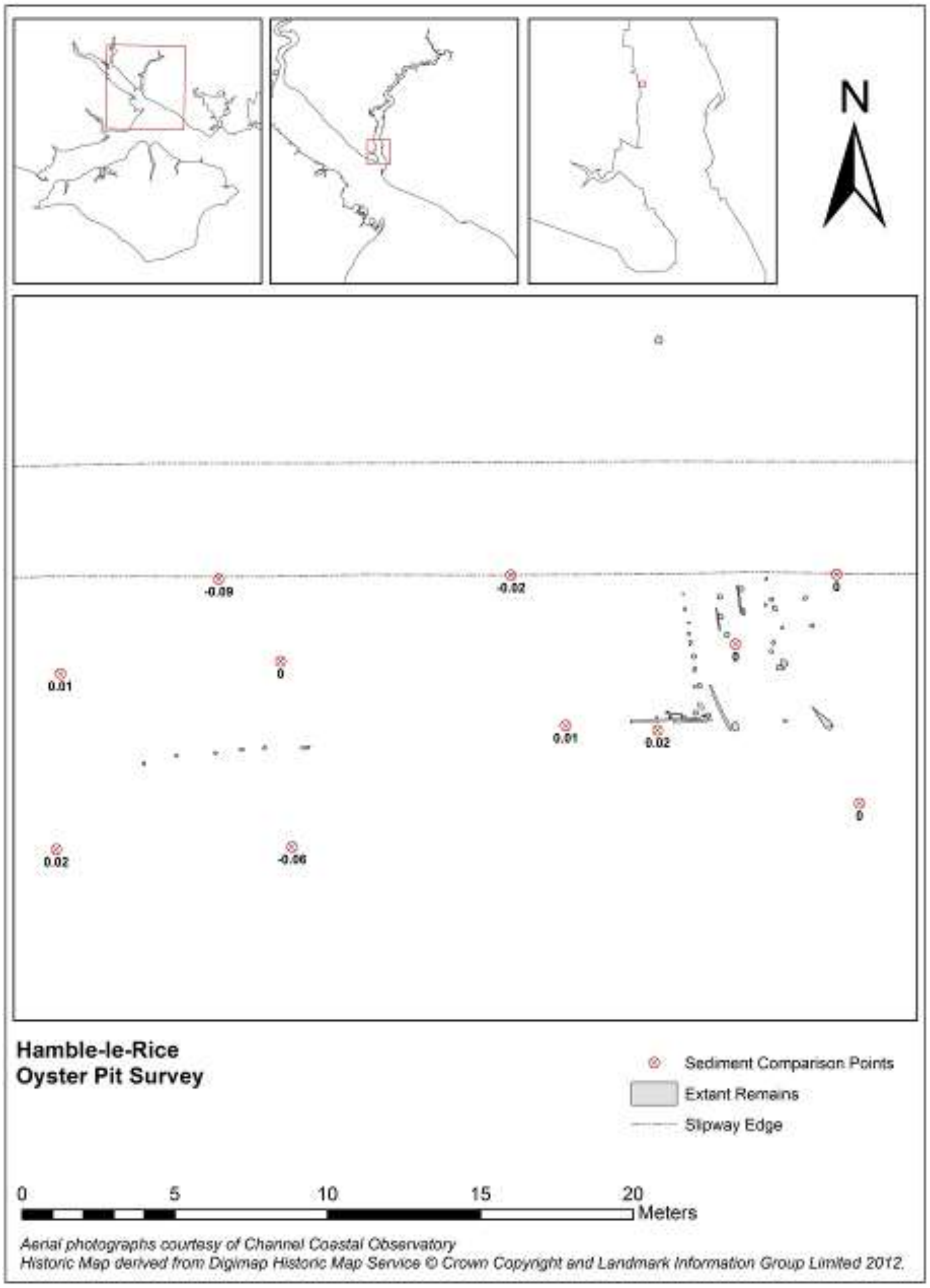


Figure 3D.66: Hamble River Oyster Pit site plan and sediment levels.

Fieldwork Results

The GPS survey established that the structural remains located on the site are generally 'L' shaped, with the long arm running west-east for 22.5m, roughly parallel to the edge of the slipway but 5-6m to the south of it. The short arm of the structure, forms a return for 5m to the north as far as the slipway. No structure was located to the north of the slipway apart from a single large post-top. A series of four, distinctive, north-south alignments of posts are located between the eastern edge of the main structure and the river. These are spaced between 0.8m and 1m apart.

A limited topographic survey of the foreshore was undertaken in the immediate vicinity of the structural remains for the purpose of future monitoring of sediment levels. Processing of this data revealed that along the southern edge of the site, the western end lies 1.04m higher than the south-eastern corner of the main structure, with a further 0.5m drop across the eastern extension of the site. Discussion with the local Parish Council Chairman following the initial exposure of the site indicated that the oyster pit remains had not previously been seen above the level of the foreshore mud. Local people were aware that foreshore sediment levels appeared to be falling over a period of time stretching back some forty years. No record of this change in sediment level at a small scale site such as the oyster pit exists. It was with this in mind that the initial topographic survey was conducted and a repeat survey carried out in 2012.

The survey results illustrate that there has been no appreciable, significant reduction or appreciation in sediment at the site over the fourteen month period between surveys. There have been small, extremely localised changes at a single point. However, given the level of accuracy of recording using the RTK system, these changes may be relatively small. It is intended to record measurements at the same locations in the future in order to begin to extend the recorded dataset over a more meaningful period of time.

Research into available historic maps held by the Ordnance Survey indicated that the visible foreshore remains directly correlated with the location of an 'Oyster Pond' between 1868 and 1909. The dimensions of the two sets of records, one historical and one archaeological, bear further comparison by way of confirming such an identification. The historic mapping shows the straight, eastern (riverward) end of the structure as c. 12m in length and the length of the entire structure as c.25m. This tallies closely with the overall length of the archaeological site which has been recorded as 22.5m along the southern edge. This would potentially allow 2.5m for the curved landward end, shown on the OS maps. The presence of a relatively modern slip makes ascertaining the width of the site harder, as it clearly cuts the remains in two. However, the distance from the south-east corner of the extant remains, to the single large post located on the north side of the slipway is 12.5m, which correlates extremely well with the historic dimensions. This serves to confirm that the archaeological remains do represent the 'Oyster Pond' marked on the OS mapping and, furthermore, suggests that the single post located on the northern side of the slipway is also likely to be part of that structure.

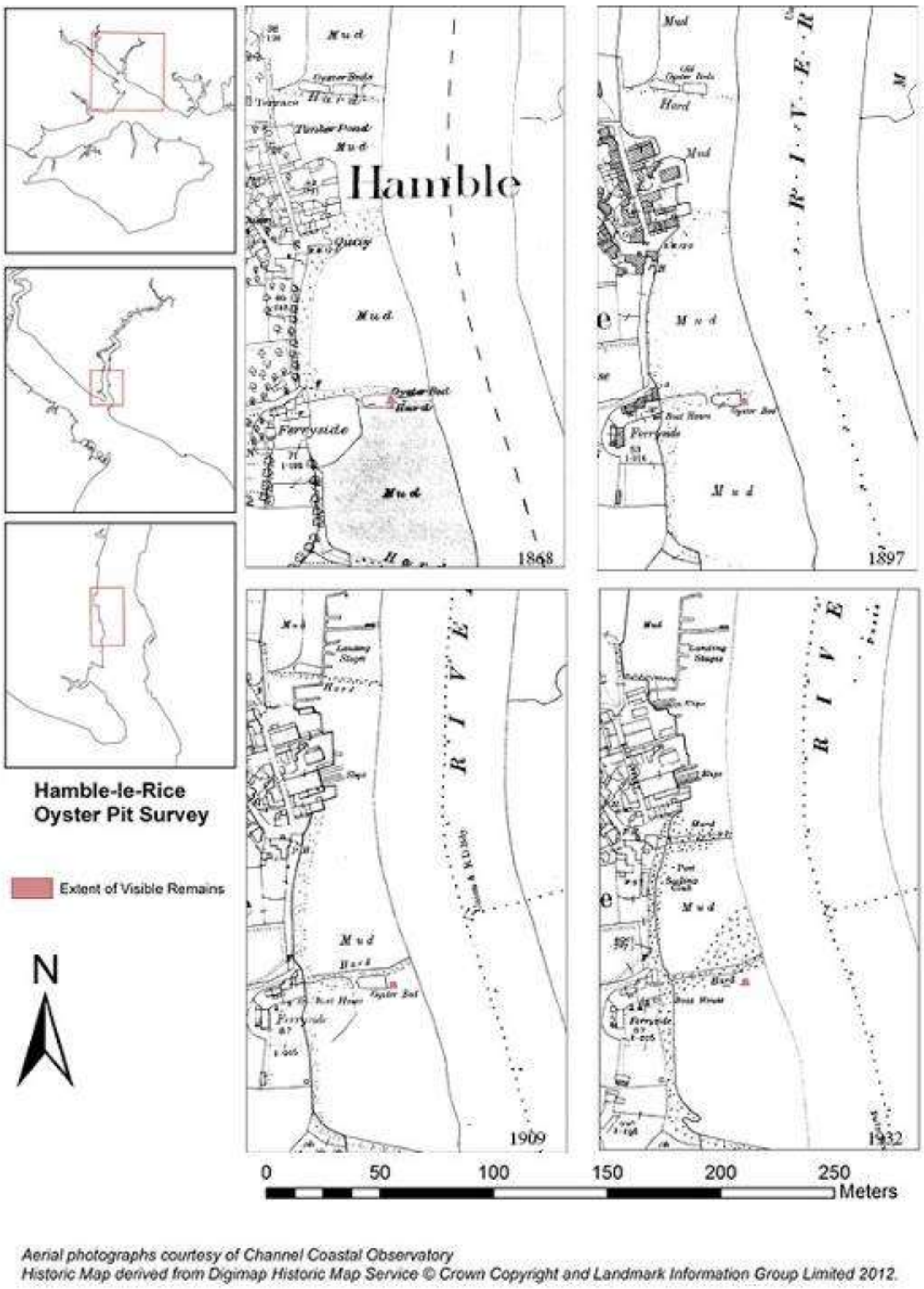


Figure 3D.67: Comparison of Ordnance Survey maps depicting the Oyster Pit from 1868, 1897, 1909 and 1932.

3D.4.4 Burrow Island Survey

Burrow Island, also known as Rat or Little Island, is situated on a spit advancing from Forton Lake into Weevil Lake and contains the ruins of Fort James. This fort was planned by Sir Bernard de Gomme as an element of the Gosport defences, and was built in 1678 at the same time as the Gosport lines (Pastscape 2007:Fort James). By 1707 however it was already falling into disrepair, and in 1742 its two guns were recovered; it was rendered obsolete by the extension of the Gosport defences to Priddy's Hard in the second half of the 18th Century (Pastscape 2007:Fort James).

Suggestions of a Norman Castle preceding the construction of Fort James also survive, though they are somewhat disputed. A letter dating from 1828 refers to the walls of a castle present upon the island being taken down; a further letter from 1847 mentions the ruins of "Borough Castle" associated with King Stephen, being used as a "burial place for convicts" (Pastscape 2007:Fort James).

After being contacted by a member of the public regarding the erosion of the island and resulting exposure of archaeological material the site was chosen as a small case study for the Arch-Manche project.

Figure 3D.68: Erosion on the small cliff of Burrow Island, recorded in 2013. MAT

Key Research Questions

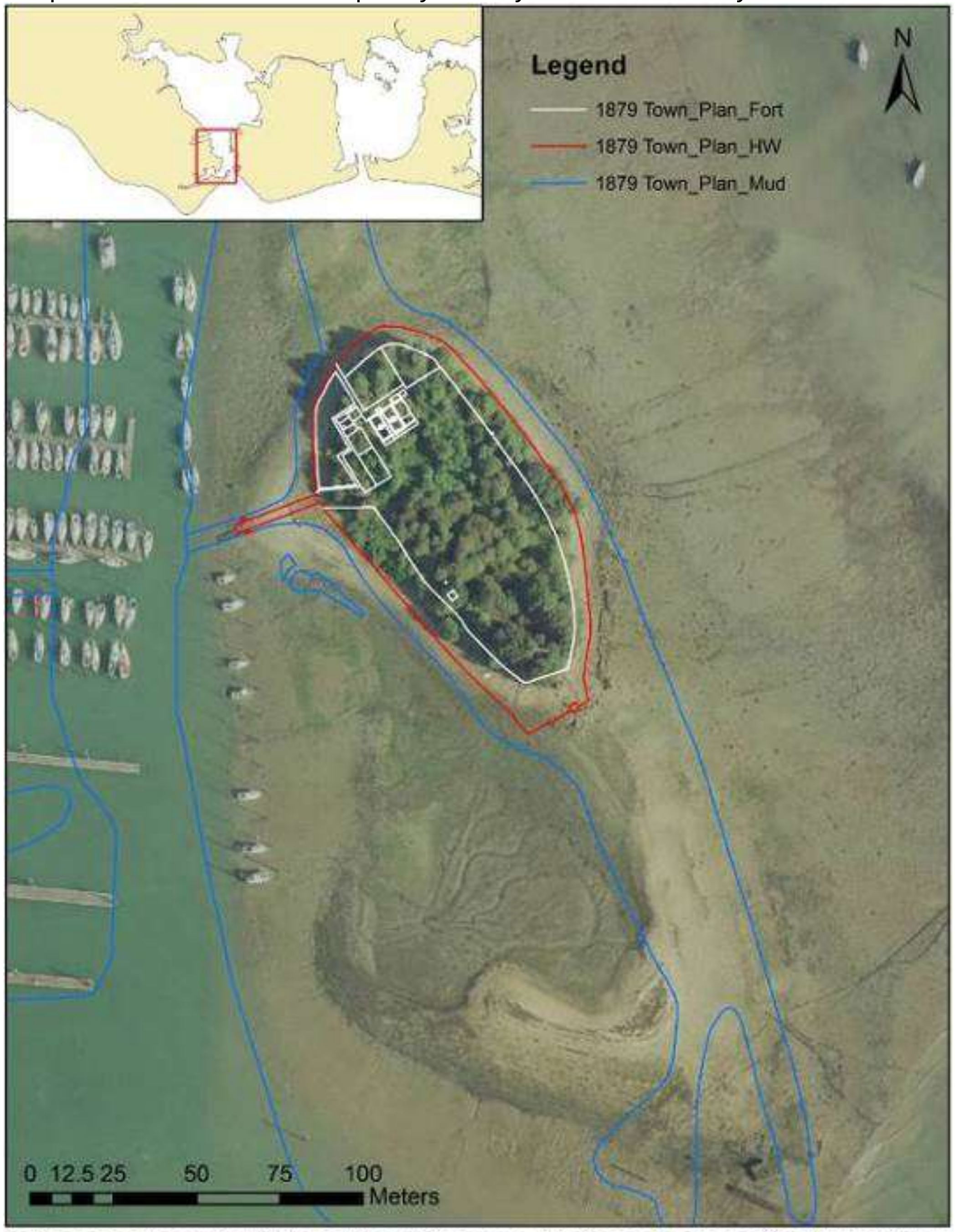
The aim of the fieldwork was to understand how the archaeological material and heritage features on the island could be used to help understand the rate and scale of erosion affecting the sites and whether these could be used in coastal management.

Fieldwork Methodology

During the fieldwork the main methods used were a walkover survey and photographic record, although a Leica 1200 Real-Time Kinematic (RTK) GPS system was also used to mark the position of any particular features of interest.

Fieldwork Results

Although further fieldwork would be required to complete a full topographic survey of the site, significant amounts of information were gained through comparison of archaeological survey results and modern aerial photographs of the island with a town plan from 1879. The historic plan shows the high water mark, the extent of the mud and an outline of the fort, this has been digitized and overlain on the modern aerial photography (Figure 3D.69). Through this it is possible to see that the shingle spit extending south from the island has shifted north westwards and the old pier has been almost completely destroyed and is now only visible at low water.



Aerial photographs courtesy of Channel Coastal Observatory. Historic map data derived from Digimap Historic Map service Crown Copyright and Landmark Information Group Ltd 2012.

Figure 3D.69: Comparison of the 1879 town plan showing the remains of the fort, the high water mark and the extent of the intertidal mud, with a modern aerial photograph.

3D.4.5 East Winner Bank Wreck Survey

Fieldwork was carried out after being alerted to the appearance of a previously unknown shipwreck on the East Winner bank, off Hayling Island in early March 2014, following a period of severe winter storms. The wreck was visited on 16th and 29th April 2014 during a low-water spring tide of 0.7m and 0.6m respectively (Chart Datum Portsmouth). The East Winner is a large sandbank located off the south-west corner of Hayling Island that firmly demarcates the eastern seaward side of the entrance channel into Langstone Harbour.

The situation of the East Winner within the surrounding sediment regime is described within the 'Portsmouth Harbour Entrance to Chichester Harbour Entrance' section of the Sediment Transport Study published by the Standing Conference on Problems Associated with the Coastline (SCOPAC). The tidal flow in the Langstone Harbour channel is dominated by the ebb tide when tidal rates can reach 1.5 knots (Bruce, 2008: 44-45). This has had the noted effect (SCOPAC: LT7) of flushing sediment seaward from the Langstone harbour channel to be deposited along the western side of the East Winner. The SCOPAC project also notes that there has been a previous suggestion that the East Winner bank itself is partially fed through the westward movement of sand from the Chichester tidal delta. Although the mechanics of this are not proven, the overall sediment transport pathway within Hayling Bay is considered to be from east to west, allowing for deposition of material onto the East Winner (SCOPAC: O1).

The circulation of sand on the East Winner itself is also covered by SCOPAC (O3) based on the previous work of Harlow (1980). This has noted that the East Winner bank is covered by ripples, sand waves and low dunes; analysis borne out by aerial photos and observation while on site. Such features are noted by SCOPAC as characterising high sediment mobility, but in this instance operating within a closed system because of the inability of sediment to move in a westerly direction across the Langstone Harbour channel. Accordingly, a system has been proposed (SCOPAC: O3) of net transport in an offshore direction by tidal currents on the western face of the bank and onshore transport on the eastern flank as a result of wave action. Study into the overall shape and volume of the East Winner by Whitcombe (1995) has highlighted the fluctuating expansion and regression of the bank caused by shifts in the alignment of the outer Langstone Harbour channel.

The exposure of this wreck highlights the dynamic nature of this sand bank, shipwrecks can be useful monitoring points in understanding changing sediment levels, it was therefore decided to use this site as a small case study in the Arch-Manche project.

Key Research Questions

Initial fieldwork aimed to record the extent of the site and particular features which may help identify and date the wreck. A second visit to the site aimed to assess the rate and scale of change in the sand bank as it began to re-cover some of the wreck and expose new areas. The overall aim was to understand whether this site could provide detailed information on the changing sediment regime in this part of the Solent.

Figure 3D.70: Aerial view of the East Winner Bank Wreck taken after the storms of January 2014.

Fieldwork Methodology

Access to the site is limited to a period of around 1.5 hours, straddling low water. This results in a reduced window of around 45 minutes when the water is at its lowest and conditions for working on the site are optimal. Even at that point, significant areas of the site continued to be underwater during the normal spring tide conditions of 0.6m (CD) during which the site was visited. Accordingly, successful work on site required limited objectives that could be effectively completed within the access window. Site visits were therefore concerned with documenting the characteristics of the site in as much detail as possible through recorded observations of the extant features, in conjunction with the creation of an extensive photographic and video record. The latter included the use of a pole-mounted camera in order to record overhead images of the site; proving especially helpful in identifying features that were not visible at ground-level (Figure 3D.70).

This work has served to establish a basic set of information about the site and the vessel itself that can be further informed through subsequent visits. In particular, the creation of a traditional site-plan was considered to be of relatively low-priority because of the amount of time required to complete it. Instead, focus was placed on recording the detail of the vessel's dimensions and constructional features in order to create a description of the site. It can be reiterated that such a description is not reliant on an overall site-plan but on the careful observation and recording of the archaeological detail present on the site.

Fieldwork Results

The extant remains are 21m in length and of variable width between two and four metres depending on the elements exposed. The visible remains are in a good condition overall and photos from the initial exposure in February/March 2014 illustrate that the wood was very 'fresh'. Since then, there has been a gradual build-up of sand and weed on exposed surfaces. The rapid period in which this has taken place suggests that although exposed, the site is afforded some protection from biological decay. Some evidence for gribble is present on the upper ends of the frames, and around the stern post indicating that there have been previous incidences of exposure limited to just the extremities of the wreck. Across the two week period in which site visits were made a large amount of new material was exposed at the northern end of the site.

The disposition of the exposed remains indicate that the hull of the vessel is orientated in a roughly north-south direction. The presence of the stern-post and associated rudder gudgeon indicates that the stern of the original vessel lies to the north and the exposed remains therefore represent the portside of the vessel. Four inaccessible upright posts lie to the west of the site that seem likely to represent the centreline of the vessel, although this is not confirmed. There is no surviving indication of any mechanical propulsion of any sort and so the vessel is considered to have been a sailing vessel. The curvature of the visible framing timbers suggests that the entire bottom of the vessel is likely to be preserved *in situ* under the sand to the west of the extant remains. Visible surviving hull elements are comprised of floor timbers, futtocks (first to third), top timbers, ceiling planking and outer planking. The partial remains of a beam is located in the centre of the site. Preserved fastenings and fixtures include treenails, copper bolts and a rudder gudgeon, additionally, a number of holes indicate the location of former fastenings.

A lump of coal was found immediately to the south of the wreck structure and its rounded appearance indicates a relatively long period in the sea. The presence of the coal may be purely incidental, but it does not occur naturally on the East Winner bank and its close vicinity to the site may therefore represent the remains of the former cargo, or stores, from the wrecked vessel.

Further work is required to identify the vessel and it is proposed that further work should be carried out with historic maps in order to further understand the nature of the East Winner Bank. More specifically to the immediate surroundings of the shipwreck, the site can also be used as a means to monitor changes to this area of the East Winner bank. Ongoing monitoring of the site, facilitated by further photography and site recording can provide micro-scale information on environmental changes to such sites and how their exposure and resulting vulnerability varies over time. Comparable schemes are in place for fully submerged sites in the eastern Solent, including the *Flower of Ugie* (see Whitewright, 2011) on the Horse Tail sand. Data from the East Winner site therefore has potential to contribute to a wider understanding of the impact of sediment processes, at a site specific and intra-site scale, within the eastern Solent.

3D.5 Ranking Artistic Depictions

The focus on artistic depictions of the study area has been on historic paintings, however several historic photographs, maps and charts were also assessed in order to highlight the potential of this resource. The results of the ranking for each of these is presented below followed by a discussion.

3D.5.1 Historic Photograph Ranking

A ranking system was developed for historic photographs, the development of the system and proposed methodology is set out in Section 2.2. The ranking system has been applied to a selection of historic photographs within this case study area.

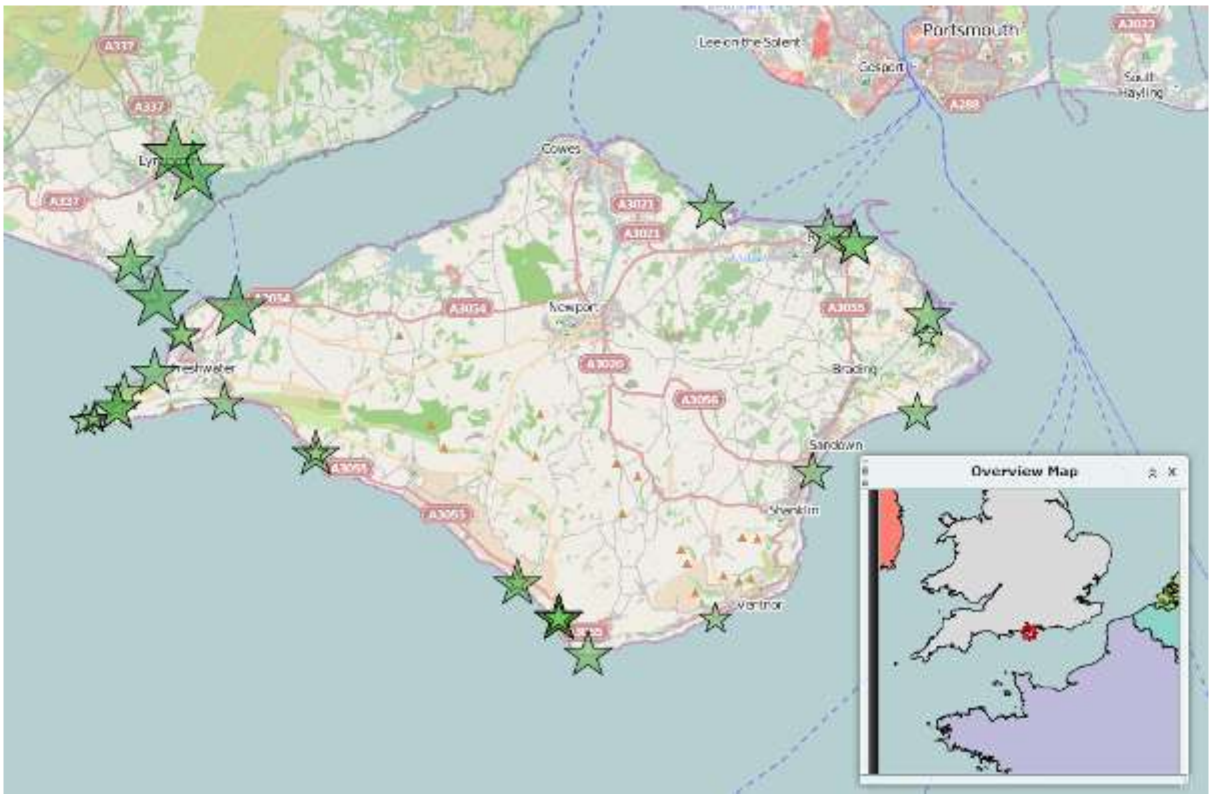


Figure 3D.71: Location of historic photographs assessed in the Solent study area.

All of the historic photos assessed were found through online searches. Many more images exist for this area, this study is not intended to be exhaustive, it simply aims to highlight the potential for historic photographs to provide information on coastal change. One of the primary resources used was the Carisbrooke Castle Museum Image Library which was launched in 2011, providing a digital resource of some of their collections.

Image Id No	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
1200	Lymington River and the Solent	1952	High		Good	100
1201	Hurst Castle & Lighthouse	1953	High		Good	100
69	Yarmouth Harbour	1910	High		Good	100
116	Royal Lymington Yacht Club	1950	High		Good	100
70	Chale and Blackgang	1900		Medium	Good	77
72	Blackgang Chine	1900		Medium	Good	77

74	Blackgang Chine	1900		Medium	Good	77
76	Brooke Shore	1900		Medium	Good	77
78	Eastern Beach at Ryde	1900	Medium		Good	77
79	Eastern Beach at Ryde	1900	Medium		Good	77
87	St Catherine's Lighthouse	1920	Medium		Good	77
82	Blackgang Chine	1900		Medium	Good	77
85	Woodside beach, Wooton	1900	Medium		Good	77
83	Blackgang Chine	1900		Medium	Good	77
88	St Helen's Old Church, St Helen's	1900	Medium		Good	77
95	Atherfield	1886		Medium	Good	77
111	Alum Bay Pier		Medium		Good	77
113	Keyhaven	1950	Medium		Good	77
114	Alum Bay Pier	1920	Medium		Good	77
117	Totland Bay	1950	Medium		Good	77
96	Ryde Esplanade	1910	Medium		Good	77

Table 3D.3: Highest scoring photographs from the Solent study area.

3D.5.2 Maps and Charts Ranking

A ranking system was also developed for maps and sea charts, the development of the system and methodology is set out in [Section 2.2.](#)

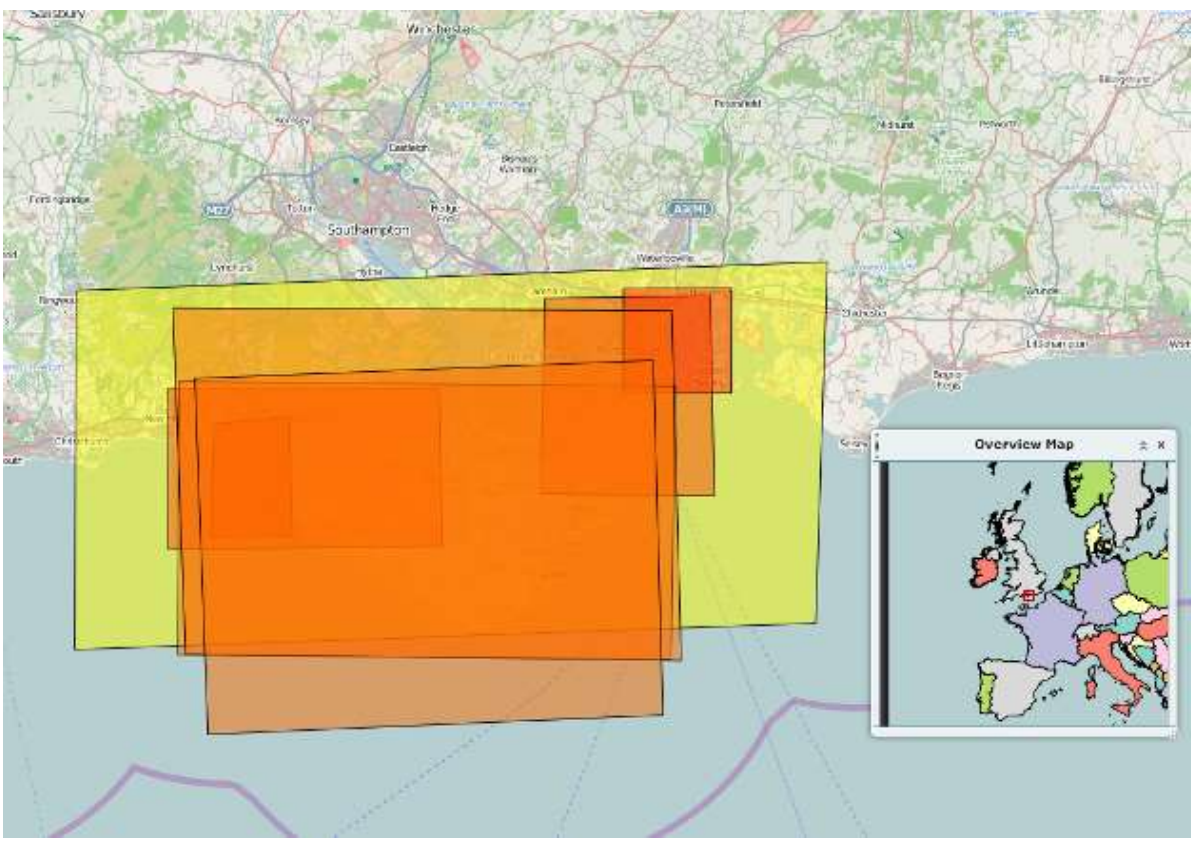


Figure 3D.72: Location of the maps and charts assessed in the Solent study area.

Map Id No	Title	Year	Score Chronometric Accuracy	Score Topographic Accuracy	Score Detail in non-coastal area	Score Geometric Accuracy	Total Map Score
148	Hurst Spit to the Isle of Wight	1934	93.3	77.8	100	83.3	88.6
146	England South Coast	1848	100	100	66.7	66.7	83.3
145	Portsmouth Harbour	1791	100	77.8	66.7	50	73.7
147	Isle of Wight to Hampshire	1791	86.7	94.4	33.3	66.7	70.3
36	Isle of Wight	1816	60	77.8	66.7	50	63.6
34	Map of the Isle of Wight	1862	86.7	50	66.7	50	63.3
37	Isle of Wight	1812	60	69.4	66.7	33.3	57.4
35	Early Map of the Isle of Wight	1600	6.7	20.8	33.3	0	15.2

Table 3D.4: Results of the maps and charts ranking in the Solent study area.

3D.5.3 Art Ranking

Thirty-eight works of art from the Solent and Isle of Wight art case study area were assessed. Artists tended to paint attractive or dramatic coastal locations as well as meeting specific demands of their patrons. On the Hampshire and Isle of Wight coastlines they were drawn to the expanding shipping ports and seaside resorts either on account of their locations or because of the interest in the activities of fishermen working along the shoreline. The result has been that many of the sites of key geomorphological and coastal risk management interest have been painted by artists particularly during the nineteenth century.

The ranking system has identified ten key paintings representing three study sites which are examined in more detail below:

Study site Number	Location	Artist	Date	Score type	Score period	Score style	Score enviro.	Total Score
D1	Portsdown Hill, P'mouth	William Daniell	1824	Aquatint	Early	Topog.	Detailed View	55
D1	Portsdown Hill P'mouth	William H. Bartlett	1848	Steel engraving	Mid.	Topog.	Detailed View	62
D1	Portsdown Hill P'mouth	William Turner	1854	Water-colour	Mid.	Topog.	Very Detailed View	51
D2	Yarmouth from the West	S. Barth & J. King	1813	Copper Plate engraving	Early	Topog.	Detailed View	37
D2	Yarmouth from the West	Robert Brandard	1848	Steel plate engraving	Mid	Topog.	Detailed View	62
D2	Yarmouth from the West	Charles Robertson	1891	Water -colour	Late	Topog.	Very Detailed View	77
D3	Ventnor Cove	Charles Raye	1825	Aquatint	Early	Topog.	Detailed view	48
D3	Ventnor from a Hill above the Cove	William Westall	1842	Steel engraving	Mid.	Topog.	Very detailed view	62
D3	The Beach, Ventnor	Rock & Co	1863	Steel engraving	Mid.	Topog.	Detailed view	55

Table 3D.5: Results of the art ranking in the Solent study area.

A more detailed explanation of each site and the interpretation of the individual artworks is provided in the study site descriptions below. The assigning of scores to each artwork suggests names of those artists who have depicted different aspects of the study site coast across the timeline 1770-1920. These artists include William Daniell, William Westall and Charles Robertson; they can be relied upon in terms of the accuracy of their depictions of the Solent and Isle of Wight coastlines.

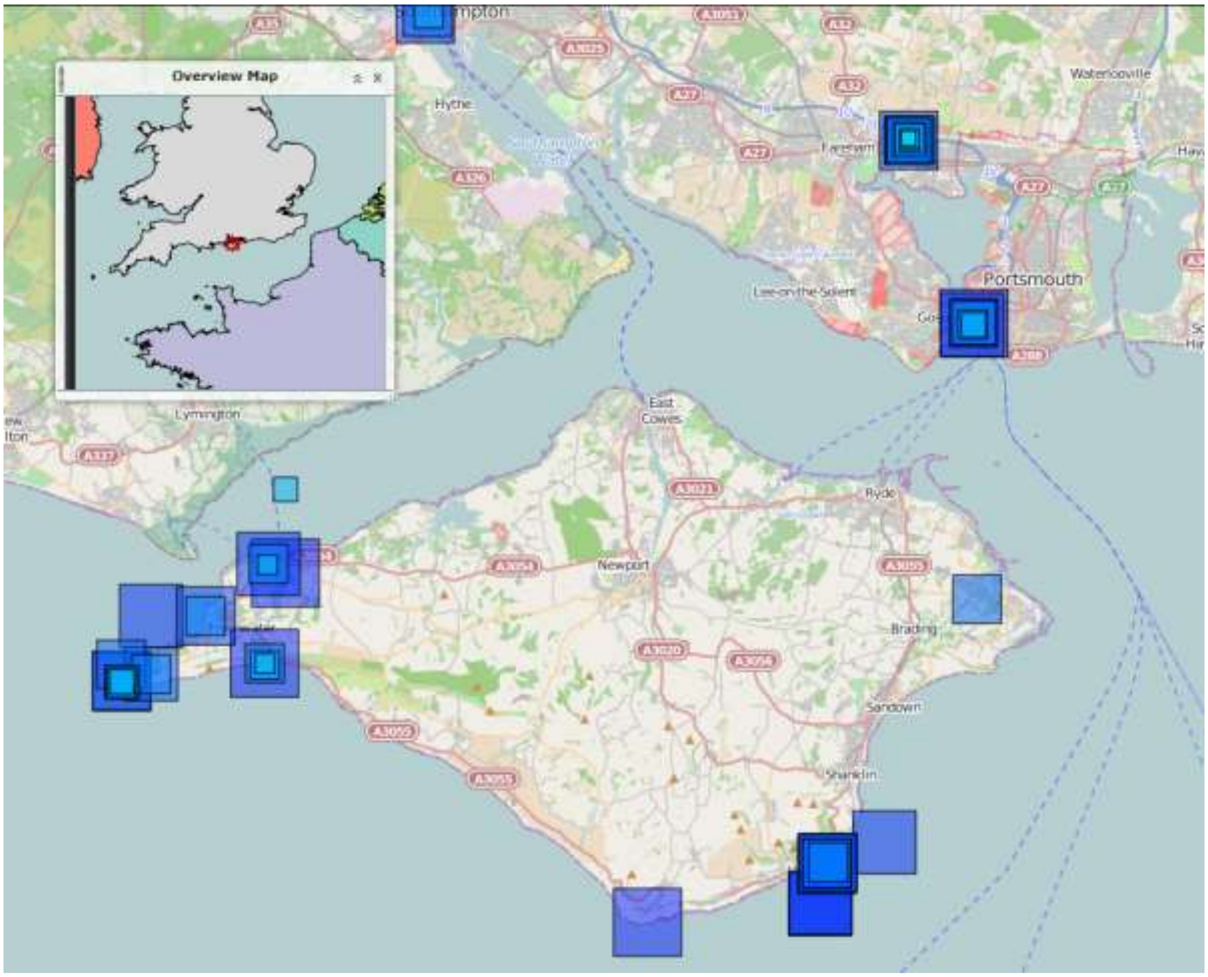


Figure 3D.73: Location of artworks assessed in the Solent/IOW study area.

3D.5.4 Discussion of Ranking Results

A total of 38 historic photographs were assessed, these ranged in date from 1886 to 1953. The highest scoring photographs contained easily identifiable features and could be compared with the present day. Because of the dynamic nature of this coastline historic photographs can be a valuable resource with many containing depictions of the cliffs, harbours and particularly of sites like Hurst Spit and the Needles with recognisable heritage features nearby, including castles, forts and lighthouses. These can be compared to the modern situation and from this an accurate idea of the rate of coastal change since the date of the photograph can be gained.

Eight maps were assessed, these ranged in date from 1600 to 1890. Although generally the more recent maps scored higher, some maps from the 1700's which were of a smaller scale also scored highly. These smaller scale maps provided detailed descriptions of the tidal areas and channels. Maps which ranked highly have been used to model changes in the landscape, particularly of the saltmarsh off Lymington and in Langstone Harbour the maps have been used in the 4D evolution models, see Section 3D.7 below.

The highest scoring artwork, a detailed watercolour of Yarmouth, by the artist Charles Robertson, gained 77 points whilst several coastal aquatints and engravings scored between 55-62 points. These are followed by oil paintings from the early and mid-nineteenth century which, with the exception of the Pre-Raphaelite artists and their Followers, generally provided less detailed information, and hence scored fewer points.

As the aim is to illustrate how art can inform us of long-term coastal change it is fortunate that within the higher scoring artworks there are examples, which include locations affected by coastal landsliding and marine erosion (Ventnor), flooding and environmental change (Portsmouth Harbour and Yarmouth). These differing physical processes and their impacts on coastal residents, assets and infrastructure could not have been easily matched to the most informative works of art without the provision of the ranking system.

Through the site studies the value of various artworks has been tested at sites of differing geomorphology. The combined approaches of desk-based research, museum and gallery searches and field visits have confirmed the added value of art from the period 1770-1920 to support other coastal surveying and monitoring technologies (e.g. space-borne, air-borne, ship-borne and terrestrial). It is important to remember that artists in the late Georgian and Victorian eras worked for very demanding, wealthy clients who often sought exact views of the coastal landscape to remind them of their visit. Before the days of photography precise images were, therefore, a prerequisite in most cases. The examination of the works of many artists painting the Hampshire and Isle of Wight coastlines testifies to their considerable artistic skills in capturing accurately the coastal topography.

Some of the artworks examined in these case studies show significant coastal change over time as well as telling the story of human intervention on the coast. Other artworks show very little change over the last two hundred years and this information is of equal interest to the coastal scientist. Importantly the artworks also illustrate, in many cases, the nature of the natural undeveloped coastline and suggest what conditions might be experienced if coastal defences were not maintained in the future. This is particularly significant as along certain coastal frontages it will not be possible to continue to defend the coast as has been the case in the past for physical or environmental reasons.

The results of the ranking have drawn attention to three sites, which differ geomorphologically from those examined already in East Anglia, East Kent and at Hastings. This case study assists in fulfilling the Arch-Manche ambition of selecting a range of coastal locations painted by artists that include the full range of environments to be found across the southern North Sea – Channel region.

3D.6 Art Field and Research Studies

In order to identify the most suitable artworks that could be studied in more detail at the field study sites a national search was undertaken involving an extensive review of landscape paintings, watercolours and prints held in public and some private collections. Following ranking of the artworks six examples have been the subject of more detailed analysis involving site visits.

3D.6.1 Key Research Questions and Fieldwork Approach

Having established, through the art ranking system that the images are likely to be true representations of the conditions that would be seen at the time they were painted, the research questions to be answered through examination of the artworks at the case study sites are:

- What information can the historical images provide to support understanding of long-term coastal change?
- How can the potential of this resource be used most effectively by the end-user?

Along the study area coastlines there are a range of physical conditions to be found including eroding cliffs, cliff instability problems, beach change and flooding of low-lying land by the sea. In order to reflect these varying conditions art images have been selected from three study sites, at Portsmouth on the Hampshire coast, and two sites on the Isle of Wight at Yarmouth on the north-west coast and at Ventnor on the south coast. Site D1 examines the coastal zone at Portsmouth when overlooked from Portsdown Hill, an elevated location looking southwards over the harbour, the city and to the Solent and Isle of Wight beyond. The key issue here is flood risk management, but the artworks also show how the city gradually developed on an open low-lying section of coast.

Figure 3D.74: A view of the entrance to Portsmouth Harbour from the south looking inland. The chalk cutting on the south face of Portsdown Hill (Case Study Site D1) can be seen in the distance. Photograph courtesy of The Wight Light Gallery.

The second study site is at Yarmouth on the Solent shoreline of the Isle of Wight. Here the historic town is at risk from flooding and important designated environments are at risk from inundation as a result of sea level rise. These issues are highlighted by the three selected artworks. Finally the coastal town of Ventnor is examined. Ventnor is situated within the largest coastal landslide complex and the case study explains how art has help to understand the nature and extent of the landslide system using historical evidence that has since been lost as a result of coastal erosion.

Each site considers the potential of the artwork to be used as a qualitative or quantitative tool to support our understanding of long-term coastal change and coastal management more widely.


Figure 3D.75 (left): A view of Yarmouth on the north-west coast of the Isle of Wight (Study Site D2). Photograph courtesy of Andrew Butler.
Figure 3D.76 (right): The town of Ventnor on the south coast of the Isle of Wight lies within the Undercliff landslide complex (Study Site D3). Image courtesy of The Wight Light Gallery.

Where it has been practical to gain access and relevant to the study, present day photographs were taken in the field to try, as far as possible, to match the views painted by the eighteenth, nineteenth and early twentieth century artists. It also provided the opportunity to assess the conditions of the cliffline and beach and changes that may have taken place over time. In terms of work in the field each of the locations has been visited and photographed in varying weather conditions. Inspections were timed to coincide with low water and a walk-over survey was made along the beach and base of the cliff returning along the cliff top. This ensured that thorough comparison could be made between the geomorphological conditions depicted in the artwork and the present day situation.

3D.6.2 Art Field Data Gathering Results

The selected Solent and Isle of Wight sites were chosen to reflect a range of geomorphological types – coastal landslides, estuaries and saltmarsh. Site inspections have confirmed that the locations selected do provide a good representation of these coastal geomorphological conditions against which the value of historical artworks can be tested.

The fieldwork element has been largely visual in terms of identifying the location of the paintings and making judgements, on site, of the role that art can fulfil as a qualitative or quantitative tool to support coastal risk management. The field inspections allowed a more accurate appraisal to be made of current physical conditions rather than relying upon written accounts and reports particularly as storm events can cause significant alterations over relatively short time periods.

The approach adopted for each case study has been the examination of one particular artwork and to make an assessment of what it tells us about changes over time from field observation. However, for some of the study sites it has been found that several artists painted the view from the same or a similar spot. This helps us to establish a chronology of coastal change through the nineteenth and twentieth centuries.

D.1. Portsdown Hill to Portsmouth Harbour, Hampshire

Location

This view by William Daniell (Figure 3D.77) illustrates the relatively undeveloped Portsmouth Harbour with Porchester Castle and the Isle of Wight beyond in 1824. It is interesting because it shows some of the islands and creeks of what is now a densely populated city in a largely natural state. The study site is the view from Portsdown Hill looking south over the harbour and the city towards the Solent and the Isle of Wight.

Why was the study site selected?
This site was selected to illustrate the role that historical artworks can play in informing us of the conditions that existed before coastal defences and other developments took place. An understanding of the natural conditions that prevailed in terms of evolution and coastal processes is a key consideration when developing a coastal risk management strategy for the future.

Geomorphological setting
The study site is located within the Hampshire Basin and comprises relatively soft rocks from the Cretaceous and Tertiary periods. Portsdown Hill stands as a ridge of chalk downland extending east to west behind the city of Portsmouth, which developed on Portsea Island. The sheltered Portsmouth Harbour lies to the west of Portsea Island whilst the large tidal bay of Langstone Harbour lies to the east.

Figure 3D.77: 'View from Portsdown Hill, Portsmouth' by William Daniell RA. 1824

Key coastal risk management issues for the frontage
Flood risk will increase because of rising sea levels threatening the coast and increased winter rainfall and summer flash flood events. Sea level will rise by approximately one metre in the next 100 years. Higher storm surges and tide levels will reduce the ability of drains to discharge into the sea, potentially increasing fresh water flooding in low lying areas. Greater frequency and intensity of short duration rainfall events will put pressure on drainage systems (surface

water and combined) and lead to localised flooding. 64.6% of the city of Portsmouth is at risk from flooding, which includes nearly 27,000 properties (Environment Agency, 2010).

Portsmouth is at risk from both surface water flooding, and tidal flooding. The most significant flooding event of recent years in Portsmouth occurred in the year 2000/01 when 114 properties flooded internally and 20 residential roads flooded. Tidal flooding presents the more significant risk as large portions of Portsea Island are below sea level, leaving nowhere for flood water to naturally drain after a flood event. In the face of climate change, flood risk is expected to rise as more severe storms will increase pressure on the existing urban drainage network (Environment Agency, 2010). The East Solent Coastal Partnership of local authorities has commissioned modelling studies in order to better understand flood and coastal erosion risks in the area (East Solent Coastal Partnership, 2013).

Observations on the artwork

The main road from London to Portsmouth passed over Portsdown Hill, a route used by many early writers and artists visiting the south coast and the Isle of Wight in the late eighteenth and nineteenth centuries. The view from Portsdown Hill over Portsmouth is spectacular and would have provided the first view of the sea for many travellers; as a result artists paused there and often painted the view. These included, in the eighteenth century, Thomas Jones (1870s), John Thomas Serres (1778) and in the nineteenth century William Daniell RA (1824), Wlliam James Callcott (1840s), William Henry Bartlett (1848) and William Turner of Oxford (1854). Following ranking the works by Daniell, Bartlett and William Turner have been examined further.

The view by Daniell is typical of his meticulous observation and eye for detail and he described the location in his famous publication '*A Voyage Round Great Britain'* (Daniell & Ayton, 1814).
"..an excursion was made to Portsdown Hill, the lofty and narrow ridge from whence was taken the annexed view, looking down on the harbour of Portsmouth. The aspect of that grand naval emporium, at this distance, is perhaps more impressive than any which would exhibit to a beholder in its immediate vicinity. On the tongue of land to the right is Porchester Castle. Farther in the distance is Gosport, backed by the Isle of Wight, of which the portion here visible extends from Brading harbour and St Helens road near Ryde. In the harbour Portsmouth are seen some objects strongly characteristic of a time of peace; they are ships laid up in ordinary. Altogether the prospect in this direction is surpassing for its grandeur and variety…"

Daniell's view looks down over Porchester Castle, the Roman fort, towards Gosport and Portsmouth with the Isle of Wight beyond. Twenty-four years later the prolific artist and engraver, William Henry Bartlett, produced a very fine steel engraving from the same location. The extent of the estuary is very clearly delineated and demonstrates the detail that could be achieved through engraving on a steel plate. The shape of the harbour and the coastline matches very closely Daniell's observations.

A third work from this location was painted by William Turner of Oxford in 1854. Turner (designated as 'of Oxford' to distinguish him from J. M. W. Turner) usually painted coastal panoramas such as this from elevated locations. His style was detailed and topographically accurate. This view is from higher up the hill than the two previous works. Porchester Castle is clearly visible, as is the city of Portsmouth on the left.

Figure 3D.78: 'Portsmouth Harbour and Spithead'. A steel engraving by W. H. Bartlett (1848). The extent of the coastline near Porchester Castle is drawn in a precise manner. The present day view is shown above (Image courtesy of Wikipedia).

Figure 3D.79: A watercolour drawing from the top of Portsdown Hill looking south by William Turner of Oxford (1854). The present day view above shows the extensive development that has taken place. Image courtesy of Andrew Bryant.

How can the artworks inform coastal risk management?
Each of these three works emphasises the changes that have taken place in the coastal zone over the centuries and allow us to reflect on the development of this low-lying land, part of which is now densely populated and vulnerable to flooding and the impacts of sea level rise. Views such as these can be useful in understanding the evolution of Portsmouth Harbour over time including changes in the form of the coast as a result of both human and natural factors. Such historical images can also assist consultations with stakeholders over issues relating to flood risk as they highlight the vulnerability of the location even before much of the development took place.

Where can the original artwork be viewed?
Each of the three images can be viewed on the Internet at ‘Portsdown Hill, Portsmouth Images’.

Ranking scores achieved:
William Daniell image: 55; William H. Bartlett 62; William Turner: 51.

D2. Yarmouth, Isle of Wight Study Site

Location
The study site comprises the mouth of the Western Yar river at Yarmouth on the north-west coast of the Isle of Wight.

Why was the site selected?
This site was chosen to illustrate how art can inform on flood risk and the impacts on intertidal environments in the face of sea level rise and climate change, as well as development impacts.

Geomorphological setting
The site lies in the flood plain of the River Yar, which flows from south to north across the western end of the Isle of Wight (Figure 3D.81a). The source of the River is on the south-west coast of the Island at Freshwater Bay where the river has cut through the west to east running chalk hills on its route northwards to flow into the Solent at the town of Yarmouth. North of the chalk downs the river flows gently through rocks of Tertiary age, which are covered by more recent deposits of alluvium.

Key coastal risk management issues for the frontage
It is the intention to continue to maintain and or improve defences that protect the town of Yarmouth because it is clear that existing defences will come under increased pressure as a result of climate change and sea level rise. The maintenance of the current defence levels without further improvements would not reduce the present and increasing risks from flooding (Isle of Wight Council, 2010). Over the next twenty years there will be a need to provide a higher standard of protection whilst rising sea levels and tidal inundation will continue to impact upon saltmarshes within the Western Yar estuary with coastal squeeze resulting in loss of habitat of nature conservation importance.

Observations on the artworks
Three artworks have been selected for this case study, which represent the three ranking time epochs (early 1770-1840; Mid 1840-1880 and Late 1880-1920). All three views are taken from the western side of the River Yar and look eastwards across the river towards the town of Yarmouth. The earliest view is a detailed copper plate engraving produced as one of a set of twelve views of the Isle of Wight by S. Barth and J. King in 1813. For such an early print it is

surprisingly detailed and gives a clear appreciation of the mouth of the Yar and the harbour at this time. The view predates the construction of the harbour breakwater and the bridge across the River Yar, which dates from the 1850s. In this view we can see the natural form of the coast prior to any human intervention. The second view is a steel plate engraving by the artist Robert Brandard (1848) and is viewed from Sandhard Beach, which is situated slightly forward and seaward of the print by Barth & King. The third image is a watercolour drawing looking across the River Yar in a north-easterly direction from rising ground just south of the two previous views. This watercolour is by Charles Robertson and was painted in 1891. Robertson was a follower of the Pre-Raphaelite Brotherhood of Artists who sought to capture nature in precise detail and this is reflected in this work.

Figure 3D.80: 'Yarmouth from the west', a copper plate engraving by S. Barth and J. King (1813). The detail of the extent of the harbour is carefully drawn in this view.

Figure 3D.81a Left: View of the mouth of the Western Yar after prolonged rainfall in 2007. Photograph: Andrew Butler. Figure 3D.81b Right: A view of the whole catchment of the Western Yar with the Solent beyond. Photograph courtesy of the Wight Light Gallery.

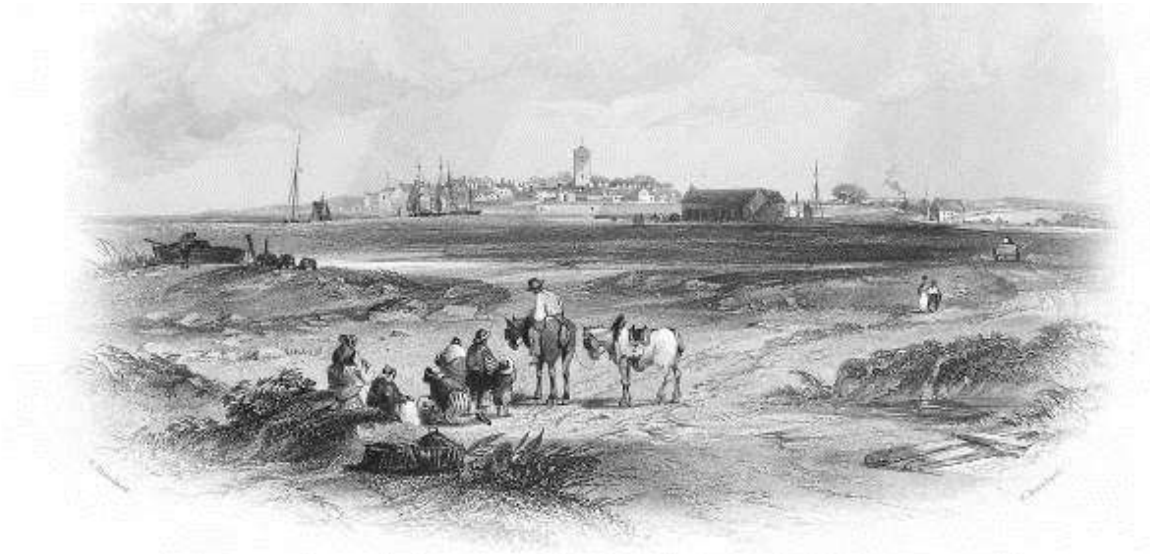


Figure3D.82: 'Yarmouth from the West' by Robert Brandard (1848)

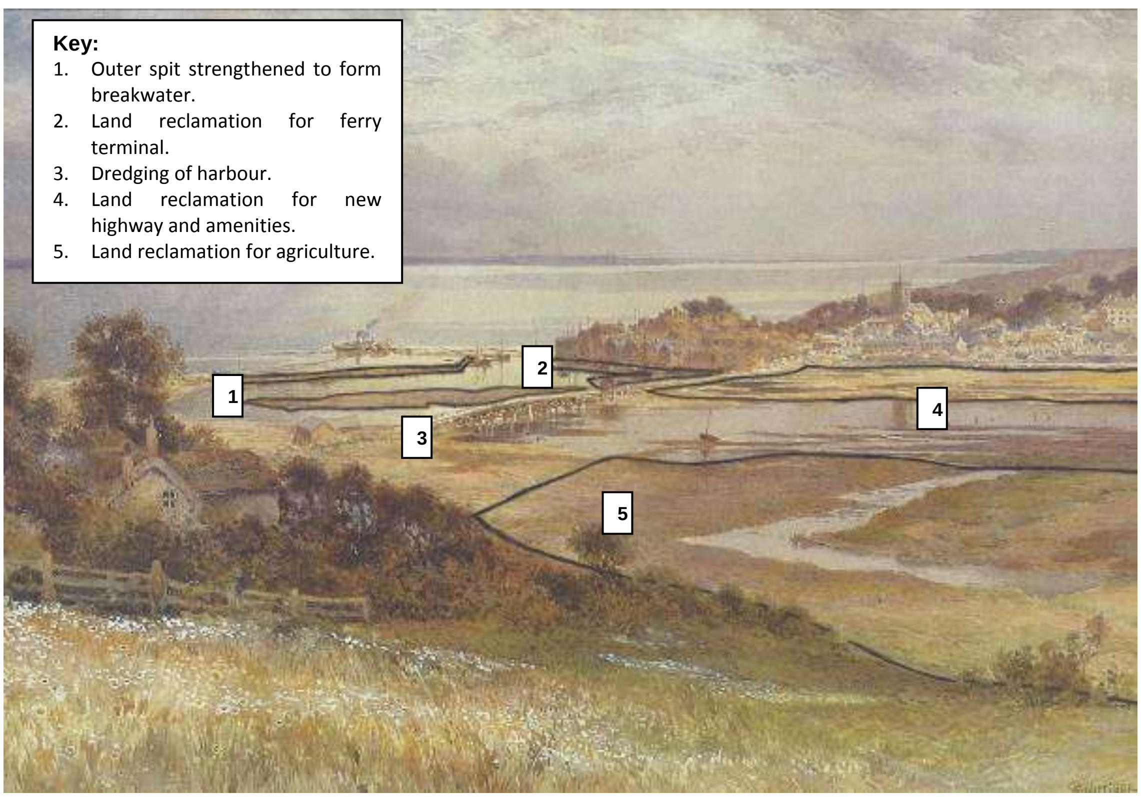


Figure 3D.83: 'Yarmouth' by Charles Robertson (1891) showing clearly the extent of the estuary and its relationship to the town. The painting has been annotated showing how harbour, highway and leisure development as well land reclamation, has reduced the width of the flood plain and the extent of the saltmarsh.

How can the artworks inform coastal risk management?

The three views of Yarmouth show a low-lying town of considerable historic and economic importance that is at risk from flooding and the impacts of climate change. They show the coastal geomorphology before it was altered by the construction of coastal defences and the harbour arm. Such views can be helpful when seeking to understand the implications of different coastal defence policy options under consideration through the shoreline management planning process.

Apart from the issue of coastal protection and flood defence such images can assist in understanding environmental loss and habitat changes. The Western Yar River, like most of the creeks and estuaries flowing into the Solent from both the Isle of Wight and Hampshire catchments, has been gradually silting up. Now, these coastlines are facing significant challenges from sea level rise with over 60% of the intertidal saltmarsh and mudflats expected to be lost by the year 2050.

In terms of understanding and quantifying this loss the watercolour by Robertson appears so accurate that it may be possible to over-lay the present day estuary limits and try and assess change over the last 130 years. The extent of riverside development in the Western Yar estuary for both commercial and agricultural purposes is indicated on the watercolour by Robertson. This has, to some extent, constrained the flows at Yarmouth. It also shows how works of art can be used to measure not just physical but also environmental and developmental changes over time.

Where can the original artworks be viewed?
The engraving by Barth and King is extremely rare and is contained in a number of art reference publications (McInnes, 2008b). The steel engraving by Bartlett is included in '*The History of Hampshire'* (Woodward *et al*., c.1848). The watercolour by Robertson is in a private collection.

Ranking scores achieved
The engraving by Barth & King scored 37 points; the view by R. Brandard scored 62. The very detailed watercolour by C. Robertson scored 77 points.

D3. Ventnor Undercliff, Isle of Wight study site

Location
The Ventnor study site comprises the section of developed coastline at Ventnor Bay on the south coast of the Isle of Wight.

Why was the case study site selected?
The Undercliff is a 12km long coastal cliff and landslide complex between Luccombe and Blackgang on the south coast of the Isle of Wight. The cliffs were formed as a result of deep-seated mass movements that occurred many thousands of years ago dating back to past glacial periods. The remnants of these ancient landslides extend a significant distance offshore and up to 700m inland of the shoreline where they comprise steep slopes and terraces up to 120m high. The Undercliff is regarded as one of the most unstable developed geological settings in the UK; the complex cliffs are formed in weak rocks that are sensitive to the effects of toe erosion and groundwater. The main area of interest for this case study concerns the section of Undercliff between Bonchurch and Ventnor.

The Undercliff study site was chosen to illustrate how art can inform us on physical change within a major coastal landslide complex.

Geomorphological setting
The coastal cliffs of the Isle of Wight Undercliff are formed within the Lower Cretaceous sequence of sedimentary rocks comprising Chalk, Upper Greensand, Carstone and Sandrock.

The sequence of strata is strongly bedded with a 2^0 dip seaward which pre-disposes the succession to large-scale landslides. The sea cliffs forming the present day 'toe' of the Undercliff are mostly cut into landslide debris, and erosion rates are typically 0.3m per year. In-situ soft sandstones (Sandrock) form the high sea cliffs at the east and west ends of the Undercliff at Luccombe and Blackgang where toe erosion rates are much higher, between 1-3m per year. The Undercliff has experienced a relative increase in sea level and winter rainfall over the historical period promoting toe erosion and excess groundwater levels both of which have an adverse impact on stability.

Figure 3D.84: View of Ventnor undercliff Landslide complex. Photo courtesy of the Wight Light Gallery.

Key coastal risk management issues for the frontage

Ground movement in the Undercliff generally takes the form of very slow and intermittent creep of the ground, the cumulative effects of which, over many years, has caused significant damage to property, businesses and other assets and services. Occasional rapid ground movements occur, for example at Blackgang in 1994, at Bonchurch in 2000, at Niton in 2001, and at Ventnor in 1960 when some residents had to be evacuated. Over the last 100 years, some 60 properties have had to be demolished in Ventnor due to impacts of ground movement, whilst others have sustained significant damage. The most notable impacts of ground movement can be observed in Upper Ventnor at a feature known as the 'Lowtherville Graben' which extends some 500m in length, 20m across, and has subsided vertically by up to 4m. The B3327 Newport Road and other services located across the graben are continually subject to damage due to ground movement. The A3055 Undercliff Drive was routed through Niton, St Lawrence, Upper Bonchurch and Ventnor and provided a strategic road network linking the coastal towns, communities and businesses across the southern and south west coast of the Isle of Wight. A landslide in February 2014 severed the route east of Niton. The present value annual risk of damage caused by ground movement in the Ventnor Undercliff has been estimated to be £4.64m (Lee & Moore, 2007).

The Undercliff is sensitive to toe erosion and deep-seated ground movement due to the inherent geology and exposure of weak rocks to weathering, excess groundwater and coastal erosion. There is concern that increases in relative sea level and winter rainfall will result in accelerated ground movement rates and more frequent landslide events over the next 100 years. The impact of these events is expected to be limited to the current extent of the Undercliff and is likely to involve significant recession of the headscarp; the Shoreline Management Plan estimates a total of 2,485 properties (worth £511m) are at risk from landslip in Ventnor and Bonchurch, and combined with estimated of replacement value of other assets including highways, footpaths and services, the total value of assets at risk is estimated to exceed £600m.

The local authority implemented a *Landslide Management Strategy* in the Undercliff in 1992. The main purpose of the strategy has been to engage key stakeholders and the community to raise awareness of the issues and promote best practice for managing ground instability through a range of practical measures and improved planning and building control. However, a quantitative risk assessment of coastal instability and erosion at Ventnor completed in 2006 demonstrated that, whilst these measures were beneficial, active civil engineering intervention would be necessary to avert the increasing risks of major ground instability due to the effects of climate change and rising sea level; further, the study identified a positive benefit to cost ratio for stabilisation in the form of deep drainage and improved coastal protection measures.

Climate change poses a significant challenge to the future stability and management of the Undercliff and other similarly marginally stable coastal landslides in southern Britain. The value of site investigation, continuous monitoring of weather, groundwater levels and ground movement rates is clearly demonstrated in this case study. The relationships and understanding derived from analysis of these data provide the basis for design of robust early warning and response strategies and engineering stabilisation works; reducing the potential adverse impacts and consequences of such events. Reliable assessment of the hazards and risk of large pre-existing coastal landslide complexes can only be achieved through detailed site investigations which are needed to inform effective planning, management and stabilisation.

Observations on the artworks

Three artworks have been selected to illustrate their value in the case of the Ventnor site. They are, first, an aquatint engraving of Ventnor Cove by Charles Raye (1825); second, a steel engraving by William Westall of the same view dated 1842. Finally a steel engraving showing Ventnor Beach by Rock & Co. dated 1863.

The views by Raye and Westall both look across Ventnor Bay from east to west. They show the coastal slopes of the seaward face of the landslide complex very clearly and bare of tree cover and later housing and tourism developments. Both views are carefully engraved with the early scene by Raye focusing more on Ventnor Cove itself whilst Westall's view includes the downland behind. The third image by Rock & Co. is of Ventnor beach looking in the opposite direction from west to east. The point of interest is the rock formation shown on the beach seaward of the sea cliff behind. The importance of the information provided in this engraving is explained below.

How can the artworks inform coastal risk management?

In recent years research has sought to understand more about the formation and development of the Undercliff landslide complex in order to support effective planning and risk management. A fundamental need was to understand how the landside complex was formed and its extent seawards. These issues were investigated through both field geomorphological mapping as well as interpretation of historical evidence including old maps, artworks and photographs.

The views by Charles Raye and by William Westall were particularly useful because they showed the town of Ventnor before the coastal frontage was extensively developed from the 1830s onwards. The planting of the Holm Oak during the early 1900s led to a rapid spread of the species; this also masks the coastal geomorphology today. In the two nineteenth century engravings it is possible to identify some of the main components of the landslide complex including back-tilted blocks of the Upper Greensand strata that have slid from the rear escarpment behind and above Ventnor Cove, peri-glacial deposits of landslide debris that were washed down from the hills behind and areas along the toe of the landslide at beach level that are affected by heave.

The small steel engraving by Rock & Co. (1863) shown in Figure 3D.87 is particularly significant. It shows the relic of a former cliffline lying seaward of the existing sea cliff. When the Undercliff geomorphology was being interpreted there was uncertainty as to whether the existing sea cliff represented the seaward extent of the Undercliff landslide complex as a whole. However, this image provided clear evidence of another cliff further seaward. Following further studies off-shore a landslide model for the Ventnor Undercliff was developed successfully (See Figure 3D.88).

Where can the original artworks be viewed?
The engraving by Charles Raye is published in his '*Picturesque Views of the Isle of Wight'* (Raye, 1825). The William Westall engraving is contained within '*Views of Carisbrooke Castle and Environs'* (Westall, 1842). The engraving by Rock & Co. of Ventnor Beach is from *'Views of Ventnor and neighbourhood'* (Rock & Co., c.1865).

Ranking scores achieved
Charles Raye *' Ventnor Cove'* – 55; William Westall *'Ventnor'* – 62; Rock & Co. *'Ventnor Beach'* - 55

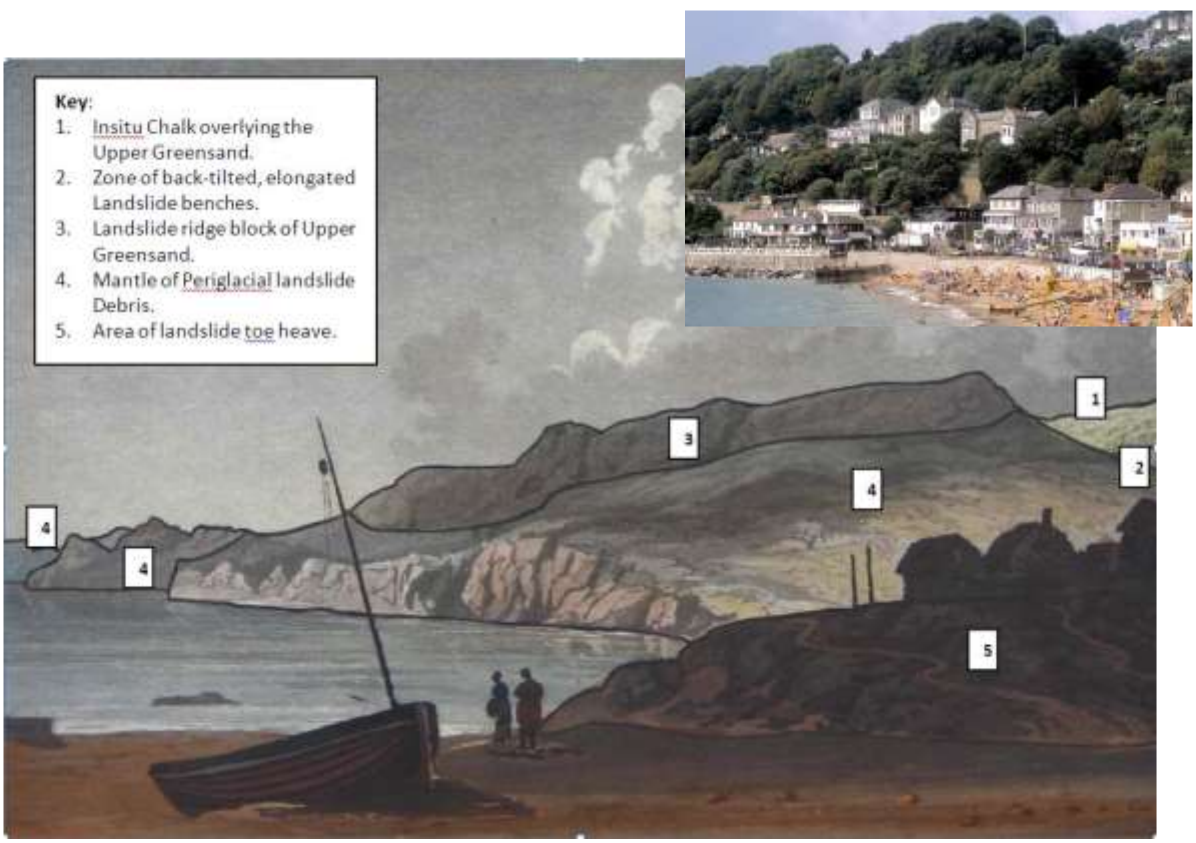


Figure 3D.85: 'Ventnor Cove' by Charles Raye. 1825. The geomorphology of the seaward face of the Undercliff landslide complex is clearly visible compared with the present day view

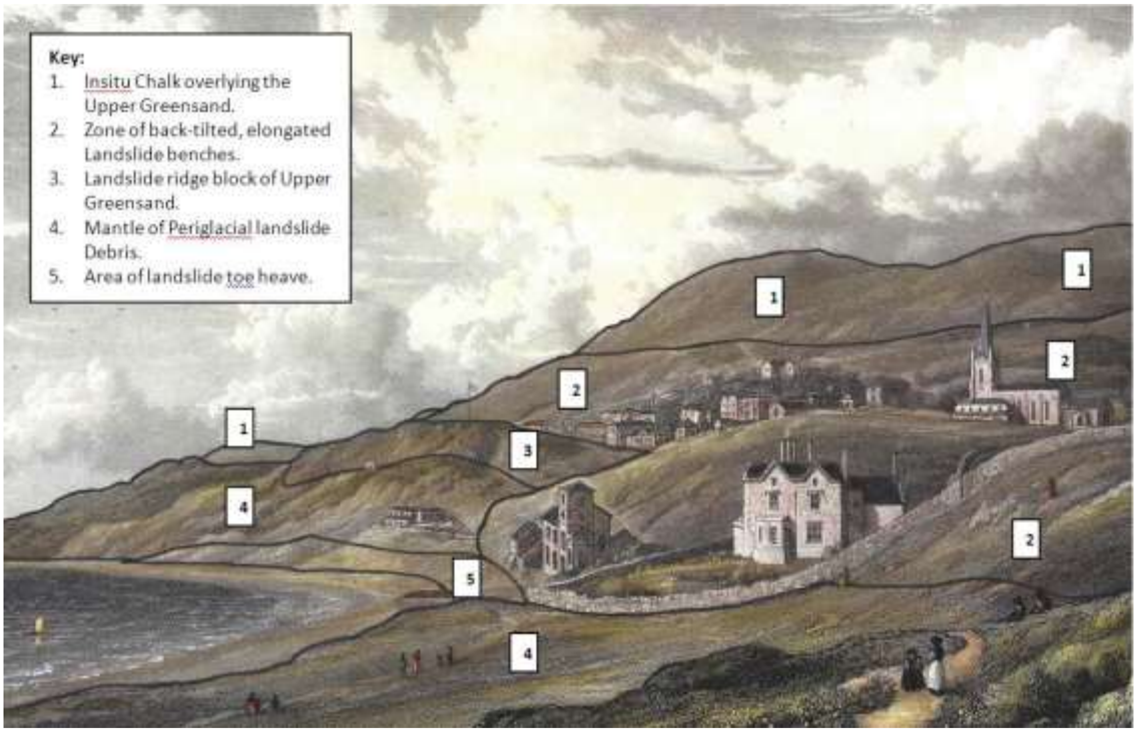


Figure 3D.86: A view of the same location by William Westall is rather more extensive and even more detailed. Victorian and Edwardian development over the coastal slopes and planting and spread of the Holm Oak in the early 20th century now masks the geomorphology.

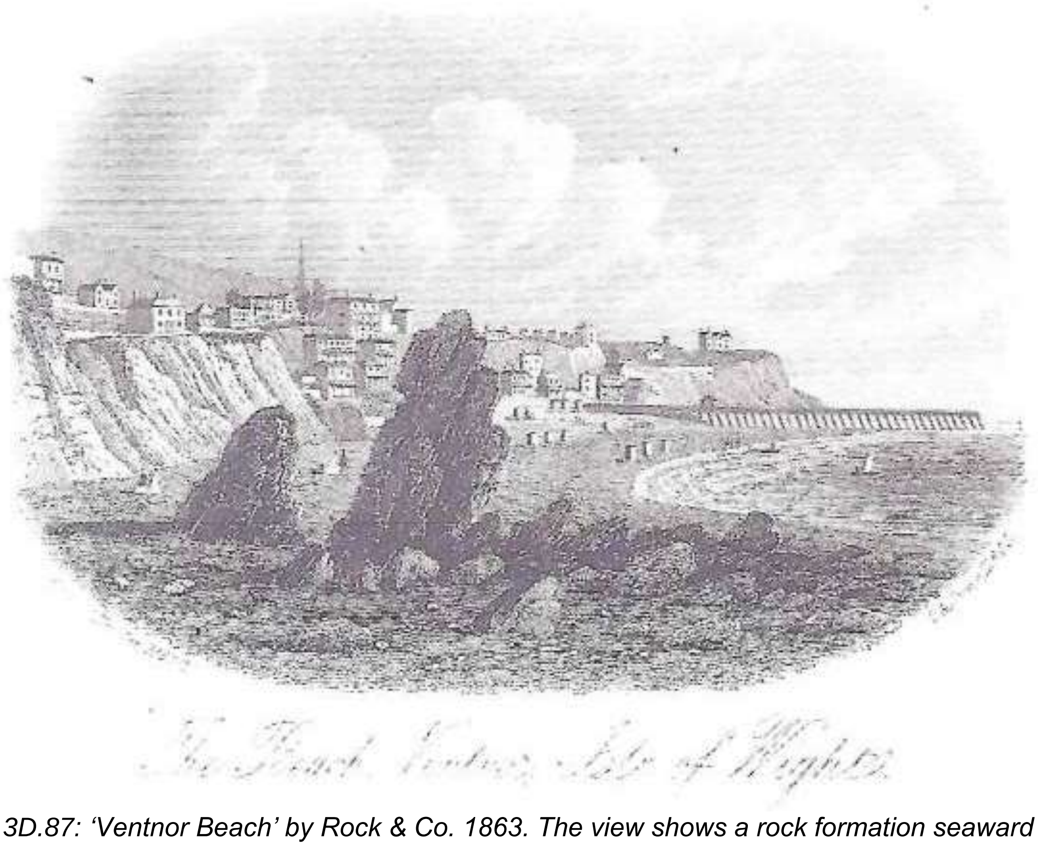


Figure 3D.87: 'Ventnor Beach' by Rock & Co. 1863. The view shows a rock formation seaward of the existing sea cliff.

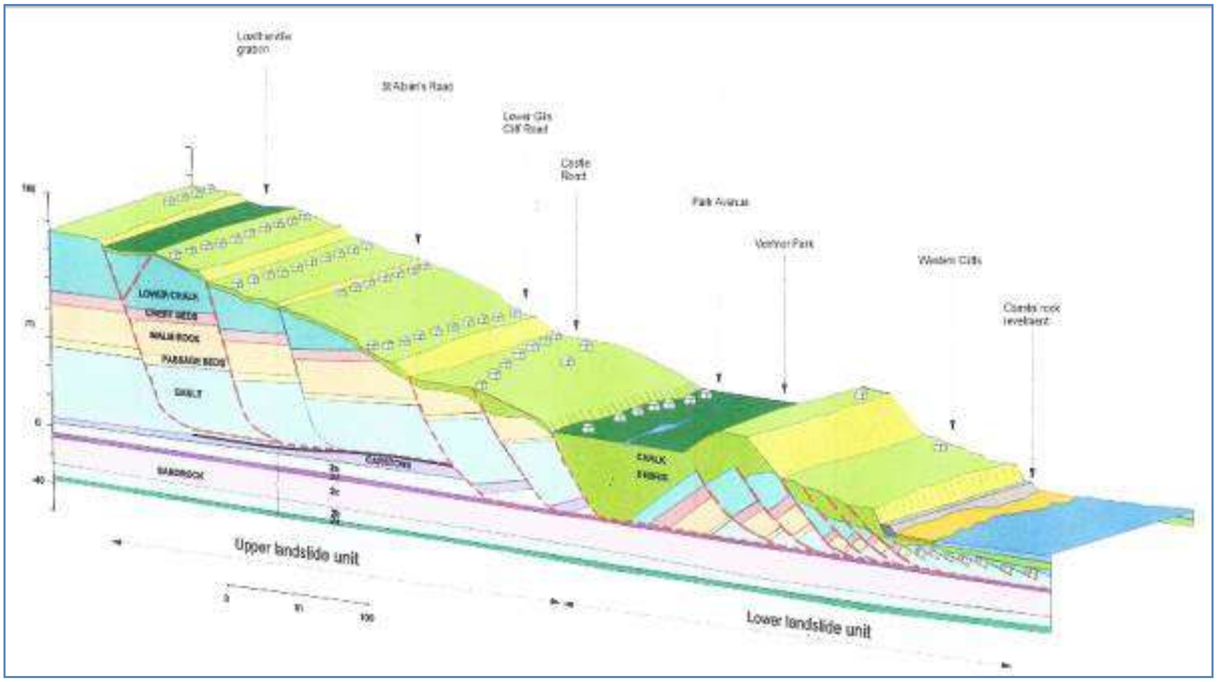


Figure 3D.88: The rocks depicted in the engraving by Rock & Co have long since been lost through erosion, they identified a former cliffline further seaward and helped to develop this landslide model for the Undercliff.

3D.7 ANALYSIS

The Solent and Isle of Wight study has combined the use of archaeological and palaeoenvironmental data, paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve our understanding of coastal change in the long and short term. The coastlines of the study area are constantly evolving, analysis of the past enables us to assess progressive changes and alterations to the coast and by understanding past coastal change it is possible to predict future changes and potential impacts more accurately. This section reviews the most informative and reliable data gathered from this study area for contributing to understanding of the scale and pace of coastal change.

3D.7.1 Archaeological and Heritage Features

Archaeological assessment focussed on the western Solent and Langstone Harbour, an analysis of the results is presented in this section.

Bouldnor Cliff and the wider landscape of the western Solent was chosen as a case study as it contains a long sequence of stratified prehistoric landscapes including Mesolithic occupation evidence (Figure 3D.89). The site scored maximum points for each criteria using the ranking methodology outlined above as it contains a long sequence of deposits demonstrating changing sea levels over 10,000 years, it contains dated and analysed evidence of the changing environment including associated human occupation evidence, and finally the long sequence of prehistoric landscapes and associated inundations are directly related to each other. Because of this it was also chosen for further archaeological fieldwork.

The well preserved sediment archives in the western Solent, particularly at the site of Bouldnor Cliff have improved our understanding of the formation of the Solent. Analysis of the bathymetry, sediments, diatoms and foraminifera at Bouldnor Cliff has revealed a sequence of events that saw final inundation by the sea around 6,000 BC. This was followed by the deposition of brackish estuarine sediments, which served to protect the palaeolandscape. Evidence suggests that the sea entered the system via the River Yar and by 4,000 BC rising sea levels eroded the barrier to the east of the basin with the western barrier being breached about 2000 years later. This formed the Solent which changed from a sedimentary sink in the estuary to the new Solent channel cutting across the infill deposits and removing most of them. Some of these deposits remain in sheltered areas to the north and south, including Bouldnor Cliff, although they are still subject to ongoing erosion (Momber et al, 2011).

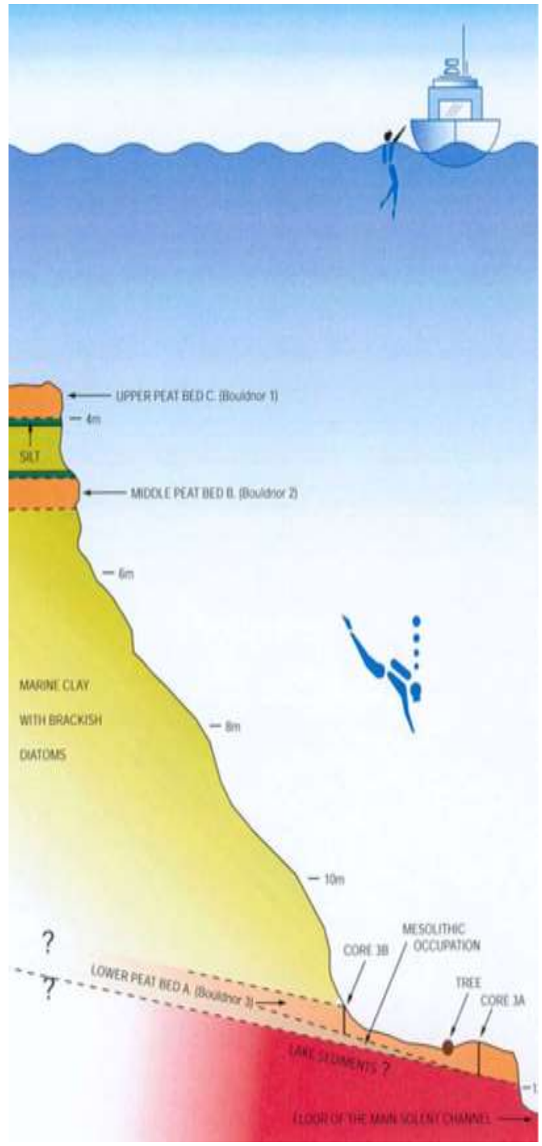


Figure 3D.89. Cross section through the submerged prehistoric landscape at Bouldnor Cliff (SCOPAC)

The formation of the Solent dramatically remodelled the seabed by reshaping and transforming the submerged palaeolandscape (Figure 3D.90). First, estuarine deposits covered protected earlier surfaces and secondly, sea level rise overtopped hills to the east and west allowing a new channel to be formed perpendicular to the original drainage pattern. This masked the previous north-south flowing river. Modern technology and analytical procedures have proven that the palaeolandscape was something other than it first appeared and shows that the seabed morphology did not reflect the earlier land surface.

It has been through detailed archaeological and palaeoenvironmental research that an understanding of how the Solent formed has been possible. These unique deposits have been preserved within an oxygen-free environment afforded by the fine fluvial and marine silt, allowing information on the past environment and how it changed to be obtained. This sequence of deposits provides vital evidence on how the Solent formed and continues to provide information on the ongoing rate and scale of coastal change which is further eroding the palaeolandscape.

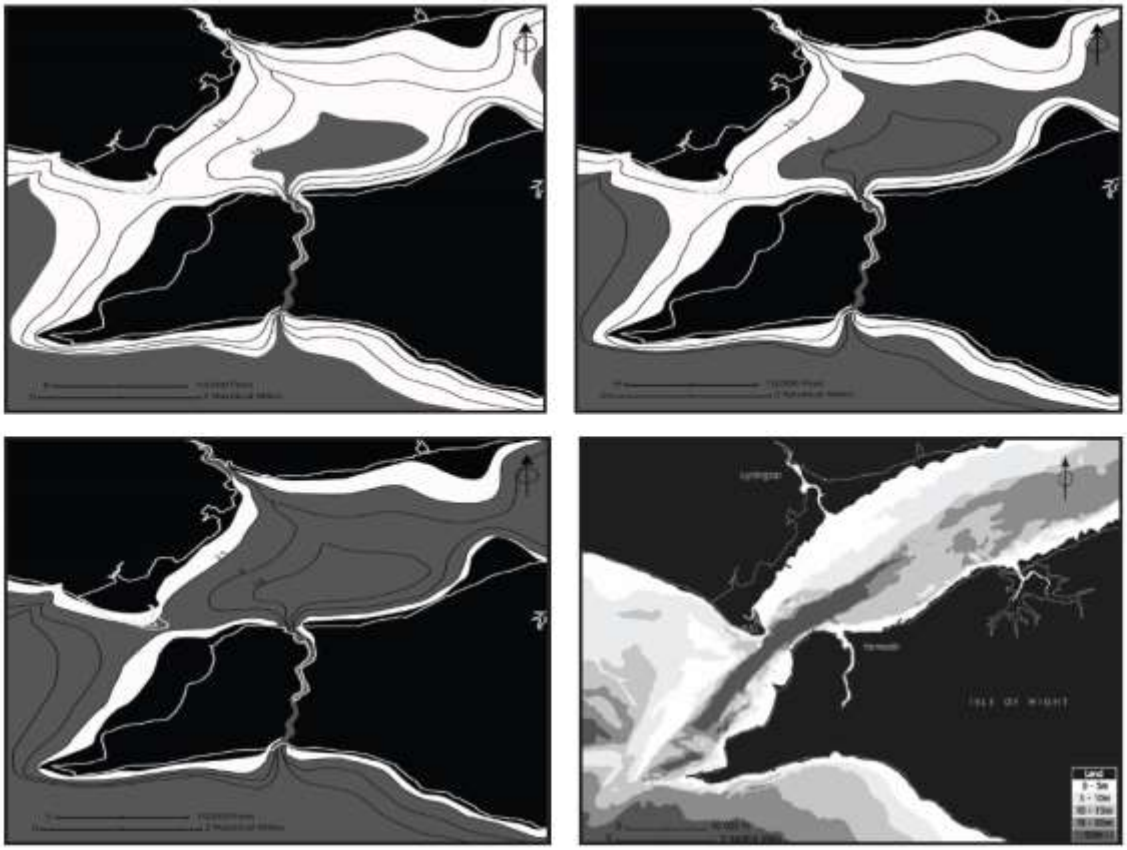


Figure 3D.90: Images showing the development of the western Solent. About 3,500 years ago, the breaching of the final land link to the island transformed a salt marsh into a channel that would eventually extend over 10km long and up to 60m deep. The strong tidal currents introduced when the channel was formed continue to erode the Solent shoreline today.

Langstone harbour was selected as a case study area due to its rich and diverse archaeological record and its history of archaeological investigation. The large project carried out in the 1990's (Allen & Gardiner, 2000) was followed by further work in 2002-2003 and again in 2012-2013 by the MAT, providing a gap of close to a decade which demonstrates how the harbour has changed over time with modern erosion exposing more material.

By combining the recent work with previous surveys and excavation it was possible to build a more accurate picture of how this landscape has changed over time, resulting in a 4D evolution model of the harbour from the Mesolithic to present day. Study of this data allows a better understanding and modelling of past incidents of, and reactions to, coastal change. This in turn can aid our planning for future changes and inform on sustainable policies for adapting to coastal change.

The combination of recent fieldwork with the previous projects in the area revealed intermittent human activity commencing in the Middle Stone Age and adapting, at various times, to a rising sea level. These changes were accompanied by a retreat of the shore from mudflats and saltmarsh. Significant stages in the evolution of Langstone Harbour began with a transition from a down-cut ravine to a silted river valley. This occurred during the Late Middle Stone Age. Dominant marine influences did not enter the channels within the harbour until after 800BC. There then followed periods of stasis and episodes of both accelerated erosion and deposition. These dynamic episodes show a relationship with concurrent changes in relative sea-level and shifts in local currents and the tidal system (Allen and Gardiner, 2000: 186-198).

Mesolithic – In the Mesolithic Langstone Harbour was an inland site, the landscape was dominated by a valley with steep sides leading down to fresh water streams.

Neolithic – The Neolithic landscape saw woodland on high and dry land while the valley had been in filled by organic material giving it a more shallow gentle profile.

Bronze Age – During the Bronze Age the area developed towards a stronger marine environment made up of salt marsh and tidal rivers.

Iron Age – The small rise in sea level during the Iron Age made the area much wetter and the now, almost non-existent valley was flooded.

Current - Langstone harbour is now a large shallow, marine inlet off the English Channel

Figure 3D.91. The evolution of Langstone Harbour, screen shots from the 4D model showing how the landscape has changed over time (the full interactive model is available on the portal).

3D.7.2 Artistic Depictions

The Solent and Isle of Wight case study sites have provided examples of how artwork can support understanding of long-term evolution of coasts, harbours and estuaries as well as environmental and habitat changes. The case studies also explain how art, maps, charts and photographs can improve our understanding of coastal geomorphology, erosion and ground instability problems.

Artworks

Where highly ranked artworks are available for study such as the view of Yarmouth by Charles Robertson or the very detailed engraving by William Westall of Ventnor it is possible to study coastal features in much more detail. Whilst the Yarmouth view shows very clearly how the river morphology and environment has been altered as a result of human intervention, the Ventnor engraving supplies geomorphological information that is now far less obvious through visual inspection; the whole of the coastal zone being masked by tree cover or development.

The small engraving by Rock & Co, which shows the vestiges of a former sea cliff on Ventnor beach illustrates how historical artworks may have recorded useful information, which has since been lost as a result of coastal erosion.

Historic Photographs

Historic photos provide detailed and accurate information on coastal change. Two areas in particular can demonstrate this; Lymington and Hurst Spit.

Hurst Spit is a cuspate shingle foreland dominating and protecting the entrance to the western Solent. This feature is best known to most for the presence of Hurst Castle. The castle is a national historic monument and tourism asset situated at the tip of the spit. Its survival depends on the future stability of the spit yet, by its very nature, the spit is an evolving coastal beach-form capable of dispersal or migration.

For observers of shoreline behaviour, the spit is of particular importance because of the natural protection it has long provided for the sheltered coasts and habitats of the western Solent seaway. The spit is an ephemeral coastal feature that is capable of changing its form and shifting its position. It is now known that its entire development must lie within the past 8,000 years. Some perceptible shifts in the configuration of the spit are evident in recent history and can be seen through historic photographs. Below is an aerial photograph from 1953 obtained through the Britain from Above Project. This is presented next to a current view of the area (Figure 3D.92).

Comparison of these images shows the extent of the sediment erosion on the spit, the sea now reaches the walls of Hurst Castle. However, further north at the old jetty by the lighthouse the accretion of shingle around the jetty made this no longer usable by boats.

Figure 3D.92: Hurst Spit in 1953 (left) and 2013 (right).

Loss of intertidal mudflats and saltmarsh at the entrance of Lymington Harbour can also be seen through historic photos. Below is an aerial view from 1952 compared to a view from 2013.

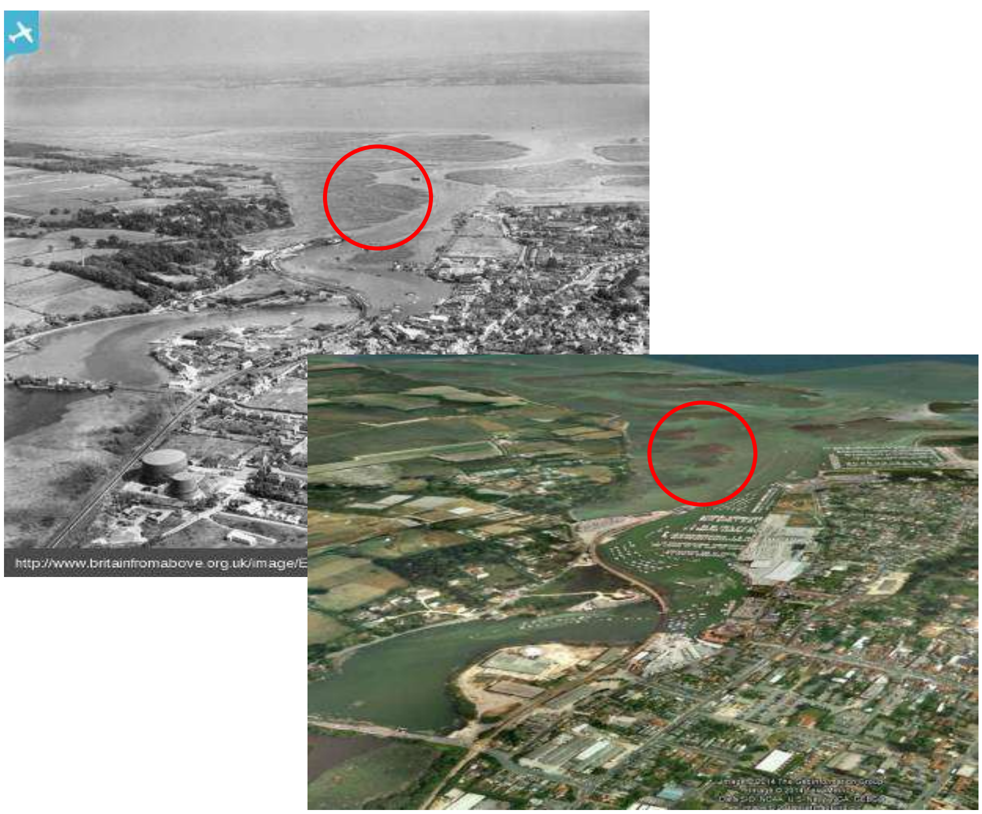


Figure 3D.93: Lymington Harbour in 1952 (left) and 2013 (right). The red circle marks the most notable changes in the saltmarsh.

The specific cause of saltmarsh loss is little understood. A combination of factors including wave action, lack of sediment supply, dieback of vegetation, tidal currents and sea level rise are all thought to influence the erosion of the saltmarsh (NFDC, 2014). The use of historic resources such as these images may not provide the answer as to the specific causes of erosion, but can provide high resolution data on the rate and scale of erosion since at least the 1950's. Combining this with historical maps, charts and archaeological/palaeoenvironmental data will provide a long term perspective on the rate and scale of change to help with management in the future.

Maps and Charts

The loss of saltmarsh around Lymington discussed above can be further understood through the analysis of historic maps. The highest scoring maps from the western Solent area were georeferenced and the limit of the saltmarsh digitised. This allowed us to see the rate of change from 1781 to the present day (Figure 3D.94).

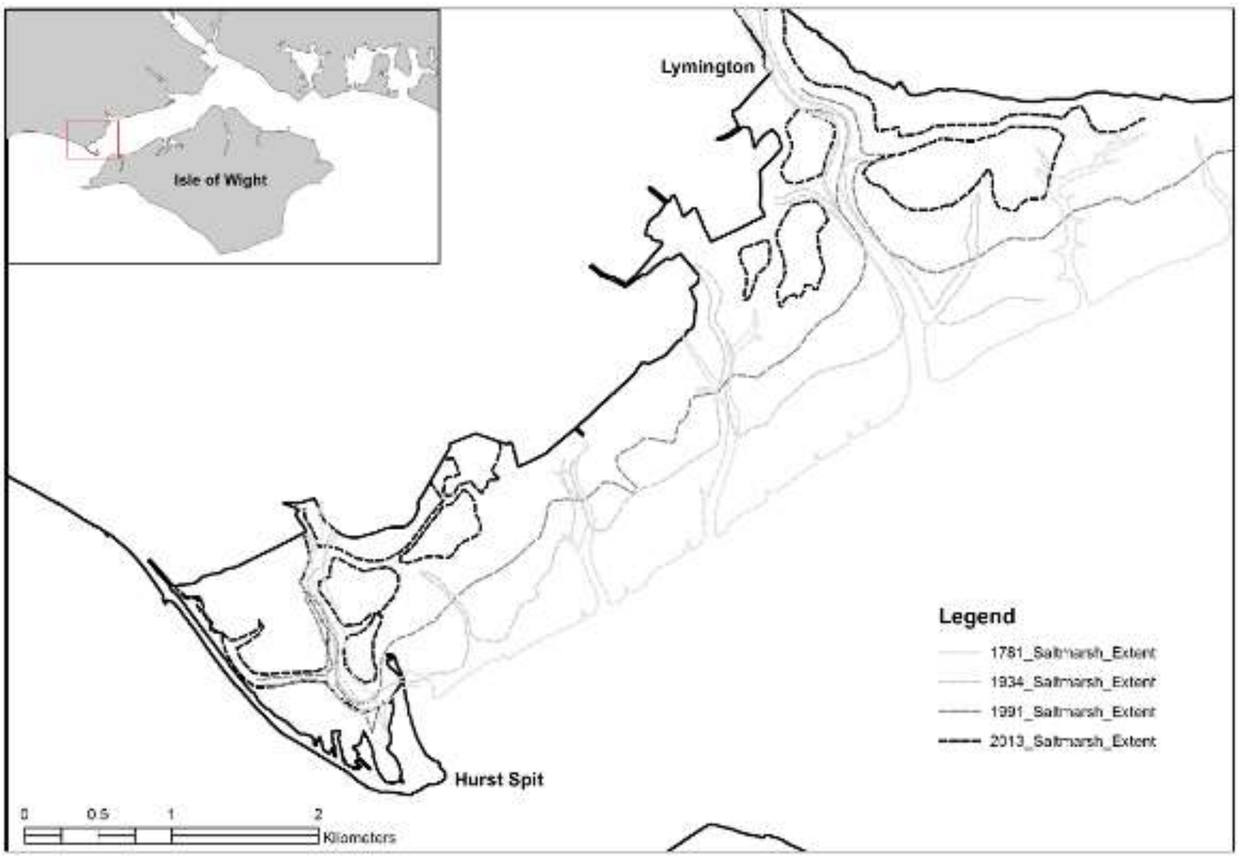


Figure 3D.94 : Saltmarsh and mudflat regression from 1781, 1934, 1991 and 2013 based on the analysis of historic maps.

This analysis has helped us to understand the rate of change in this area. Over a period of 153 years from the date of the first map (1781) to the second map (1934), the area witnesses around 500m regression of the saltmarsh. Over the next 57 years this is between 200-400m, then dramatically in just 22 years the saltmarsh erodes by up to 500m in places. The rate of erosion has dramatically increased in the last 100 years. As mentioned above the specific cause of saltmarsh regression is little understood and these maps cannot provide an answer, but they can provide high resolution detail on the rate and scale of change from the 18th century.

3D.7.3 Combined Resources

The issues of saltmarsh and mudflat regression in the north west Solent are detailed above. Data from archaeological diver survey, seabed monitoring points, maps, charts, art and marine geophysical survey have been utilised to map changes in this area. Understanding the underlying formation processes in the Solent can help resolve the patterns of change. In turn, this could help anticipate the cumulative effects of future coastal intervention.

By its very nature and position, Hurst Spit holds a key position in the natural protection of the coast of the western Solent. The shoreline habitats to its east are clearly dependent upon its survival and on the nature of its configuration. Despite these dependencies, far too little is known of the evolution of the spit and its eastward migration. Little is also known of the sediment history of the coastal wetlands that the spit may, or may not, continue to protect. A principal historic building on the spit offers some prospect of observing recent changes in sea level or water-level in later historic times and the analysis of historic photographs, maps and charts outlined above demonstrates these more recent changes.

It is in the sediment archives that the highest potential may be found at this location. Some of these lie in the cusp of the spit where there is an opportunity to gain firm knowledge of the long-term agenda of spit-formation and coastal behaviour that is shaping this vulnerable coastline. Through the project it was possible to recover some samples from the spit for environmental analysis. The results of this analysis and dating, outlined in Section 3D.4.1.5 above demonstrate how new data is constantly transforming understanding of the movement of the spit and its relationship to long-term geomorphological processes from the formation of the Solent.

The 3D model of Langstone Harbour was primarily created using archaeological and palaeoenvironmental data as detailed above, this covered the Mesolithic to the Saxon period. However, in order to reconstruct the post-medieval landscape several high ranking historic maps and charts were used. This has allowed us to create a model covering a period of over 8,000 years, demonstrating how the harbour has changed (Figure 3D.95). Similarly in Belgium, the Scheldt polders have been mapped using a combination of archaeological and palaeoenvironmental data for prehistoric periods and historic maps and charts for the post-medieval period (see case study report 3M).

Figure 3D.95 Left: reconstruction of the post-medieval landscape prior to the reclamation of Farlington marshes in 1771. This has been based on high ranking historic maps such as the one presented above right by Milne and can be compared with the present day (bottom right), aerial image courtesy of the CCO.

3D.8 Conclusions and Recommendations

The western Solent archaeological study area provides evidence of how the Solent formed, these processes which formed the Solent continue to affect the area with continuing erosion deepening and widening the seaway. Evidence from the archaeological and palaeoenvironmental studies of the submerged landscapes can reveal past environmental changes and human responses to this, which in turn can be compared with the events being witnessed today and improve our understanding of how this coastline evolved. Through a better understanding of how the Solent became what it is today coastal managers will be better placed in planning for the future.

The huge dataset available from the western Solent, particularly the sequence of deposits analysed at Bouldnor Cliff should now be used to create a 4D evolution model of the area. This will provide a visual tool for coastal managers to see the rate and scale of change in this region and to emphasise that the area is continuing to change and we will need to adapt. Combining the archaeological and palaeoenvironmental data with artistic resources, including historic maps, charts, photographs and artworks will allow us to understand change from prehistory up to the present day. Artistic resources have been valuable tools in understanding the rate of saltmarsh loss in the north west Solent, the recent changes to Hurst Spit and erosion affecting the soft cliffs around the west coast of the Isle of Wight.

It has been possible to use all of these resources to create an evolution model of Langstone Harbour, this should now be used in future shoreline management plans and provides a clearer understanding of how the harbour became what it is today which can in turn help better understand how it may change in the future. These resources can support the development of sustainable policies for adapting to future coastal climate change.

The art case studies demonstrate the value of examining a sequence of artworks over time by different artists in terms of providing a record of long-term coastal change. They allow detail and accuracy to be compared across artists and artworks to improve confidence in the reliability of the depictions in addition to the value of the information they impart.

The Solent and Isle of Wight coastlines were one of the most painted regions of the British Isles. The opportunity exists, therefore, to apply the Arch-Manche approach along most of this extensive coastal frontage.

In many locations around the Southern North Sea - Channel coastline monitoring has taken place for less than twenty years. The case studies help explain the rate of change over past centuries as a result of erosion or sea level rise. This can supplement existing and future monitoring of trends and can support predictions for the future.

The Ventnor case study provides an example of a geomorphological feature depicted in an artwork that does not exist today and which provided an important clue to the interpretation of the history of landsliding at that location.

Recommendations

The results of the case study and density of the archaeological, historical and artistic resources for this region make it a key area for demonstrating the Arch-Manche approach. Following the project the following recommendations are put forward:

- All studies relating to coastal and shoreline management should take full account of the archaeological, palaeoenvironmental, art and other historical resources available to improve understanding of coastal evolution and trends.
- Where ranking has indicated archaeological and palaeoenvironmental sites have the potential to reveal important data on coastal change then field studies should be undertaken.
- Potential impacts on important archaeological and palaeoenvironmental sites through either natural or humanly induced risks should take into account the potential loss of data on coastal change.
- Where artworks are sufficiently detailed and have been ranked highly it may be possible to make qualitative comparisons of change against present day views.
- Early artworks of sufficient accuracy can improve understand of coastal geomorphology by showing the landscape prior to extensive seaside development taking place.

Figure 3D.96. The Old Battery on the Needles, Isle of Wight. This heritage feature is now being destroyed by erosion, resources including archaeology, art, historic photographs and maps can all help improve our understanding of the rate and scale of past change to help plan for the future.

3D.9 Case Study References

Allen, L C, & Gibbard, P L, 1993 Pleistocene evolution of the Solent River of Southern England, Quaternary Science Reviews, 12, 503-528

Allen, M J & Gardiner, J (eds), 2000 Our changing coast:a survey of Langstone Harbour, Hampshire, CBA Res Rep 124. York: Council for British Archaeology

Alley, R B, Meese, D A, Shuman, C A, Gow, A J, Taylor, K C, Grootes, P M, White, J W C, Ram, M, Waddington, E D, Mayewski, P A, and Zieginski, G A, 1993 Abrupt increase in Greenland snow accumulation at the end of the Younger Dryas event. Nature 362, 527-529

Alley R B, 2000 The Younger Dryas cold interval as viewed from central Greenland, Quaternary Science Reviews, 19, 212-26

Anderson, F W, 1933 The new dock excavations, Southampton, Papers and Proceedings of the Hampshire Field Club 12,169-176

Andersen, S T, 1970 The relative pollen productivity and pollen representation of north European trees and correction factors for tree pollen spectra. Danmarks Geologiske Undersogelse R.II. 96, 1-99

Andersen, S T, 1973 The differential pollen productivity of trees and its significance for the interpretation of a pollen diagram from a forested region, 109-115, in Birks, H.J.B West, R.G. Quaternary Plant Ecology. Blackwell, Oxford.

Archibald, E. H. H., 1980. 'Dictionary of Sea Painters'. Antique Collectors Club. Woodbridge, Suffolk.

Baily, B and Pearson, A. (2007) Change detection mapping and analysis of saltmarsh areas of Central Southern England from Hurst Castle Spit to Pagham Harbour.

Bates, MR, 2001 The meeting of the waters: raised beaches and river gravels of the Sussex Coastal Plain/Hampshire Basin, in Wenben-Smith, F F, & Hosfield, R T (eds), Paleolithic Archaeology of the Solent River, Lithic Studies Occasional paper No 7, 27-45

Bradbury, A.P., Colenutt, A.J., Cross, J., Eastick, C. and Hume, D. (2003). Evaluation of coastal process impacts arising from nearshore aggregate dredging for beach recharge - Shingles Bank, Christchurch Bay. In International Conference on Coastal Management 2003, R. G. McInnes (ed.), pp. 98-112. London.

Brampton, A. H., Evans, C. D. R and Velegrakis, A. F., 1998. Seabed Sediment Mobility Study - West of the Isle of Wight. Project Report No 65. London: CIRIA.

Brannon, A., c.1860. 'A Voyage Around the Isle of Wight – Being an Indispensable Handbook to every Stranger'. Wootton, IW.

Brannon, G., 1841. 'Graphic Delineations of the most Prominent Objects in the Isle of Wight'. Wootton, IW.

Brannon, G., 1850a. 'A Picture of the Isle of Wight'. Wootton, IW.

Brannon, G., 1850b. 'The Pleasure Visitors' Companion in making a Tour of the Isle of Wight'. Wootton, IW.

Brannon, G. & A., 1821-1876. 'Vectis Scenery'. Private Press. Wootton, IW.

Bridgland, D R,& D'Olier, B, 2001 The Pleistocene evoloution and Paaeolithic occupation of the Solent River, in Wenben-Smith, F F, & Hosfield, R T (eds), Paleolithic Archaeology of the Solent River, Lithic Studies Occasional paper No 7, 15-25

Brown, R.C., Gilbertson, D.D., Green, C.P. and Keen, D.H. 1975. Stratigraphy and environmental significance of Pleistocene deposits at Stone, Hamphire.*Proceedings of the Geologists' Association, London,* 86, (3) 349-363

Bruce, P., 2008. Solent and Island Tidal Streams. Lymington: Boldre Marine.

Bullar, J., 1819. 'A Companion in a Tour of Southampton'.

Calvert, F., 1846. 'The Isle of Wight Illustrated'. London.

Case, C., 2009a. Isle of Wight. Annual Report 2007. Southeast Strategic Regional Coastal Monitoring Programme. Channel Coastal Observatory.

Case, C., 2009b. Isle of Wight. Annual Report 2009. Southeast Strategic Regional Coastal Monitoring Programme. Channel Coastal Observatory.

Cooke, W. B., 1808. 'A New Picture of the Isle of Wight'. Private Press. London.

Cope, S N, Bradbury, A P, and Gorczynzka, M, 2008 Solent Dynamic Coast Project: Summary report, Available: http://www.channelcoast.org/reports/ Accessed:12 August 2008

Crocombe, A., 2008. Isle of Wight. Annual Report 2004. Southeast Strategic Regional Coastal Monitoring Programme. Channel Coastal Observatory.

Daniell, R. & Ayton, R., 1814. 'A Voyage Round Great Britain'. Longman & Co. London.

Dean, J M, 1995 Holocene paleo-environmental reconstruction for the nearshore Newton area, Isle of Wight, Unpubl BSc Thesis, University of Southampton.

Devoy, R J, 1982 Analysis of the geological evidence for Holocene sea-level movements in southeast England, Proceeding of the Geologist Association 93, 65-90.

Dix, J, 2000 A geological and geophysical investigation of the submerged cliff at Bouldnor, in McInnes, R & Jakeways, J, (eds), Coastal change, climate and instability, final technical report, LIFE 97 ENV/UK/000510, European Commission, L'instrument foncier pour l'environnement. 2, 5-13

Dix, J K, 2001 The geology of the Solent river system in F. F. Wenban-Smith & R T Hosfield (eds) Palaeolithic archaeology of the Solent River, Lithic Studies Society, Occ. paper. No 7, British Museum. Quaternary Section, London, 7-14

Draper, J C, 1968, Mesolithic distributions in SE Hampshire. Proc. Hampshire Field Club & Archaeological Society 23, 110-119

Drummond, M, and McInnes, R. 2001. The Book of the Solent. Chale, Isle of Wight: Cross Publishing.

Dyer, K R,1969 Some aspects of coastal and estuarine sedimentation. PhD thesis, Department of Oceanography, Southampton University.

Dyer K R, 1975 The buried channels of the 'Solent River' Southern England, Proceedings of Geological Association of London, 86(23), 9-246.

East Solent Coastal Partnership., 2013. 'Southsea and North Portsea Island Coastal Flood and Erosion Risk Management Schemes – Scoping Report'. Portsmouth City Council.

Ellis, A (Ed.). 2004. 'Catalogues of Oil Paintings in Public Collections in Southampton, Hampshire and the Isle of Wight'. 2 Vols. The Public Catalogues Foundation.

Englefield, Sir H., 1816. 'The Isle of Wight – A Description of its Scenery, Antiquities and Geological Phenomena'. Private Press. London.

Environment Agency, 2010. 'Fact Sheet – An Environmental Summary of Portsmouth'.

Everard, C. E. 1954 The Solent River: a Geomorphological Study, Transactions of the Institute of British Geographers 20: 41-58.

Fox, W E, 1862 How and when was the Isle of Wight separated from the mainland? Geologist 5, 452

Fulford, M, Champion, T, & Long, A, 1997 Englands's coastal heritage; a survey for English Heritage and the RCHME. EH/RCHME, London.

Galloway, J. 2009, Storm flooding, coastal defence and land-use around the Thames Estuary and tidal river c.1250-1450'. Journal of Medieval History Volume 35, Issue 2, June 2009, Pages 171-188

Gilpin, W., 1804. 'Observations on the Coasts of Hampshire'. London.

Graves, A., 1901. 'A Dictionary of Artists who have Exhibited Works in the Principal London Exhibitions from 1760-1893'. Kingsmead Press. Bath.

Grove, R. A., 1832. 'Views of the Principal Seats and Marine and Landscape Scenery in the Vicinity of Lymington'. Private Press.

Hack, B, 1999 More stone tools from Rainbow Bar, Hillhead, Proc. Hants Field Club & Archaeological Society 54, 163-171

Hampshire County Council. 2014. Lymington-Keyhaven Nature Reserve. Available from: http://www3.hants.gov.uk/countryside/lymington-keyhaven.htm [Accessed April 2014].

Harlow, D. A., 1980. Sediment Processes, Selsey Bill to Portsmouth. Unpublished PhD thesis, Department of Civil Engineering, University of Southampton.

Hodson F, & West I M, 1972 Holocene Deposits of Fawley, Hampshire, and the Development of Southampton Water Proceedings of Geological Association, 83, 421-442

HWTMA, 2002/2003 A Year in Depth. The Annual Report of Hampshire and Wight Trust for Maritime Archaeology.

Isle of Wight Council, 2010. 'Isle of Wight Shoreline Management Plan Round Two. Centre for the Coastal Environment. Ventnor, IW.

Ke, X, & Collins, M, 2002 Saltmarshes in the West Solent (southern England): their morphodynamics and evolution, in T Healy, Y Wang & JA Healy (eds), Muddy Coasts of the World: Processes, Deposits and Function, Elsevier Science BV, 411-440

King, R., 1845. 'A Handbook of Lymington and the New Forest'.

King, A. & Soffe, G. 1994 'The Iron Age and Roman temple on Hayling Island' In A P Fitzpatrick & E L Morris (eds) The Iron Age in Wessex: Recent Work. Salisbury: Wessex Archaeology, 114 -16.

Lambourne, L. & Hamilton, J., 1980. 'British Watercolours in the Victoria and Albert Museum'. Crown Copyright. London.

Langstone Harbour Board, 2009. Langstone Harbour Management Plan Environmental Revisions.

Lee, E. M. & Moore, R., 2007. 'Ventnor Undercliff Development of Landslide Scenarios and Quantitative Risk Assessment'. Proceedings of the International Conference on Landslides and Climate Change, Ventnor, Isle of Wight, p.323-333.

Loader, R, 2007 *Isle of Wight: Upper Palaeolithic and Mesolithic Resource Assessment*. Contributory section for the Solent – Thames Regional Research Framework. http://www.buckscc.gov.uk/bcc/content/index.jsp?contentid=-1701835648

Long, A J, & Scaife, R G, 1996 Pleistocene and Holocene Evolution of Southampton Water and its tributarie,. Report of Environmental Research Centre, Department of Geography, University of Durham.

Long, A J, & Tooley, M J, 1995 Holocene sea-level and crustal movements in Hampshire and Southeast England, United Kingdom, Journal of Coastal Research Special Issue No.17, 299-310.

Lugar, R., 1828. 'Villa Architecture'. London.

MacKenzie, I., 1987. 'British Prints'. Antique Collectors Club. Woodbridge, Suffolk.

Mallalieu, H. L., 1984. 'The Dictionary of British Watercolour Artists up to 1920'. Antique Collectors Club. Woodbridge, Suffolk.

McInnes, R. G., 1989. 'The Isle of Wight Illustrated'. Cross Publishing. Chale, IW.

McInnes, R. G., 1993. 'A Picturesque Tour of the Isle of Wight'. Cross Publishing. Chale, IW.

McInnes, R. G., 1999. 'The Garden Isle – Landscape Paintings of the IW'. Cross Publishing. Chale, IW.

McInnes, R. G., 2004. 'Fifty years along the Undercliff'. Cross Publishing. Chale, IW.

McInnes, R. G., 2008a. 'Art as a Tool in Support of the Understanding of Coastal Change in Hampshire and the Isle of Wight'. The Crown Estate-Caird Fellowship 2008. Crown Copyright.

McInnes, R. G. 2008b., 'A Romantic and Picturesque Tour of the Isle of Wight'. Cross Publishing.

Melville, R.V. and Freshney, E.C. ,1982, British Regional Geology: The Hampshire Basin and adjoining areas, 4th ed., Institute of Geological Services, HMSO.

Momber, G., 2000. Drowned and Deserted: A submerged prehistoric landscape in the Solent, England. The International Journal of Nautical Archaeology, 29.1: 86-99

Momber, G, 2004 The inundated landscapes of the western Solen in N. Flemming (ed). Submarine Prehistoric Archaeology of the North Sea. The inundated landscapes of the Western Solent. CBA Research Report 141. 37-42

Momber, G & Geen, M, 2000 The application of the Submetrix ESIS 100 Swath Bathymetry system to the management of underwater sites, Int J Naut Archaeol, 29(1), 154-62

Momber, G., Tomalin, D., Scaife, R., Satchell, J. and Gillespie 2011 Bouldnor Cliff and the Submerged Mesolithic Landscape of the Solent. York: CBA Monograph Series 164.

Momber, G. 2011a. Changing landscapes fit for human occupation. In Momber, G., Tomalin, D., Scaife, R. Satchell, J. & Gillespie, J. (eds), 2011. Mesolithic occupation at Bouldnor Cliff and the submerged prehistoric landscapes of the Solent. Council for British Archaeology (York): pp123-125.

Momber, G., 2011b Submerged landscape excavations in the Solent, southern Britain: climate change and cultural development. In: Benjamin, J., Bonsall, C., Pickard, C & Fischer, A. (eds): Submerged Prehistory. Oxbow Books (Oxford): 85-98.

Moore, PD & Webb, JA, 1978. An Illustrated Guide to Pollen Analysis. London: Hodder & Stoughton

Moore PD, Webb, JA & Collinson, ME, 1991 Pollen Analysis, 2nd edn. Oxford: Blackwell Scientific

Moore, R., Carey, J. M. & McInnes, R. G., 2010. 'Landslide Behaviour and Climate Change: Predictable Consequences for the Ventnor Undercliff, Isle of Wight'. Quarterly Journal of Engineering Geology and Hydrogeology; Vol. 43, pp. 447-460.

Mottershed, D., 1976 The Quaternary history of the Portsmouth region. In Portsmouth Geographical Essays, Vol 2, 1-21

Mudie, R., 1840. 'Observations on the Coasts of Hampshire'. London.

Munt, M. & Burke, A. 1987. The Pleistocene geology and faunas at Newtown, Isle of Wight.*Proceedings of the Isle of Wight Natural History and Archaeological Society*, **8**: 7-14

New Forest District Coastal Group. 2007. Summary Notes of NFDC Coastal Group's research relating to Lymington saltmarshes. Available from:
http://www.rlymyc.org.uk/Harbour/documents/saltmarsh%20loss%20summary%20for%20RLYC.pdf
[Accessed April 2014].

NFDC, 2014. Saltmarsh Erosion. New Forest District Council http://www.newforest.gov.uk/index.cfm?articleid=7182

Nichols, R J, & Clarke, M J, 1986 Flandrian peat deposits at Hurst Castle Spit'. Proc. Hants. Field Club and Arch. Soc. 83, 421-441.

Nowell, D A G, 1995 Faults in the Purbeck-Isle of Wight Monocline, Proceedings of the Geologists Association, 106, 145-150

Pastscape 2007: Fort James:
http://www.pastscape.org.uk/hob.aspx?hob_id=238752&search=all&criteria=fort

Pennant, T., 1801. 'Journey from London to the Isle of Wight'. London.

Raye, C., 1825. 'A Picturesque Tour of the Isle of Wight'. London.

Rock & Co. c.1865. 'Views of Ventnor and Neighbourhood'.

Rowe, G., 1826. 'Views of the Isle of Wight'.

Russell, R., 1979. 'Guide to British Topographical Prints'. David and Charles. Newton Abbot.

Scaife, R G, 1980 Late-Devensian and Flandrian palaeoecological studies in the Isle of Wight. Unpubl. PhD thesis. University of London, King's College.

Scaife, R G, 2000a Palaeo-environmental investigations of the submerged sediment archives in the West Solent at Bouldnor and Yarmouth, Chapter 4, 13-26 in Coastal Change, Climate and Instability. European Commission LIFE project. LIFE-97 ENV/UL/000510 (1997-2000). Isle of Wight Council.

Scaife, R., 2003 The Langstone Saxon Log Boat: A preliminary Pollen Analysis of the associated sediments. Unpublished Archive Report.

Scaife, R. G. 2011 Pollen Evidence for Vegetation Changes, in G. Momber et al. (eds.) Bouldnor Cliff and the Submerged Mesolithic Landscape of the Solent. . York: CBA Monograph Series 164.

SCOPAC. Standing Conference on Problems Associated with the Coast. www.scopac.org.uk

Taylor, K C, Mayewski P A, Alley, R B, Brook, E J, Gow, A J, Grootes, P M, Meese, D A, Saltzman, E S, Severinghaus, J P, Twickler, M S, White, J W C, Whitlow, S, Zielinski, G A, 1997 The Holocene-Younger Dryas Transition Recorded at Summit, Greenland, Science, 278, 5339, 825 – 827

Tomalin, D J, 2000a Palaeo-environmental investigations of submerged sediment archives in the West Solent study area at Bouldnor and Yarmouth, in R McInnes, D J Tomalin & J Jakeways (eds) Coastal change, climate and instability: final technical report vol 2, European Commission Life Project 97 ENV/UK000510. Ventor: Isle of Wight Centre for the Coastal Environment, 13-45

Tomalin, D, J, 2000b Geomorphological evolution of the Solent seaway and the severance of Wight: a review, in M. B. Collins & K. Ansell (eds) Solent Science: a review, Elsevier, Amsterdam, 9-19.

Tomalin, D, J, 2006, Coastal Villas, maritime villas; a perspective from Southern Britain. In Journal for Maritime Archaeology, vol 1, no 1, 29 – 84.

Tomalin, D, J, 2011 The assemblage of lithic artefacts from the Mesolithic occupation features on the sea floor at Bouldnor Cliff. in G. Momber et al. (eds.) Bouldnor Cliff and the Submerged Mesolithic Landscape of the Solent. . York: CBA Monograph Series 164.

Tomalin, D J, Loader, R D and Scaife, R G 2012 Coastal Archaeology in a Dynamic Environment: a Solent case study. Oxford BAR British Series 568, 292-294

Tomkins, C., 1796. 'Tour of the Isle of Wight'. London.

Trott, K. & Tomalin, D. J., 2003. The maritime role of the island of Vectis in the British pre-Roman Iron Age. In, International Journal of Nautical Archaeology 32.2: 158– 181.

Turley, R., 1975. 'Hampshire and Isle of Wight Bibliographies'. Barry Shurlock & Co (Publishers Limited). Winchester.

Turley, R., 1977. 'Hampshire and Isle of Wight Art'. University of Southampton Library. Southampton.

Velegrakis, A F, Dix,, J K & Collins, M B, 1999 Late Quaternary evolution of the upper reaches of the Solent river, Southern England, based upon marine geophysical evidence, J Geol Soc London 156, 73-87

Velegrakis, A, 2000 Geology, geomorphology and sediments of the Solent system in M B, Collins & K, Ansell, (eds), Solent Science: a review. Elsevier. Amsterdam, 21-34.

Wenban-Smith, F F, & Hosfield, R, (eds), 2001. Palaeolithic Archaeology of the Solent River, London, Lithic Studies Society, Occasional Papers, 7:112

Wessex Archaeology. 2010a. New Forest Rapid Coastal Zone Assessment, Phase 1: Desk Based Assessment. Ref: 72200.02.

Wessex Archaeology. 2010b. New Forest Rapid Coastal Zone Assessment Survey, Phase 3: Final Report. Ref: 72201.02.

West I M, 1980 Geology of the Solent Estuarine System In: The Solent Estuarine System: An assessment of the present Knowledge. NERC Publications, Series C, No 22, 6-19.

West, I M, 2008 Hurst spit Barrier Beach of the West Solent Hampshire: Geology of the Wessex Coast. Available: http://www.soton.ac.uk//~imw/Hurst-Castle-Spit.html

Westall, W., 1842. 'Carisbrooke Castle and its Environs'. Private Press.

Whitcombe, L. J., 1995. Sediment Transport Processes, with Particular Reference to Hayling Island. Unpublished PhD thesis, Department of Oceanography, University of Southampton.

Whitewright, J., 2011. Monitoring the Flower of Ugie. In The Archaeology and History of the Flower of Ugie, wrecked 1852 in the Eastern Solent, J. Whitewright and J. Satchell (eds), pp. 79-84. Hampshire and Wight Trust for Maritime Archaeology Monograph Series 1, Oxford: British Archaeological Reports, British Series 551.

Wood, C., 1978. 'The Dictionary of Victorian Painters (2nd Edition)'. Antique Collectors Club, Woodbridge, Suffolk.

Woodward, B. B., Wilks, T. C. & Lockhart, C., Not dated. 'The History of Hampshire'. London.

Woollard, D., c.1915. 'Pencil Sketches of the Isle of Wight'. A. & C. Black, London.

Worsley, Sir R., 1781. 'History of the Isle of Wight'. London.

Wymer, J, 1991 Mesolithic Britain, Princes Risborough: Shire Publications

Wyndham, H. P., 1793. 'A Picture of the Isle of Wight'. London.

CASE STUDY 3E - WEST DORSET AND EAST DEVON

Case study area: West Dorset and East Devon, UK.

Main geomorphological types: Harder and soft clifflines, shingle and sandy beaches

Main coastal change processes: Coastal erosion, landsliding, beach change, sea flooding

Primary resources used: Art.

Summary: The study area coastline comprises high cliffs of Jurassic and Cretaceous age, which include extensive landslides. These cliffs back beaches of pebbles, shingle and sand. Where rivers flow towards the sea through valleys such as at West Bay there have been historical flooding problems.

Recommendations: Analysis of artistic depictions has demonstrated areas of the coast where active landslips have taken place, in addition to showing where there has been little change over time. Further review of artistic images in conjunction with archaeological and historic sites would provide more detail of past change to coastal managers.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

West Dorset and East Devon is one of six UK case study areas for the Arch-Manche project. This section introduces the study area and why it was chosen as part of the project, and then presents the results of the art study. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. For further details about the project and the methodology see Section 2.

Within the study area the available art resource has been researched, ranked and analysed. The extents of the detailed study areas are shown in Figure 3E1 below.

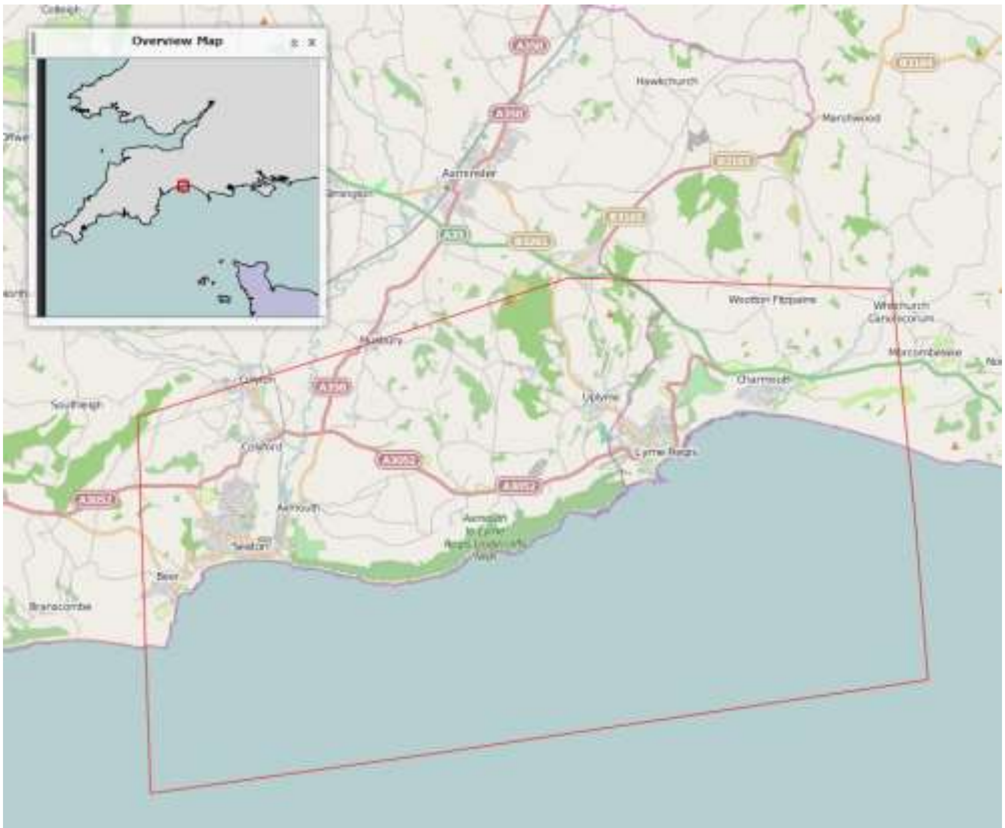


Figure 3E1: Map of the West Dorset and East Devon case study area

3E.1 Introduction to the Study Area

The West Dorset and East Devon case study area extends from the coastal resort of West Bay near Bridport in Dorset westwards via Charmouth to the town of Lyme Regis; it then continues westwards as far as the village of Beer in East Devon; in total a coastal frontage length of 16 miles (25km). The site forms part of the Dorset and East Devon Coast World Heritage Site known as the *Jurassic Coast*. This part of the coastline of the west of England has provided inspiration for numerous artists over the last 200 years, and the popularity of these counties for tourism on account of the dramatic coastal scenery has ensured that there is a rich resource of landscape paintings, drawings and prints, as well as illustrated literature accounts, to support this study.

3E.1.1 Geology and Geomorphology

This case study area considers two coastal frontages to the east and west of Lyme Regis. The eastern study site is West Bay near Bridport where a small harbour was constructed in 1722 at the mouth of the River Britt. On either side of the village the cliffs rise up steeply and are composed of vertical cliffs of the Bridport Sands of Jurassic age, which rise in height to over 45m. The river valley runs through an alluvium flood plain and across the beach to the sea. The construction of the two parallel harbour arms allowed access to the sea but has interrupted sediment transport along the coast. This has led to increased erosion on the western cliffs and necessitated artificial beach nourishment in the past. Major improvements to flood and coastal defences were completed in 2009.

The western section of the East Devon - Dorset World Heritage Site coast provides an outstanding combination of significant geological and geomorphological features. At the western end of the frontage, the Chalk and Upper Greensand strata form the cliffs at the village of Beer, whilst, to the east of the River Axe, which enters the English Channel at Axmouth, the cliffs are composed of mudstones overlain by the Upper Greensand and Chalk, with a capping of recent Plateau Gravels. These sequences continue in the cliffs until, approaching Lyme Regis, the Blue Lias Clay of the Jurassic period start to appear in the lower part of the cliffline.

Figure 3E2: A view looking eastwards along the Lyme Regis Dorset frontage. To the east of the town is the landslide complex of Black Ven. Further east is the village of Charmouth whilst the eastern end of the study site is at West Bay (out of photograph). Photograph courtesy of Wightlight Gallery.

The Blue Lias forms the dramatic cliffs to the west of the town of Lyme Regis, with parts of the exposure being obscured by the extensive landslip systems at Bindon and Downlands, which were dramatically depicted in the nineteenth century lithographs by Dawson, Conybeare and Buckland (Conybeare and Buckland, 1840). To the west of Lyme Regis, which occupies the banks of the River Lyn and the adjacent hillsides, lies Black Ven, which forms one of the largest coastal landslide systems in Great Britain. The cliffs are composed of Jurassic Black Ven Marls and are capped by the Gault Clay and Upper Greensand. At this point the cliffs reach a height of approximately 134m. To the east the River Char, at the village of Charmouth, marks the eastern boundary of this part of the study area.

The rocks on this part of the Devon and Dorset coast were folded and faulted during the earth movements that formed the Alps and the Himalayas some 20 million years ago, known as the Alpine Orogeny. These earth movements led to formation of geological structures, such as the Weymouth and Purbeck Anticlines to the east, and the dramatic series of ridges and valleys to be found in South Dorset. The area was not directly impacted upon by the repeated advances and retreats of the great ice sheets of the Ice Age during the last two million years, however, the Arctic tundra climate, which prevailed during glacial periods, was instrumental in the formation of the chalk downs.

The lower Jurassic Lias cliffs between Lyme Regis and Charmouth are particularly important on account of the well-preserved specimens of marine reptiles that have been found since the eighteenth century. These continued finds, as cliff erosion exposes fresh rock, highlight the historical significance of the area for the study of palaeontology.

The landslides along the coastal cliffs of this part of Dorset are a relatively frequent occurrence and are linked to both the underlying geology, coastal processes and the meteorological conditions. In West Dorset, the lower part of the cliff sections are composed of Jurassic clays and limestones, whilst the top of the cliffs at Black Ven, Stone Barrow and Golden Cap are capped by Upper Greensand of Cretaceous age. Rainwater percolates through the sands of the Upper Greensand until it reaches the clay. Water builds up at this level and seeps out through the cliffline along a spring line. During periods of prolonged rainfall the water levels lubricate the clay surface and increase the mass of the cliff top sediments, causing the Greensand to slide over the clay, across the undercliff below, and onto the beach.

3E.1.2 Environmental Impacts and Coastal Management Approach

The coastline between West Bay and Lyme Regis, and extending on westwards along the South Devon coast, forms one of the most spectacular coastal landslide complexes in Europe and lies within the World Heritage Site, celebrated for its unique geology and natural environment. These clifflines are subject to large-scale potentially catastrophic landslides, which may pose a significant risk to cliff top assets and to public access along the beach and the clifftops themselves. The cliffs form a valuable case study in relation to issues surrounding coastal erosion and landslides, the protection of built assets and safe public access. Development has taken place close to the clifftop and on a landslide complex at Lyme Regis. Although first protected in the nineteenth century, the coast was protected to a higher standard by stabilisation measures above the sea cliffs, comprising slope drainage and piling.

For much of the historical period, the land to the east of the town of Lyme Regis, known as the Spittles, has remained relatively stable. Historical rates of cliff retreat of the unprotected sea cliffs reach up to 0.7 of a metre a year and these rates were exacerbated as a result of the removal of limestone ledges from the foreshore in the past for local cement production. During the mid-1980s a major reactivation of the Spittles landslide complex commenced and has continued to this day, necessitating further studies and investigations, and in 2013/14 further coast protection and drainage measures.

Over time the cliff instability and erosion processes have resulted in the loss of farmland, three coastal roads and a number of properties. The whole frontage has been the subject of detailed study and investigation over many years and the frontage presents serious challenges looking ahead to the future in terms of managing coastal change and striking a balance between the protection of people and the built environment through sympathetic civil engineering schemes, which embrace and celebrate the natural landforms, geology and processes that attracted the World Heritage status.

Figure 3E3: East Cliff at Lyme Regis. Coast and cliff protection and drainage works are currently in progress in order to reduce risks for cliff top properties and assets. Photograph courtesy Halcrow CH2M HILL.

Key to the success of the shoreline and coastal strategy for the area has been the significant effort and investment by engineers to understand the geology, geomorphology, cliff behaviour, coastal processes and environment, whilst fully engaging with the local community in determining acceptable and sustainable policies and scheme concepts. Complex ground conditions require complex solutions combining both slope stabilisation and coast protection measures, and these are being developed successfully along this part of the frontage.

Coastal risk management issues along this part of the Devon-Dorset coast are overseen by the South Devon and Dorset Coastal Advisory Group, which was established in 2006 to oversee coastal risk management and the preparation of the Durlston Head to Rame Head Shoreline Management Plan, which amalgamates two earlier plans for frontages to the east and the west. This Coastal Advisory Group brings together ten local authorities covering a 308km length of coastline, with the aim of ensuring the development of a strategic approach for coastal risk management across the frontage.

3E.1.3 Description of the Coastal Art of the Study Area

The coastlines of South Devon and West Dorset, with their dramatic and varied physical environments, attracted numerous artists from the eighteenth to early twentieth centuries. The varied geological formations exposed in the coastal cliffs and unique landforms provided them with inspiration and many were drawn back to these shores time and time again.

During the early years of the eighteenth century, J. M. W. Turner painted numerous views in the west of England. For example, in c.1811 he painted *'Lyme Regis'*, which was taken from Charmouth to the east, looking along the coastline towards the town of Lyme. Between 1811 and 1814 Turner also produced several views along the Devon coastline.

In 1825 William Daniell completed several aquatint engravings of coastal scenes in Dorset and South Devon for inclusion in the latter part of his *'Voyage Round Great Britain'* (Daniell & Ayton, 1814); for example *'Bridport Harbour'* (now called West Bay), and *'Lyme Regis from Charmouth'*. At Bridport Daniell wrote *"it appeared in a deplorable state with the entrance being choked with sand"* (Daniell & Ayton, 1814). Later, the Finden Brothers' publication *'Ports, Harbours, Watering Places and Picturesque Scenery of Great Britain'* (Finden and Finden, 1838) also portrayed this dramatic coastline.

On the Dorset coast, in particular, the fascinating coastal scenery drew artists and gentry who were studying the emerging science of geology. They produced illustrations for fine publications as well as individual prints of the major landslide events that took place at Bindon and Downlands to the west of Lyme Regis (Conybeare & Buckland, 1840), as well as watercolour drawings and fine oil paintings. The prolific coastal artists Samuel Phillips Jackson and William Borrow also painted views of Lyme Regis.

Edward Francis Drew Pritchard (1809-1905) painted along the Dorset coastline, for example, *'East Cliff, with Portland, Dorset in the Distance*' and '*View towards Portland, Dorset'*, whilst Henry Joseph Moule (1825-1904) was a prolific local artist who *"constantly painted the landscape"* and his collection of works provides us with a *"unique record of the Victorian countryside"* (Dorset County Museum). A fellow Victorian artist, Frederick Whitehead (1853-1938), was a naturalist painter who captured the Dorset landscape and coastline with remarkable detail. Other artists who accurately depicted the coastal scenery in this area included William Callow (1812-1908), William Collins (1788-1847), Myles Birket Foster (1825-1899) and Thomas Girtin (1775-1802), who painted a watercolour of Lyme Regis.

The geologically rich coastline of Devon and Dorset also drew many followers of the Pre-Raphaelite Brotherhood in the mid-to-late nineteenth century. Artists such as John Brett

(1831-1902), John William Inchbold (1830-1888) and the topographical and marine artist Edward William Cooke (1811-1880) produced fine paintings and drawings of the coastline.

Cooke was drawn to paint the coastline of the south west of England in part due to a keen interest in geology. Cooke began his *"series of highly-finished pictures in oil to illustrate the chief geological features of the British coast"* (Munday, 1996) such as *'Beer Beach Number 4. Fishing Cove of Beer'* in the 1860s. Cooke was fascinated with the geology of the coastline and he sought to depict the rocks, shingle and cliffs in the most accurate way possible, a technique advanced by the famous Victorian art critic and writer, John Ruskin (1819-1900).

John Brett explored the Dorset coast during the summer of 1870, painting a large number of watercolours of locations including Swanage, Lulworth Cove, Lyme Bay, Charmouth and Lyme Regis. One of Great Britain's leading sea painters, Charles Napier Hemy (1841-1917), also painted the harbour of Lyme Regis, while the Pre-Raphaelite painter, Sir John E. Millais, painted *'The Boyhood of Raleigh'* (1870) in the nearby small resort of Budleigh Salterton.

The turn of the twentieth century and the increasing number of tourists visiting coastal locations in the south west led to a greater demand for illustrated books and colour picture postcards depicting local scenes. Two artists, Henry Wimbush (1858-1943) and Alfred Robert Quinton (1853-1934), were particularly prolific in their production of pretty watercolours for postcard publishers A. & C. Black, who produced colour plate regional guide books. Popular subjects by A. R. Quinton included Babbacombe, Beer, Budliegh Salterton, Sidmouth, Lyme Regis, Weston-super-Mare and St Michael's Mount.

The coast of the study area does, therefore, have a rich art heritage that can be interrogated to support the analysis of change over time.

3E.1.4 Art Resources Consulted for the Case Study Sites

In order to establish the art resource available for this study it was necessary to review the topographical paintings, drawings and prints held by the principal national, region and local collections covering the West Dorset and East Devon coastal frontage. To achieve this objective, online reviews were carried out of the collections held at the national level within key museums and art galleries including the Tate Britain, the Victoria and Albert Museum, the National Maritime Museum, the British Museum, the National Gallery and the Witt Library at the Courtauld Institute in London.

In addition it was necessary to establish if there were relevant artworks contained in museums and art galleries in Devon and Dorset including the Russell Cotes Museum in Bournemouth and the Dorchester and Lyme Regis Museums. As part of the research it was necessary to contact museum and gallery curators and search available publications, as well as undertaking research on the Internet, taking advantage of new facilities such as the Public Catalogue's Foundation volume (Ellis, 2004a & 2004b) and the BBC *Your Paintings* website (See Section 2.1.2.1 for further information on this resource). Research also made use of important publications and exhibition catalogues (also see Section 2.1.2.1 for more detail).

3E.2 Results of the Art Scoring

The development of the ranking system is described in Section 2. In order to rank the artworks a database was established into which data was entered for both archaeological/maritime heritage sites and for artworks. By entering the data on artwork type, medium, subject matter, time period and other parameters the database was then able to calculate the ranking scores for eighteen works of art from the West Dorset and East Devon case study site. The highest scoring artwork, a watercolour by Arthur W Perry of '*Beer Beach*' gained 70 points whilst two coastal lithographs of '*Axmouth Landslip'* and of *'Lyme*

Regis' each scored 66 points. The information imparted by these artworks and others is described in the study examples below. Further details on the ranked artworks are provided in Table 3E.1.

Artists tended to paint attractive or dramatic coastal locations as well as meeting specific demands of their patrons. On the Devon and Dorset coasts they were drawn to the expanding and fashionable coastal resort of Lyme Regis, the imposing sea cliffs and the activities of fishermen working along the shoreline at Beer and elsewhere.

The result has been that many of the sites of key geomorphological and coastal risk management interest have been painted by artists particularly during the nineteenth century. As the aspiration of this study is to illustrate how art can inform on long-term coastal change it is fortunate that within the higher scoring artworks there are examples, which include locations affected by coastal and beach change.

Figure 3E4. Location of artworks in the West Dorset and East Devon study area

These differing coastal landforms and processes and their impacts on coastal residents, assets and infrastructure could not have been easily matched to the most informative works of art without the provision of the ranking system. The system has identified two study locations along the beach frontage and, for each, several works are analysed as follows:

Study Ref	Location	Artist	Date	Score type	Score period	Score style	Score enviro	Total Score
E.1	Bridport Harbour (West Bay)	William Daniell	1825	Aqua-tint	Early	Topog.	Detailed View	55
E.2	Lyme Regis from Charmouth	William Daniell	1825	Aqua-tint	Early	Topog.	Detailed view	48
E.2	Lyme Regis	David Dunster	c.1840	Litho-graph	Mid.	Topog.	Very Detailed View	51
E.2	Landslip at Bindon near Axemouth	W. Dawson	1840	Litho-graph	Mid.	Topog.	Very Detailed View	66
E.2	Ruins at Lanslip	J. Dawson	1840	Litho-graph	mid.	Topog.	Very Detailed	66

	Axemouth						View	
E.2	The Landslip, Lyme Regis	Alfred Robert Quinton	1920	Water-colour	Late	Topog.	Detailed View	70
E.3	Beer Beach	Arthur W. Perry	c.1890	Water-colour	Late	Topog.	Detailed View	70
E.3	Beer Beach	Alfred Robert Quinton	1900	Water-colour	Late	Topog.	Detailed View	70
E.3	Fishing Cove of Beer	Edward William Cooke RA	1858	Oil	Mid.	Topog.	Very detailed view	62
E.3	Distant view of Beer Head	Edward William Cooke RA	1858	Oil	Mid.	Topog.	Very detailed view	62

Table 3E1 Art ranking results for West Dorset and East Devon

A more detailed interpretation of the individual artworks is provided in the study descriptions below. The assigning of scores to each artwork suggests names of those artists who have depicted different aspects of the West Dorset-East Devon Study Site coast most accurately across the timeline 1770-1920. These artists include William Daniell, William Dawson, Edward William Cooke, Arthur W. Perry and Alfred Robert Quinton. They can be relied upon in terms of the accuracy of their depictions of this coastline.

3E.3 Discussion of the Art Scoring Results

The West Dorset and East Devon coastlines have seen pockets of development established in the bays and coves over the last two centuries; these have usually been based on fishing communities such as at Beer. Some of these communities, such as Lyme Regis, expanded rapidly during the Victorian and Edwardian seaside development periods. Over the last twenty years considerable efforts have been made to encourage improved coastal management in the west of England and this has led to the development of risk management plans for the coast in support of the principle of sustainable development. As part of this process, thorough consideration has been given by the South West Coastal Group (covering the extensive coastline from Portland Bill in Dorset to Hartland Point in North Devon) to natural hazards, and the resulting risks to people, property and the environment. Climate change is with us now and is going to exert an increasing influence on the lives of coastal residents over the next decades by affecting the severity of coastal erosion, flooding and landslide events.

The case study has assessed the value of various artworks in terms of informing us about beach change and cliff conditions through a combined approach of desk-based research, museum and gallery searches and field visits. These have confirmed the added value of art from the period 1770-1920 to support other coastal surveying and monitoring technologies (e.g. Space-borne, air-borne, ship-borne and terrestrial). It is important to remember that artists in the late Georgian and Victorian eras worked for very demanding, wealthy clients who often sought exact views of the coastal landscape to remind them of their visit. Before the days of photography precise images were, therefore, a prerequisite in most cases. The examination of the works of many artists painting the geologically fascinating East Devon and West Dorset coasts testify to their considerable artistic skills in capturing accurately the coastal topography.

The artworks examined illustrate the evolution of this coastline over time and help to explain the nature and rate of the geomorphological processes occurring there. This study focused on the use of historic paintings, however several historic maps, charts and photographs were also consulted to review the potential of these data sources. Because of the dynamic nature of this coastline historic photographs can be a valuable resource with many historic photos containing depictions of the cliff with recognisable heritage features nearby, including churches, wells and houses. These can be compared to the modern situation and from this an accurate idea of the rate of erosion since the date of the photograph can be gained.

3E.4 Art Field and Research Studies

Fieldwork within this case study area was undertaken in support of the art study. It was possible to establish, through the art ranking system that the images are likely to be true representations of the conditions that would be seen at the time they were painted. Fieldwork aimed to help answer the research questions through examination of the artworks at the case study sites. The key questions were:

- What information can the historical images provide to support understanding of long-term coastal change?
- How can the potential of this resource be used most effectively by the end-user?

In order to identify the most suitable artworks that could be studied in more detail at the field study sites a national search was undertaken involving an extensive review of landscape paintings, watercolours and prints held in public and some private collections. Following ranking of nineteen artworks twelve examples were the subject of more detailed analysis involving site visits.

Along this frontage there are a range of physical conditions to be found that are of concern for coastal managers including eroding cliffs and cliff instability problems to the east of the town, and issues surrounding the interruption of sedimentary transport processes at West Bay near Bridport. In order to reflect these varying conditions art images have been selected which examine these issues and which allow helpful comparison with the present day.

Where it has been practical to gain access and relevant to the study, present day photographs were taken in the field to try, as far as possible, to match the views painted by the eighteenth, nineteenth and early twentieth century artists. It also provided the opportunity to assess the conditions of the cliffline and beach and changes that may have taken place over time. In terms of work in this field each of the locations has been visited and photographed in varying weather conditions. Inspections were timed to coincide with Low Water and a walk-over survey was made along the beach and base of the cliff returning along the cliff top. This ensured that thorough comparison could be made between the geomorphological conditions depicted in the artwork and the present day situation.

The fieldwork element was largely visual in terms of identifying the location of the paintings and making judgements, on site, of the role that art can fulfil as a qualitative or quantitative tool to support coastal risk management. The field inspections allowed a more accurate appraisal to be made of current physical conditions rather than relying upon written accounts and reports particularly as storm events can cause significant alterations over relatively short time periods.

3E.5 Art Field Data Gathering Results

The West Dorset and East Devon case study was chosen to illustrate two geomorphological processes, namely beach conditions at a site where coastal development has interrupted natural coastal processes (Bridport), and eroding, unstable coastal cliff and slopes between Charmouth and Axmouth and at Beer. Site inspections have confirmed that the locations selected do provide a good representation of these coastal geomorphology types against which the value of historical artworks can be tested.

The approach adopted for each case study has been the examination of one particular artwork and to make an assessment of what it tells us about changes over time from field observation. However, for some of the study sites it has been found that several artists painted the view from the same or a similar spot. This helps us to establish a chronology of coastal change through the nineteenth and twentieth centuries. The results for each case study location are described below.

E.1 West Bay, Dorset

Location
Bridport is located at the eastern end of Lyme Bay, 15 miles (24km) to the west of Dorchester, and seven miles (10km) to the east of Lyme Regis. The town is located within the East Devon-Dorset Jurassic Coast World Heritage Site.

Why was the study site selected?
This site was selected to examine issues surrounding beach change on the open coast at West Bay (referred to as Bridport Harbour in early artworks). The harbour arms at West Bay extend across the wide beach and, as a result, have an impact on sediment transport along this part of the coastline. The processes are compared between the view portrayed by William Daniell in 1825 and the present day situation.

Geomorphological setting
The frontage lies within the internationally renowned Jurassic Coast World Heritage Site. At this location the River Brit runs out to the sea through a valley it has cut through the Bridport Sands, which are of Jurassic age. These sandstones form dramatic clifflines on either side of the small seaside resort of West Bay, which is located in the river valley.

Figure 3E5: 'Bridport Harbour' (West Bay) by William Daniell RA (1825).
Figure 3E5a (inset top) shows the present day view with the much more extensive beach on the east side of the twin harbour arms compared with the western beach. Image courtesy of Halcrow.

Key coastal risk management issues for the frontage
West Bay is situated at the western end of the shingle spit of Chesil Beach. The east beach at West Bay is designated as a Site of Special Scientific Interest, whilst West Dorset Jurassic

coast is England's first national World Heritage Site. Once a flourishing port, West Bay's fortunes declined after devastating floods occurred in 1824. The parallel historic piers and sea defences at West Bay have suffered major and sustained damage over the last 50 years, and were deemed to be in urgent need of repair to prevent flooding and protect properties from the sea. A major refurbishment of flood and coastal defences was completed in 2009.

Observations on the artwork

The aquatint engraving by William Daniell (1825) shows a view of *'Bridport Harbour'*, now known as West Bay, viewed from the hillside on the eastern side of the valley of the River Brit.

Since Daniell's view, the harbour has developed considerably for commercial, tourism and residential reasons. The engraving shows a ship passing through the two parallel harbour arms, which provide access through the beach to the harbour. The extent of the beach is well displayed in the early engraving and bears interesting comparison with the present day view.

How can the artworks inform coastal risk management?

A key consideration for coastal engineers is achieving an understanding of natural coastal processes such as longshore drift. Wherever possible it is highly desirable for the natural coastal systems to be maintained without interruption by structures such as harbour arms or other forms of coastal defences. However, at West Bay, the harbour arms were a necessity if access was to be achieved to the town and quayside, across the wide beach. Here there is a complex sediment transport mechanism (see Figure 3E.6 below). There is a dominant transport in Lyme Bay from west to east; however, at West Bay there is also significant transport just offshore in a westerly direction. This has led to a large accumulation on the eastern side of the harbour and a much reduced beach volume and erosion and cliff set-back by about 100m on the western side (Bray *et al*., 2004).

In the view by William Daniell (1825) the differences in cliffline and beach volume either side of the harbour arms appear much less marked. This probably relates to the repair, infilling and upgrading of the harbour, which only took place at about the time of Daniell's visit in the mid-1820s. Improvements to the harbour may have led to increased wave reflection and scour and it has been estimated that this could have reduced beach volumes by 0.5million M^3 since the mid-nineteenth century (Brunsden and Moore, 1999). The situation at West Bay has necessitated beach nourishment to reduce erosion and more recently the implementation of a Beach Management Plan. Certainly, his view seems to indicate a more extensive beach on the up drift side rather than the down drift, which is what might be expected.

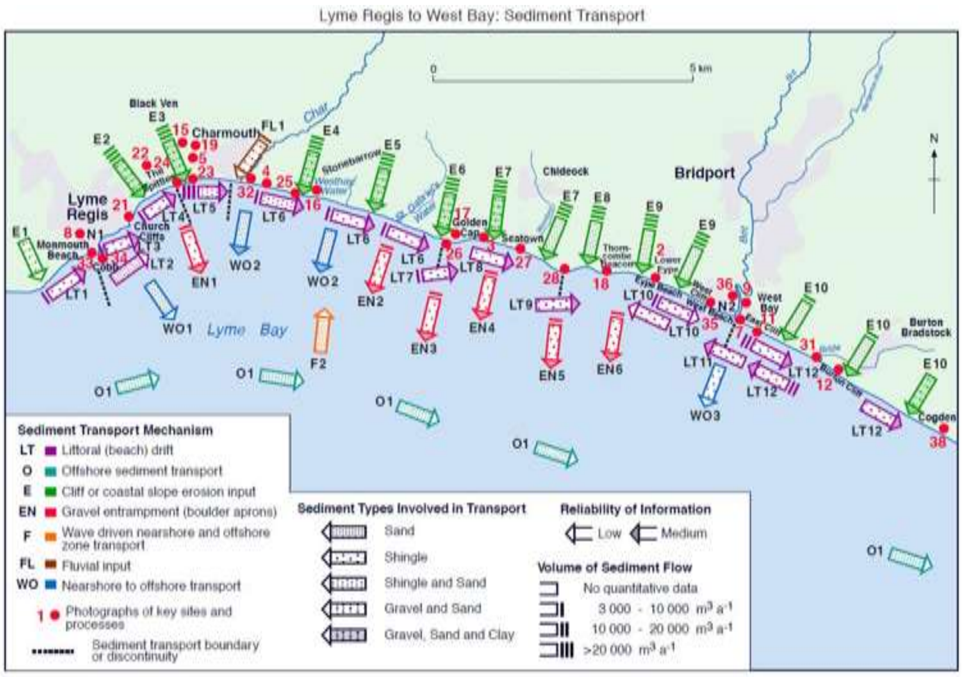


Figure 3E6: Sediment transport in Lyme Bay Dorset (SCOPAC: Bray et al., 2004).

A particular concern and interest to coastal engineers is the volume of beach material that may be available, looking ahead over the next century, from eroding cliffs which will help maintain beaches as a natural form of coastal defence. Rising sea levels may result in increased scour and loss of beach material, but equally, if rates of erosion increase, further material may be added to the coastal sediment budget as a result of cliff falls and coastal landslides. For these reasons, long-term coastal monitoring is essential, and this is being undertaken very effectively around the English coast under the auspices of the Channel Coast Observatory at the National Oceanography Centre, Southampton. However, for many parts of the coastline, monitoring is a relatively recent innovation (less than 20 years) so, if historical information can contribute to our understanding of coastal processes, it is to be welcomed and Daniell's views can support our understanding of the chronology of beach change in this area.

Where can the original artwork be viewed?

The view by William Daniell can be viewed easily on the Internet.

- **Ranking score achieved:** The Daniell view scored 55 points (see Table 3E.1).

E.2. Charmouth to Axmouth

Location

The study site includes the coastline from Charmouth to the east of the seaside resort of Lyme Regis extending westwards to the village of Axmouth.

Why was the study site selected?

The coastline is composed of rocks of the Jurassic period, which are subject to massive coastal land sliding. The study site was chosen to illustrate large-scale geomorphological change along the frontage over the last 200 years.

Geomorphological setting

The coastal topography is dominated by four flat-topped ridges rising to 200m, which have been truncated by coastal erosion. These ridges are cut by southern flowing rivers including the Lym at Lyme Regis, the Char at Charmouth and the Brit at West Bay. The coastline of

West Dorset and East Devon includes steeply terraced clifflines formed by coastal erosion and landsliding over the centuries. The natural coastal processes in operation maintain, a unique, diverse and distinctive landscape. Where development has taken place comprehensive coastal risk management measures have been implemented but along some frontages, such as at Black Ven, to the east of Lyme Regis, the scale of the processes are so great that intervention would be both impractical and undesirable.

Coastal erosion, the nature of the geology and ground water movements through the coastal cliffs and slopes has led to the formation of landsllde complexes, in which the backscar is separated from the beach by zones of degradation and material transport that can extend to several hundred metres in length; these have been the subject of detailed research (Brunsden & Chandler, 1996). The eroding and sliding cliffs contribute to the west to east moving sediment budget.

Key coastal risk management issues for the frontage

Coastal defences have been constructed in the past at both Charmouth and Axmouth and at Lyme Regis with further works at the eastern end of the town currently in progress. Elsewhere the frontage between the two locations is undefended on account of the limited assets that require protection and for environmental reasons. As a result, coastal erosion and landsliding have been allowed to continue uninterrupted. Apart from the coastal risk management at Lyme Regis the main coastal risk management issue is for users of the coastline along the cliff top and the cliff base in terms of public safety.

Observations on the artworks

Daniell's view (Figure 3E.7) is taken from the western side of the beach at Charmouth at high water, looking along the coastline, past the Black Ven landslide complex towards Lyme Regis. In his view, the cliffline in the middle distance appeare exposed (rather than vegetated), although there is no obvious evidence of cliff failure. He does, however, depict the lower part of the cliff in the middle distance in a darker colour, perhaps indicating the Blue Lias strata. The hillside beyond shows scattered development with the town of Lyme Regis round the headland. The image shows no obvious signs of instability and although Daniell refers to the fact that '*the cliffs in the neighbourhood contain peculiar attractions for the geologist'* (Daniell and Ayton, 1814) he does not mention cliff or slope instability. This suggests that perhaps the landslides were activated or reactivated during the nineteenth century as a result of changing climatic conditions, sea level rise and human activity.

Figure 3E7: 'Lyme Regis from Charmouth' by William Daniell RA; 1825. The view looks westwards along the study site frontage towards the harbour arm (The Cobb) at Lyme Regis. The Regency resort of Lyme Regis was starting to expand at this time.

Figure 3E8 'Lyme Regis' from the Charmouth road at the top of the cliff looking westwards across the town (by Daniel Dunster). The view is taken from above Black Ven, a very large coastal landslide. The town of Lyme Regis developed on an adjacent landslide complex. Image courtesy R.McInnes.

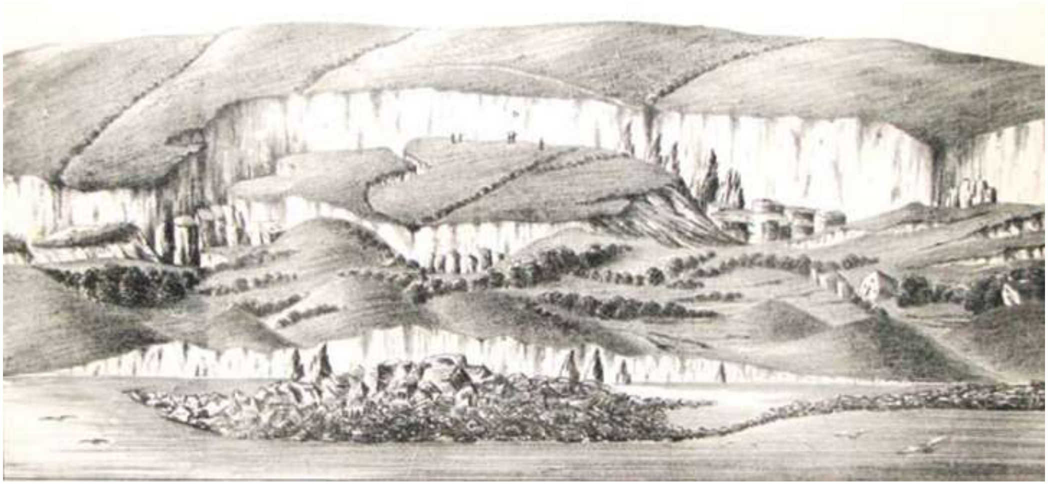


Figure 3E9 A view of the great landslide that took place at Bindon and Dowlands to the west of Lyme Regis on Christmas Day 1839. Image courtesy R.McInnes.

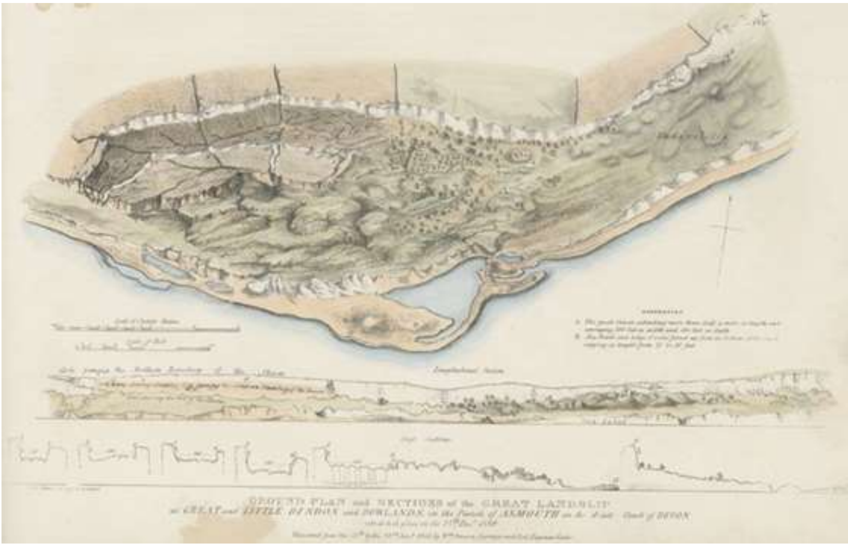


Figure 3E10: The area of the Bindon and Dowlands landslip was studied in detail and the geomorphology was mapped. Private Collection.

Figure 3E11: A further view of the landslide at Bindon and Dowlands is shown in this lithograph. Image courtesy R.McInnes.

Figure 3E12: A view of the Bindon landslide by the prolific watercolourist Alfred Robert Quinton, c.1900. Image courtesy J.Salmon Ltd.

Figure 3E13: This view of the coast west of Lyme Regis shows how the geomorphology is now largely obscured by vegetation. The nineteenth century lithographers, therefore, allow the processes to be viewed more clearly and be better understood. Photograph courtesy: Ian West.

The fine, lithographed view of '*Lyme Regis from the Charmouth road'* (Figure 3E.8) by Daniel Dunster provides a detailed depiction of this part of the Dorset coast in 1840 and demonstrates the level of detail that could be achieved using this technique. The landsliding to the west of Lyme Regis towards Axmouth has been described and illustrated through the famous illustrated publication '*Memoirs and Views of the Landslips on the Coast of Devonshire &c.'* (Conybeare & Buckland, 1840), which provides several detailed lithographic plates, maps and geological cliff sections as well as informative descriptions. These images and others (see Figures 3E.9 – 3E.12) and works by other artists have helped to understand the geomorphological processes that have taken place along this coast and were helpful when hazard and risk investigation and management strategies were being developed for this coast in the 1980s and 1990s.

How can the artwork inform coastal risk management?
It has been explained that this section of coast is largely undeveloped, although some properties exist along the clifftops, particularly on the eastern approach to Lyme Regis at The Spittles (see Figure 3E.8). The images do show the progressive development of the town of Lyme Regis across the coastal landslide complex, which forms the coastal slope and cliffs at Lyme Bay. The large number of views of Lyme Regis' produced partly as a result of the town's popularity during the Regency, Victorian and Edwardian eras, but also on account of the geological interest of the locality, collectively form a unique archive of coastal evolution along this frontage.

Where can the original artwork be viewed?
The views by William Daniell can be found easily on the Internet. The plates from Conybeare and Buckland's book can be view on the website of Lyme Regis Museum at www.lymeregismuseum.co.uk/bindon.

- **Ranking scores achieved:** The two views by Daniell scored 48 and 55 points, whilst the lithographed views of the landsliding scored 66 points (see Table 3E.1).

E3. Beer, East Devon

Location
The village of Beer is located in the County of Devon, immediately to the south west of the resort of Seaton. It is situated towards the western end of Lyme Bay overlooking the English Channel.

Why was the study site selected?
This site was selected in order to provide comparison between a selection of coastal landscape paintings showing the location depicted from almost exactly the same spot over a period of seventy years. It provides the opportunity to compare the approaches of the artists and to consider the detailed information that these artworks provide.

Geomorphological setting
Beer is located in a valley within Cretaceous strata of the Upper Greensand overlain by the Chalk. The top of the cliffline is capped with more recent Plateau Gravels. The chalk cliffs are well jointed and include horizontal bands of flint, indicating the deposits are within the Upper Chalk. The beach is comprised of mainly shingle with some sand.

Key coastal risk management issues for the frontage
The coastline at Beer is undefended and so the key issues are public safety, in terms of access to the beach and along the foot of the high chalk cliffline.

Figure 3E14: 'Fishing Cove of Beer' by Edward William Cooke RA; 1858. Cooke was very interested in geology and stated that he would have become a geologist were he not an artist. His oil paintings are remarkable for their clarity as well as the attention to geological detail. This view looks eastwards towards Dorset. Image courtesy of the late John Munday/Private Collection.

Figure 3E15: A detailed watercolour of Beer beach and cliffs by Arthur W. Perry (c.1900). Image courtesy: Private collection. This is a similar view to that shown in Figure 3E.16 below.

Figure 3E16: Watercolour by Alfred Robert Quinton also painted c.1900 (Image courtesy of J. Salmon Limited). And Inset Figure 3E.16a: the present day scene (courtesy of Ian Woolcock).

Observations on the artwork

Three views of Beer are provided, each looking at the chalk headland from the west. The artworks are very similar in terms of subject matter. The very detailed oil painting by the 'Pre-Raphaelite follower' and geological artist, Edward William Cooke RA, provides the most extensive view looking eastwards. Cooke also painted a view from the opposite side showing Beer Head in the distance (1858). The watercolour by Arthur W Perry, painted c.1900, depicts a closer view of the headland. As in the work by Cooke the geological formations are painted in careful detail. The third and most recent view, a watercolour by Alfred Robert Quinton, was painted in the early twentieth century.

What these artworks show is a remarkable similarity in terms of the shape of the cliffline, the jointing in the cliff face, and the form, profile and nature of the beach. These paintings were all produced by artists who were known for their topographical accuracy, and visual comparisons of this kind help to provide confidence in artworks amongst professionals interested in coastal management in support of their understanding of geomorphological change along their particular frontage.

How can the artwork inform coastal risk management?

These artworks indicate, first, that the cliffline at Beer is subjected to extremely slow change as a result of coastal erosion and cliff weathering. Second, the beach has remained relatively static over a period of some 70 years, even though there may have been fluctuations over the intervening period. Finally, the vegetation patterns also seem very similar over time. Images, which confirm that the coastal frontage has changed very little over time, are equally important to those which show more dramatic changes, and help to build up a long-term perspective of coastal change along any particular frontage.

Where can the original artwork be viewed?

The views are all in private ownership.

- **Ranking score achieved:** The view by E. W. Cooke scored 62 points and the watercolours by Perry and by Quinton scored 70 points.

3E.6 Conclusions and Recommendations

The West Dorset and East Devon case study area has a rich art history comprising landscape paintings, watercolour drawings and prints as well as finely illustrated books spanning the period particularly from 1825 to 1900. The dramatic coastal scenery including the landslip topography, and the fossiliferous strata led to a demand for accurate artworks and descriptions of the coast, which now form an important resource available for scientific study.

The works by William Daniell provide a generally accurate overview of the coastal scenery in the mid-1820s whilst the great coastal artists such as E. W. Cooke RA offer precise detail in their works; this quest for topographical accuracy is echoed by later artists including A. Perry and A. R. Quinton. This case study has enabled the formulation of a number of conclusions and recommendations for future work.

3E.6.1 Conclusions

1. The West Dorset and East Devon case study area illustrates the processes of coastal change along the frontage including the impacts of landsliding. Elsewhere only modest changes are observed to cliffs and beaches.

2. This part of the English coast was painted by numerous artists and their output provides a chronological succession of works available for study, such as those views of the village of Beer, East Devon.

3. The artworks included in these case study examples demonstrate the level of artistic detail that could be achieved by some the leading British nineteenth century artists.

3E.6.2 Recommendations

1. Artworks of the West Dorset and East Devon coast can be used to support understanding of the dramatic physical changes that have taken place since the early nineteenth century.

2. These views allow an improved understanding of the changes to the coastal zone as they depict the scenery before extensive tree growth along the coastline.

3. The names of artists that depicted this coastline most accurately (contained in Table 3E.1) can be interrogated by those wishing to learn more about historical coastal conditions in this location.

This report is a section of the Technical Report for the Archaeology, Art and Coastal Heritage – tools to support coastal management and climate change planning across the Channel Regional Sea (Arch-Manche) Project. To cite this report please use the following:

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3E.7 Case Study References

Bray, M. J., Carter, D. J. & Hooke, J. M., 2004. *Coastal Sediment Transport Study – Lyme Regis to Hurst Castle Spit.* Volume Two of Report for SCOPAC. University of Portsmouth.

Brunsden, D. & Moore, R., 1999. *Engineering Geomorphology on the Coast: Lessons learnt from West Dorset.* Geomorphology 31. 391-409.

Brunsden, D. & Chandler, M. J. 1996. *Development of an Episodic Landform Change Model Based Upon Black Ven Mudslide 1946-1995.* In M. J. Anderson and S. M. Brooks (Eds) *Advances in Hillslope Processes 2,* Chichester. John Wiley. Pps869-896.

Conybeare, W and Buckland, W. 1840. *Memoir and Views of Lasndslips on the Coast of East Devon &c.'* John Murray. London.

Daniell, W. & Ayton, R., 1814. *A Voyage Round Great Britain.* Longman & Co.

Ellis, A. (Ed.), 2004a. *Oil Paintings in Public Ownership in Devon.* The Public Catalogues Foundation.

Ellis, A. (Ed.), 2004b. *Oil Paintings in Public Collections in Dorset.* The Public Catalogues Foundation.

Finden, E. & Finden, W., 1838. *'Views of the Ports, Harbours and Watering Places of Great Britain'.* Virtue & Co. London.

Munday, J., 1996. *E.W Cooke – A Man of his Time. 1811-1880.* Antique Collectors' Club. Woodbridge.

CASE STUDY 3F – WEST CORNWALL

Case study area: West Cornwall, UK.

Main geomorphological types: Hard cliffs at the rear of sandy beaches.

Main coastal change processes: Beach change and potential coastal squeeze.

Primary resources used: Art.

Summary: The study area was selected to examine the relationship between beaches (very important for tourism) and the hard cliffs behind. The risk to beaches from coastal squeeze is a particular concern in such locations.

Recommendations: Results indicate relative stability at the beaches studied through art works, with changes due to storms being a key coastal threat. The rich art resource available for the Cornish coast means further studies would be useful to maximise data from these sources.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

West Cornwall area is one of six UK case study areas for the Arch-Manche project. This Section introduces the study area and why it was chosen as part of the project, the results of the art study are then presented. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. For further details about the project and the methodology see Section 2.

Within the study area the available art resource has been researched, ranked and analysed. The extents of the detailed study areas are shown in Figure 3F1 below.

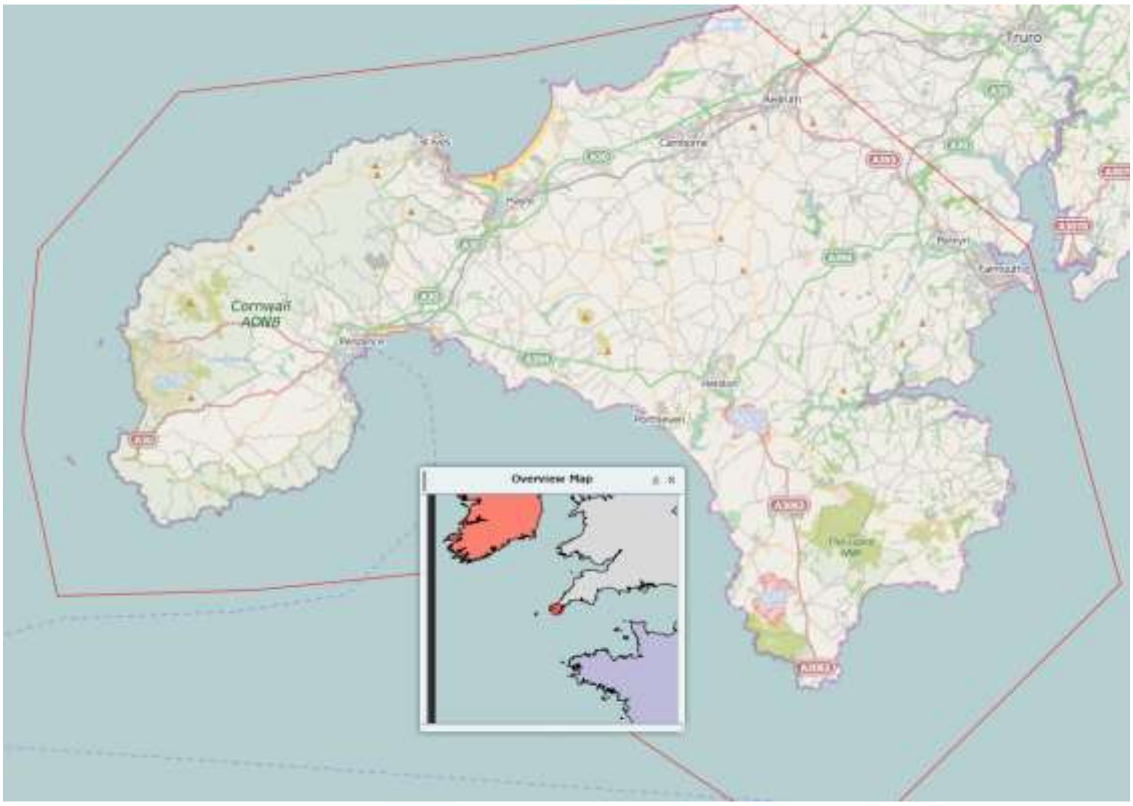

Figure 3F1: Map of the West Cornwall case study area

3F.1 Introduction to the Study Area

The study site comprises the western extremity of the county of Cornwall in south west England and considers the issues of beach change at three locations west of the town of Falmouth. The rugged and dramatic coastline of west Cornwall is surrounded by the sea on three sides, and is almost an island geographically. The predominantly hard rock coastline includes a number of magnificent sandy beaches, which represent a vital resource for the county's flourishing tourism industry. The local authorities responsible for this region have played a pro-active role for many years in terms of both integrated coastal zone management and coastal risk management, including the development of management plans and a beach management strategy.

3F.1.1 Geology and Geomorphology

West Cornwall is dominated by its granite backbone, which was formed during the Variscan Orogeny. To the east the Upper Devonian Slates occupy an extensive part of the county. Being located on a peninsula, the coastline is exposed to the full force of Atlantic storm waves, however, the coastline is composed of highly resistant rocks that, whilst susceptible to occasional rock falls, are generally steep and form impressive coastal landscapes.

The extensive beaches which lie below the cliffs, particularly in the sheltered bays, may be prone to beach lowering and coastal 'squeeze' as a result of rising sea levels over the next century. Beach levels are closely monitored in order to assess changes that may be taking place and establish long-term trends.

Within this case study area, three sites have been examined at Falmouth Bay, Marazion within Mount's Bay to the east of Penzance, and, finally, Carbis Bay to the east of the seaside resort of St Ives.

Figure 3F2: Map of West Cornwall by Thomas Moule 1840

3F1.2 Environmental Impacts and Coastal Management Approach

It has been explained that coastal erosion is generally less of a problem in west Cornwall on account of the durability of the rock formations. However, erosion can affect beaches, particularly after storm events. For the longer term, sea level rise, causing more aggressive coastal erosion, and the squeezing of the beach against hard cliff lines at the back of the beach, could result in increased scour and, consequently, beach lowering.

In order to address these issues and understand the long-term trends, a Shoreline Management Plan for Cornwall and the Isles of Scilly SMP2 (Royal Haskoning, 2011) has been completed. In addition, a Beach Management Strategy has been prepared by Cornwall County Council and the Cornwall Coastal Group (Cornwall County Council, 2013), which is a forum for all relevant authorities in Cornwall with an interest in coastal management.

3F.1.3 Description of the Coastal Art of the Study Area

The western end of the Cornwall peninsula has been painted visited by numerous artists over the last two hundred years. They were attracted by the rugged cliff scenery, the brightness of the light and the colours of the sea as well as the day-to-day lives of the villagers and fishermen. Some artists moved to the area living within artist colonies at St Ives and Newlyn whilst others visited on a regular basis.

During the early years of the eighteenth century J. M. W. Turner painted numerous views in Cornwall, for example *'Pendennis Castle'*, *'Falmouth Harbour'* and *'Boscastle'*. Between 1814 until 1825 William Daniell produced numerous aquatint engravings of coastal scenes, which are contained in his '*A Voyage Round Great Britain'* (Daniell & Ayton, 1814). His west Cornwall views are particularly fine and include *'Falmouth'*, *'The Lizard'*, *'Mullion Cove'*, *'St Michael's Mount'* (two views), *'Penzance'* and *'Land's End'*. Later, the Finden Brothers' publication *Ports, Harbours, Watering Places and Picturesque Scenery of Great Britain* (Finden and Finden, 1838) portrayed a dramatic view of *'Tintagel Castle'*.

The Pre-Raphaelite painter of coastal scenery, John Brett, is particularly renowned for his very detailed depictions of the Cornish coast, which he first visited Cornwall in 1870. Cornwall provided a *"lasting source of inspiration, drawing him back time and time again over the course of three decades"* (Brett *et al.*, 2006). The frequency of his visits has left a lasting legacy capturing an astonishing number of views of the Cornish coastline.

The rugged coastline of the Cornish peninsula *"appealed to the geologist in Brett"* and he produced a significant number of sketches, watercolours and oils of the rocky coastline. In the summer of 1873 Brett and his large family travelled around Cornwall, visiting Penzance, Perranporth, St Agnes, Tintagel and Bude. It has been argued that this particular summer was *"one of the most extended and ambitious [years] of Brett's career"* (Brett *et al.,* 2006). A further visit in 1876 saw Brett paint his beautiful view of the Lizard from the Rill above Kynance Cove. Brett was high up on the cliffs overlooking the Lizard Point and captured the rocks in the foreground with precision. The Cove was also painted by the celebrated artist Edward William Cooke RA whose coastal views have an accuracy sometimes of photographic quality.

The Cornish coastline remained a popular venue for artists throughout the latter part of the nineteenth century and early twentieth century. Many of Britain's great painters of coastal scenery visited the region including John Mogford, Samuel Phillips Jackson and George Wolfe. The quality of the reflected light from the sea, the rugged coastal scenery and the coastal fishing communities led to the establishment of large colonies of artists at Newlyn, St Ives and Lamorna in Cornwall. The artist Charles Napier Hemy was a *"constant and almost lifelong illustrator of Cornish scenery"* (Hardie, 2009) and he owned a house in Falmouth. The port of Penzance Harbour was described by Stanhope Alexander Forbes RA (1857-1947) as *"active and picturesque…from the first time I was fascinated by those wet sands"* (Hardie, 2009).

Stanhope Alexander Forbes, along with Walter Langley (1852-1922), was a founder of the Newlyn School of artists, located in the small fishing village next to Penzance. Forbes has been referred to as the *'Father of the Newlyn School'* and was instrumental in the development of the area as an established artists' School. Forbes moved to Newlyn in 1884 after a period of time studying in Cancale, Brittany with Henry Herbert La Thangue (1859-1929). Forbes lived out his experience in the Breton colonies in Newlyn and as such described it as "an English Concarneau" (Newton, 2005). In 1895 he established the Newlyn Art Gallery and was chairman and trustee. In 1899 he formed the popular Newlyn Art School. Walter Langley has been credited with being the *"earliest 'pioneer' of the Newlyn colony of artists"* and he settled there in 1882 (Hardie, 2009). The term 'Newlyn School' was applied to those artists who shared a *"degree of unity of vision and a broadly similar approach to painting"* (Newton, 2005).

A significant number of the artists who settled in Newlyn had previously studied (often together) in the *ateliers* of Paris and were greatly influenced by French *plein-air* naturalism as championed by Jules Bastien-Lepage. The artists were eager to capture the realities of life for the local inhabitants, but also to *"capture the effect of natural light…inspired by the French plein-air painters"* (Newton, 2005). Bastien-Lepage also inspired the 'square-brush' technique, now synonymous with the Newlyn School.

Figure 3F3: A nook near The Lizard by John Mogford; 1878. Oil on Canvas. Mogford painted the coastal geology in precise detail. Image courtesy R.McInnes.

The artists who gathered in the town of Newlyn were drawn to it by its 'other-worldliness', being as it was so far away geographically and culturally from the large industrial towns that were developing across England. The simple life of the fishermen and women of Cornwall proved inspirational to the visiting artists of Newlyn. It was arguably a tonic to the rapid spread of industrialisation in Great Britain. However, the artists were inspired by the unflinching realism of the French and sought to capture nature in its truest form and avoid sentimentalising the lives of the inhabitants. The realism that they sought to depict in their work involved a *"plein-air ideal when it came to painting the fisher folk upon the quays and in the boats of the Cornish fishing village"* (Hardie, 2009).

The artists painted their subjects against the backdrop of authentic locations and frequently within the models' homes. There was a fascination amongst the artists with the fishermen's working lives and the inevitable tragedy that accompanied such work. On a practical note, many artists chose to stay and work in Newlyn due to the inexpensive living costs and readily available models willing to sit for their work. Wives waiting for their husbands to return safely to the village from fishing excursions was a recurrent theme. For example, Langley's watercolour *'Among the Missing – Scene in a Cornish Fishing Village'* dating 1884 (Newton, 2005) illustrates the anguish experienced by the women left in the wake of the loss of their husband at sea.

Forbes' Art School continued to thrive during the early years of the twentieth century and attracted new artists to the area because of the sense of "*artistic camaraderie…the light and the landscape*" (Newton, 2005). For example, Samuel John *'Lamorna'* Birch RA RWS (1869-1955) settled near to Newlyn in Lamorna valley and was so enamoured with the location, he styled himself '*Lamorna'* Birch; Harold Knight RA (1874-1961) and Laura Knight DBE RA RWS (1877-1970) also settled in Newlyn (and later Lamorna Cove) from 1907 onwards after having previously been instrumental in the development of the artists' colony in Staithes, on the north east coast of England. Laura Knight continued the *plein-air* tradition right up until the 1920s and captured a number of bright coastal scenes during her time on the Cornish coast.

The art colony of St Ives also flourished during the latter part of the nineteenth century. This may be in part due to it featuring in many London art and literary journals at that time. It may also be due to the fact that the sheer volume of artists attracted to that area at that time led inevitably to further areas being 'discovered' by artists. In 1889 the *Daily Telegraph* noted that Louis Grier and Julius Olsson were *"building up what, one day, might be recognised as the St Ives School of painting"* (Newton, 2005). By the 1890s the local art club boasted over 100 members. Grier and Olsson began to take on students from 1895 and Olsson has been described as the driving force in the school. Olsson was described by Folliott Stokes as, *"a big man with a big heart, who paints big pictures with big brushes in a big studio"* (Newton, 2005). It has been said that Olsson *"did more than any other painter to stamp St Ives as a British outpost of Impressionism"*. Olsson lived in St Ives until 1912 and it has been argued that his influence as a teacher *"spread over a generation or more of young painters from Britain and overseas"* (Hardie, 2009).

The town of St Ives continued to grow and thrive as a creative community, attracting painters and also sculptors, potters and writers throughout the twentieth Century. There were many friendships and working relationships that developed between the artists living and working in the towns of St Ives, Newlyn and Falmouth during this time. Ideas and techniques were disseminated between the art colonies and schools. For over one hundred and twenty years "*there [was] a succession of influential role models living in and around St Ives*" (Newton, 2005).

The turn of the twentieth century and the increased level of tourists visiting coastal locations in the south-west led to a greater demand in watercolour and photographic postcards. Two artists, Henry Wimbush (1858-1943) and Alfred Robert Quinton (1853-1934), were particularly prolific in their production of picture postcards of this area. Popular subjects by A. R. Quinton included Falmouth, St Michael's Mount and St Ives.

3F.2 Ranking the Importance of the Artworks

The development of the ranking system has been outlined within Section 2. In order to rank the artworks a database was established into which data was entered for both archaeological/maritime heritage sites and for artworks. By entering the data on artwork type, medium, subject matter, time period and other parameters the database was then able to calculate the ranking scores for twelve works of art from the case study site (Figure 3F4).

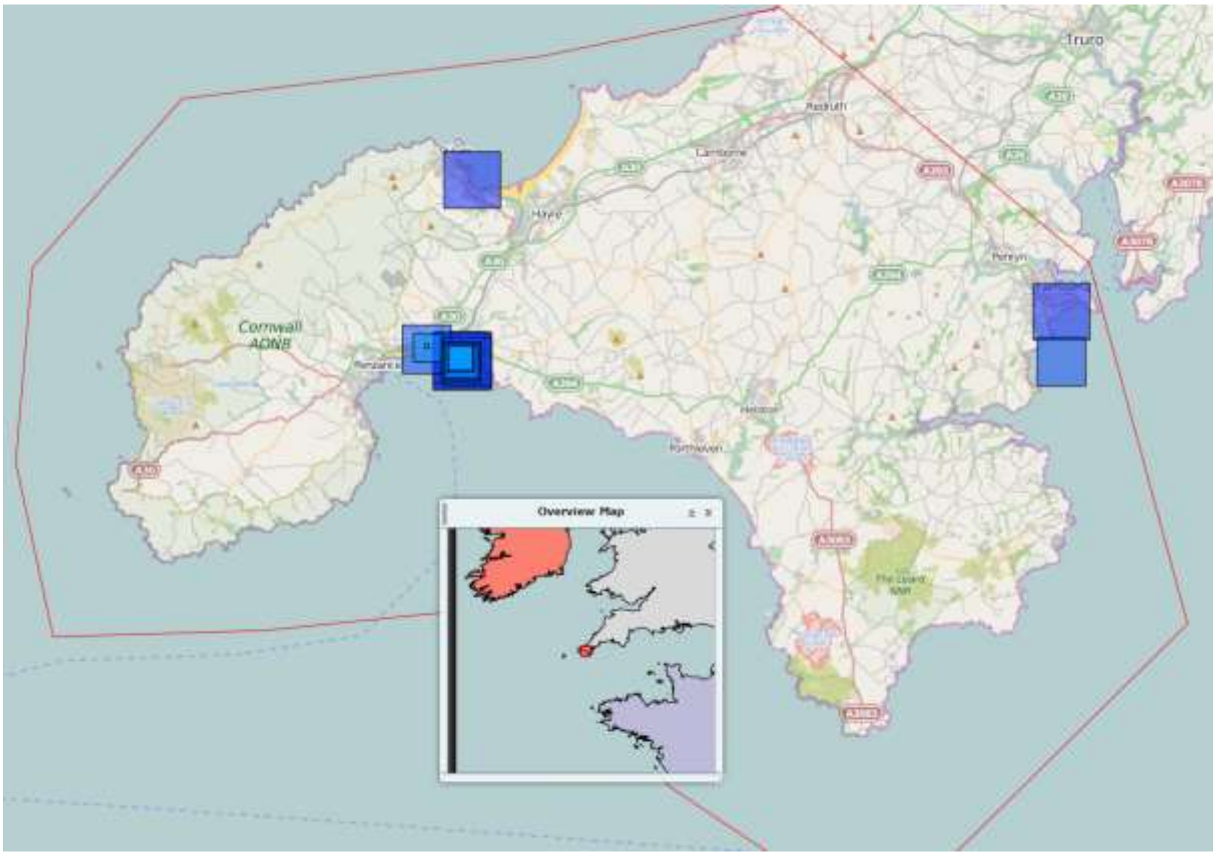

Figure 3F4. Location of the artworks.

The highest ranking artworks, watercolours by Alfred Robert Quinton and Henry Wimbush, scored 70 points whilst coastal engravings by Townsend and Daniell scored 62 and 55 points respectively. The information imparted by these artworks is described below. The study images depict three locations – Mount's Bay at Marazion just to the east of Penzance; Gyllngvase Beach on the south Cornish coast just to the west of Pendennis Point, Falmouth and finally Carbis Bay at St Ives. There are a large number of views of picturesque St Michael's Mount and a selection of these are illustrated. However, for the other two sites just one image of each location is considered as these are the highest ranking images and allow comparison to be made of beach conditions in a very helpful way. Further details on the ranked artworks are provided in Table 3F.1 below.

These differing coastal conditions and processes and their impacts on coastal residents, assets and infrastructure could not have been easily matched to the most informative works of art without the provision of the ranking system. The ranking identified the three case study locations and, for each, several works are analysed as follows:-

Location	Artist	Date	Score type	Score period	Score style	Score enviro	Total Score
St Michael's Mount – View 1	William Daniell	1825	Aqua-tint	Early	Topog.	Detailed View	55
St Michael's Mount – View 2	William Daniell	1825	Aqua-tint	Early	Topog.	Detailed View	55
St Michael's Mount	G. Townsend	c.1850	Steel Engraving	Mid.	Topog.	Very Detailed View	62
Near The Lizard	John Mogford	1885	Oil	late	Topog.	Detailed View	48
The Lizard	John Brett	1876	Oil	Late	Topog.	Very	62

						Detailed View	
Mount's Bay	John Brett	1877	Oil	Late	Topog.	Very Detailed View	62
St Michael's Mount	Henry B. Wimbush	c.1900	Water-colour	Late	Topog.	Detailed View	70
St Michael's Mount	Alfred Robert Quinton	c.1900	Water-colour	Late	Topog.	Detailed View	70
Gyllyngvase Beach, Falmouth	Alfred Robert Quinton	c.1900	Water-colour	Late	Topog.	Very Detailed View	70
Carbis Bay, St Ives	Alfred Robert Quinton	c.1900	Water-colour	Late	Topog.	Very detailed view	70

Table 3F1 Art ranking results for West Cornwall

A more detailed interpretation of the individual artworks is provided below. The assigning of scores to each artwork suggests names of those artists who have depicted different aspects of the study site coasts most accurately across the timeline 1770-1920. These artists include William Daniell, John Mogford, John Brett and Alfred Robert Quinton; they can be relied upon in terms of the accuracy of their depictions of the East Sussex coastline.

3F.3 Discussion of the Art Ranking Results

Over the last twenty years considerable efforts have been made to encourage improved coastal management in Cornwall and this has led to the development of risk management plans for the county coastline in support of the principle of sustainable development. As part of this process, thorough consideration has been given by the South-West Coastal Group to natural hazards, and the resulting risks to people, property and the environment. Climate change is with us now and is going to exert an increasing influence on the lives of coastal residents over the next decades by affecting the severity of coastal erosion and the potential for beach change.

The Cornish case study has assessed the value of various artworks in terms of informing on beach change through a combined approach of desk-based research, museum and gallery searches and field visits. These have confirmed the added value of art from the period 1770-1920 to support other coastal surveying and monitoring technologies (e.g. Space-borne, air-borne, ship-borne and terrestrial). It is important to remember that artists in the late Georgian and Victorian eras worked for very demanding, wealthy clients who often sought exact views of the coastal landscape to remind them of their visit. Before the days of photography precise images were, therefore, a prerequisite in most cases. The artworks examined illustrate the form of important beaches in the late nineteenth or early twentieth centuries. Some of the paintings show little change over the last two hundred years and this information is of importance to the coastal scientist.

Although the west Cornwall case study has focused on the use of historic paintings, several historic maps, charts and photographs were also consulted to review the potential of these data sources. Because of the dynamic nature of this coastline historic photographs can be a valuable resource with many historic photos containing depictions of the cliff with recognisable heritage features nearby, including churches, wells and houses. These can be compared to the modern situation and from this an accurate idea of the rate of erosion since the date of the photograph can be gained.

3F.4 Art Field and Research Studies Approach

No archaeological or palaeoenvironmental fieldwork was carried out for the west Cornwall case study site, this section, therefore, outlines the field studies undertaken as part of the art study.

The art ranking system confirmed which images were likely to be true representations of the conditions that would be seen at the time they were painted; the research questions to be answered through examination of the artworks were:-

- What information can the historical images provide to support understanding of long-term coastal change?
- How can the potential of this resource be used most effectively by the end-user?

In order to identify the most suitable artworks that could be studied in more detail at the field study sites a national search was undertaken involving an extensive review of landscape paintings, watercolours and prints held in public and some private collections. Following ranking of seventeen artworks seven examples have been the subject of more detailed analysis involving site visits. This is a smaller number than at other case study sites because there has been a particular focus here on comparing change at specific beaches – Carbis Bay near St Ives and Gyllynvase Beach near Falmouth. The artworks being examined at these sites are also particularly high scoring (70 points).

Where it was practical to gain access and relevant to the study, present day photographs were taken in the field to try, as far as possible, to match the views painted by the eighteenth, nineteenth and early twentieth century artists. It also provided the opportunity to assess the conditions of the cliffline and beach and changes that may have taken place over time. In terms of work in this field each of the locations has been visited and photographed in varying weather conditions. Inspections were timed to coincide with Low Water and a walk-over survey was made along the beach and base of the cliff returning along the cliff top. This ensured that thorough comparison could be made between the geomorphological conditions depicted in the artwork and the present day situation.

3F.5 Art Field Data Gathering Results

The west Cornwall study sites were chosen to assess how artworks can assist evaluation of beach change; an issue of considerable concern in the south west of England. The opportunity was taken to examine change at three sites each of which was painted by high scoring artists of known reliability and accuracy. Careful comparison was made between the artworks and the present day views by examining beach levels against the cliffs and other elements shown in the paintings. The examination of the art was followed up by site inspections and generally there appeared to be little change since the early part of the twentieth century. The field inspections allowed a more accurate appraisal to be made of current physical conditions rather than relying upon written accounts and reports particularly as storm events can cause significant alterations over relatively short time periods.

Whilst the state of the sandy beach in Mount's Bay appears less obvious in the artworks (some are depicted at half-tide) the extent of the sandy foreshore at the other two sites is remarkable. The present day views suggest that beach conditions are remaining healthy at all three sites although steepening and some reduction in volume are likely to be the consequences of sea level rise and coastal squeeze, particularly in Mount's Bay, which is backed by hard defences.

F1 Gyllyngvase Beach, Falmouth

Location
Gyllyngvase beach is one of four beaches located to the south of the town of Falmouth, Cornwall's most important sea port and a fine natural harbour. The beach is backed by steep slopes, lined with hotels, and comprises a long crescent shaped stretch of sand broken by rocks at low water.

Why was the study site selected?
The three sites chosen for study in west Cornwall were selected as they provide examples of important pocket beaches, which are backed by clifflines or hard defences, and which may be subject to coastal squeeze as a result of rising sea levels over the next century.

Geomorphological setting
The geology is composed largely of granite intrusions into the adjacent sedimentary rocks, which are of the Devonian period. The study site is bounded on the east by Pendennis Point at the mouth of Carrick Roads and faces the English Channel, with exposure also to the waves from the Atlantic Ocean.

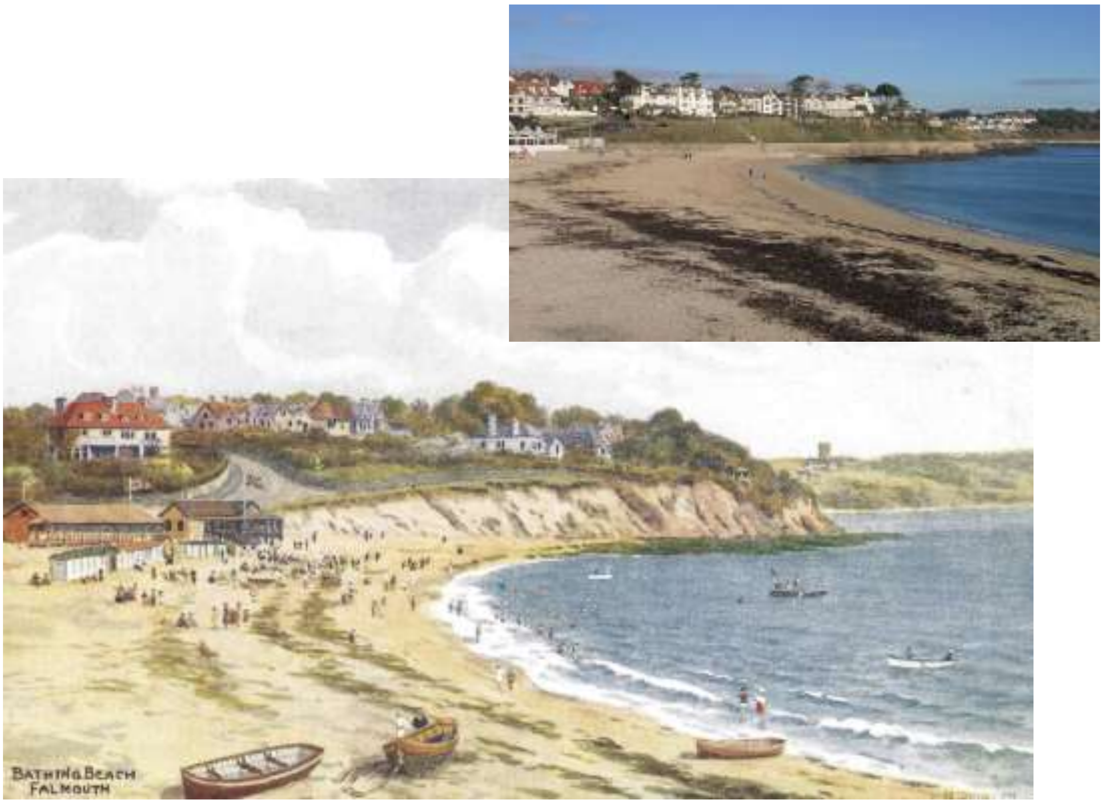

*Figure 3F5: Gyllynvase Beach near Falmouth, Cornwall by Alfred Robert Quinton; c.1900. Image courtesy of J. Salmon Limited. Figure 3F.5a***:** *View of the beach today; image courtesy of Claire Ogden.*

Key coastal risk management issues for the frontage
The key objectives are to prevent or minimise economic losses by reducing coastal erosion and coastal flooding that might affect residential, commercial and industrial properties and infrastructure. In addition the Shoreline Management Plan (Royal Haskoning, 2011) wishes to identify opportunities for maintaining and improving the natural environment by managing the risks from flooding and erosion, and to minimise any adverse impacts on the geological and geomorphological interest of the coast, as well as the significant heritage assets. These objectives will be achieved by continuing a policy of 'hold the line'.

Observations on the artwork

The artwork shows a view of the beach, looking eastwards, in about 1900. Both the watercolour by Alfred Robert Quinton and the present day view depict a healthy beach, although the view by Quinton is slightly closer, being taken from the middle of the beach. The cliff line in the centre of the watercolour seems rather more active than the present day, where the slopes are more vegetated. Overall, the image suggests relatively little change over the last 100 years, although there is likely to be some increasing pressure as a result of sea level rise, through the twenty-first century.

How can the artwork inform coastal risk management?
The artwork provides a representation of beach and cliff conditions in about 1900. It provides an indication of the nature of the beach some 30 years before the earliest aerial photographs became widely available. It does, therefore, provide a useful description of the beach at that particular time.

Where can the original artwork be viewed?
The watercolours by A.R Quinton were produced for reproduction as colour picture postcards from the late nineteenth century. The watercolours remain in the ownership of the publishers, however, the postcard reproductions are widely available on the Internet.

Ranking score achieved: This view by Quinton received the high score of 70 points.

F2 St Michael's Mount, Mount's Bay near Penzance

Location
The site is located on the south coast of Cornwall, approximately 2km east of the town of Penzance.

Why was the study site selected?
The site is located at the village of Marazion, which is a popular beach resort overlooking the island of St Michael's Mount. The Mount is connected to the foreshore by a causeway, which is covered at high water. The site is under significant pressures from both tourism, as well as, physical coastal processes including storm surges affecting the beach and its nature conservation interest. Hard defences covering much of the Bay may lead to 'coastal squeeze' in the future.

Geomorphological setting
The site lies along the rocky coastline of west Cornwall. This part of the coastline receives some shelter from the dominant westerly Atlantic wave climate, as a result of the Penwith Peninsula to the west. However, the frontage is vulnerable to storm events generated from the south and the south-east. The granite outcrop of St Michael's Mount and the rocky shoreline helps control the form of the beach and contributes sediment accretion along the frontage.

Key coastal risk management issues for the frontage
The developed frontage is protected by seawalls but there are concerns about lowering of beach levels and the impacts of rising sea levels and increased erosion, resulting in beach drawdown, which has already been noted as taking place. The adjacent coastline is of nature conservation importance on account of its bird species, and forms a nature reserve, as well as being designated as a Special Protection Area.

Figure 3F6: A view of St Michael's Mount engraved in about 1850.

Figures 3F7 and 3F8: Two views of St Michael's Mount by William Daniell RA; 1825.

*Figures 3F9. The present day view of St Michaels Mount**;** image courtesy of Rssing.com*

Figure 3F10 was painted by Alfred Robert Quinton in about 1900.

Figure 3F11: The view by Henry B. Wimbush and is of a similar date to Figure 3F.10 (image courtesy of J. Salmon).

Observations on the artworks

The two views of St Michael's Mount from the shore at Marazion by Alfred Robert Quinton (Figure 3F.10) and by Henry Wimbush (Figure 3F.11) were both painted in watercolour in about 1900. They depict the situation at low water, as evidenced by the visiblility of the causeway linking the Island to the mainland, which is being accessed by pedestrians in the picture. In the foreground the rocky foreshore can be seen, which lies seaward of the sandy beach. The watercolours indicate the nature of the foreshore, and it appears that there has been little change since the view was painted.

How can the artwork inform coastal risk management?

Works by these artists have been proved to provide a reliable record of conditions at the time they were painted. Comparison of the image with the present day appears to show relatively little change and this is supported by evidence from monitoring of the frontage. The watercolours help provide a long-term perspective in terms of the nature of conditions at this important location.

Where can the original artwork be viewed?

The views by William Daniell (Figures 3F.7 and 3F.8) can be viewed readily on the Internet. Although the images by A. R. Quinton and H. B. Wimbush are held privately they were also reproduced as colour picture postcards and can be viewed on the Internet.

Ranking score achieved: The watercolour views by view by Quinton and Wimbush both received the high score of 70 points. The aquatint engravings by William Daniell scored 55 points (see Table 3F.1).

F3 Carbis Bay, St Ives, West Cornwall
Location
Carbis Bay lies on the western side of St Ives Bay in west Cornwall. The bay is located immediately to the east of the town of St Ives, in a sheltered position.

Why was the study site selected?
The site was selected as a location where an excellent tourist beach is backed by a hard rock cliffline that may be subject to coastal squeeze as sea levels rise in the future. The issues at this site should be seen collectively with those at the two previous sites.

Geomorphological setting
St Ives Bay lies on the northern coast of the west Cornwall peninsula and has been formed within granite rock cliffs, which make up the frontage between St Ives and Land's End. The bay itself lies within rocks of the Devonian age, including slates, sandstones and limestones. The bay has not been affected by significant coastal erosion in the past.

Key coastal risk management issues for the frontage
Carbis Bay has a wide sandy beach, which although sheltered, can be impacted upon by severe storm events from the north west to north east (Royal Haskoning, 2011). The north western frontage, which is relatively undeveloped, will not be defended for the future, whilst the existing defences will be maintained along the developed frontage of the bay itself.

Observations on the artwork
The watercolour drawing by Alfred Robert Quinton (Figure 3F.13) depicts the view from Porthminster Point, looking across Carbis Bay towards Carrick Gladden. It shows the relatively undeveloped nature of the bay at the time, and also precisely defines the extent of the beach at Low Water.

A further point of interest is the comparatively bare coastal slopes, which are now heavily vegetated. Watercolour drawings up to this date can be particularly useful in terms of comparing vegetation patterns, particularly as they represented the only images in colour available at that time, prior to the widespread introduction of colour photography in the early twentieth century.

The beach itself appears very healthy in the Victorian (c.1900) watercolour, and yet the extent of the beach today (Figure 3F.12) matches precisely the historical image. This suggests that there has been relatively little coastal change over the last 114 years.

How can the artwork inform coastal risk management?
Figure 3F.13 provides an exact depiction of coastal conditions in 1920 at Carbis Bay. It allows those interested in coastal management to understand what conditions were like long before the days that monitoring programmes for beaches were put in place. Alongside the coastal risk management issues these images also describe environmental and developmental change over the intervening period.

Figure 3F12: Present day view. Courtesy of T.Bakes (Panoramio.com).

Figure 3F13: Carbis Bay, St Ives by Alfred Robert Quinton; c.1900. Image courtesy of J. Salmon limited.

Where can the original artwork be viewed?
The watercolours by A. R. Quinton were produced for reproduction as colour picture postcards from the late nineteenth century. The watercolours remain in the ownership of the publishers, however, the postcard reproductions are widely available on the Internet.

Ranking score achieved: The watercolour view by view by Quinton received a high score of 70 points.

3F.6 Analysis of Artistic Depictions

The three west Cornwall study sites were selected to provide examples of how artwork can support understanding of beach evolution (form, extent and volume). They illustrate relatively little change over the last century although conditions may fluctuate depending on the severity of storm events.

The government has recognised that in the past insufficient attention had been given to long-term coastal and beach change as part of coastal risk management, and the second round of Shoreline Management Plans, which were completed in England and Wales by 2010 sought to address this. In addition, over the last decade a Strategic Coastal Monitoring programme has been rolled out around the English and Welsh coasts (www.channelcoast.org) and this is now providing much more detailed information on beach change. This new approach can be supported by the historical information on beach change that is provided by artistic works such as these of Cornwall's beaches.

3F.7 Conclusions and Recommendations

3F.7.1 Conclusions

- The aquatint prints and watercolour drawings highlighted in these Cornish studies can be examined to support understanding of long-term beach change. They allow detail and accuracy to be compared across artists and artworks to improve confidence in the reliability of the depictions in addition to the value of the information they impart.
- The county of Cornwall has an exceedingly rich art history and forms one of the most painted coastlines in The British Isles. The opportunity exists, therefore, to apply the Arch-Manche approach along the whole of this extensive coastal frontage.
- The studies show relatively modest change over the past century as a result of erosion or the impact of sea level rise.

3F.7.2 Recommendations

- A record of the condition of these Cornish beaches is available for examination (in colour) by coastal scientists and engineers.

- It is recommended that all studies relating to coastal and shoreline management should take full account of the art record and other historical resources available to improve understanding of coastal evolution and trends.

This report is a section of the Technical Report for the Archaeology, Art and Coastal Heritage – tools to support coastal management and climate change planning across the Channel Regional Sea (Arch-Manche) Project. To cite this report please use the following:

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3F.8 Case Study References

Brett, C.; Hickox, M. & Payne, C., 2006. *' John Brett A Pre-Raphaelite in Cornwall*. Sansom and Company Limited. ISBN: 1 904537 51 0.

Cornwall County Council. 2013. *Beach Management Strategy.* Transport, Waste & Environment 2011-2015.

Daniell, W. & Ayton, R., 1814. *'A Voyage Round Great Britain'.* Private Press. London.

Finden, E. & Finden, W., 1838. *'Views of the Ports, Harbours and Watering Places of Great Britain'.* Virtue & Co. London.

Hardie, M. (Editor), 2009. *'Artists in Newlyn and West Cornwall 1880-1940.* Art Dictionaries Ltd. ISBN: 978 0 953260 96 6.

Newton, L. (Editor), 2005. *'Painting at the Edge British Art Colonies 1880-1930.* Sansom and Company Limited. ISBN: 978 1 904537 26 7.

Royal Haskoning. 2011. *Cornwall and Isles of Scilly Shoreline Management Plan Round 2.* South-West Coastal Group.

CASE STUDY 3G – NORTH CORNWALL & NORTH DEVON

Case study area: North Cornwall and North Devon, UK.

Main geomorphological types: Hard cliffs, rocky outcrops, sandy beaches.

Main coastal change processes: Coastal erosion, beach change, some cliff instability, low lying areas vulnerable to flooding.

Primary resources used: Archaeology.

Summary: The high cliffs, interspersed with small natural harbours and sandy beaches face the full force of the Atlantic Ocean. The cliffs consist of relatively hard geology but are vulnerable to landslides. Although few major archaeological studies have been undertaken in this area, there are extensive prehistoric landscapes surviving. Knowledge of the heritage resource clearly demonstrates changes in relation to erosion and changes in sedimentation.

Recommendations: Coastal managers should use archaeological and palaeoenvironmental resources to understand long term changes, in particular where humanly-made structures (such as Bude breakwater) have influenced the sediment regime. Extensive Bronze Age peats buried under the coast provide opportunities for detailed modelling of change.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

The North Cornwall and North Devon coast is one of six UK case study areas for the Arch-Manche project. Work in this area has focused on the archaeological and palaeoenvironmental evidence. The ranking results are presented followed by an analysis of the results and the potential for demonstrating the scale and rate of sea level change. For further details about the project and the methodology see Section 2.

Within the study area the archaeological and palaeoenvironmental resource has been researched, ranked and analysed. The extents of the detailed study area is shown in Figure 3G1 below.

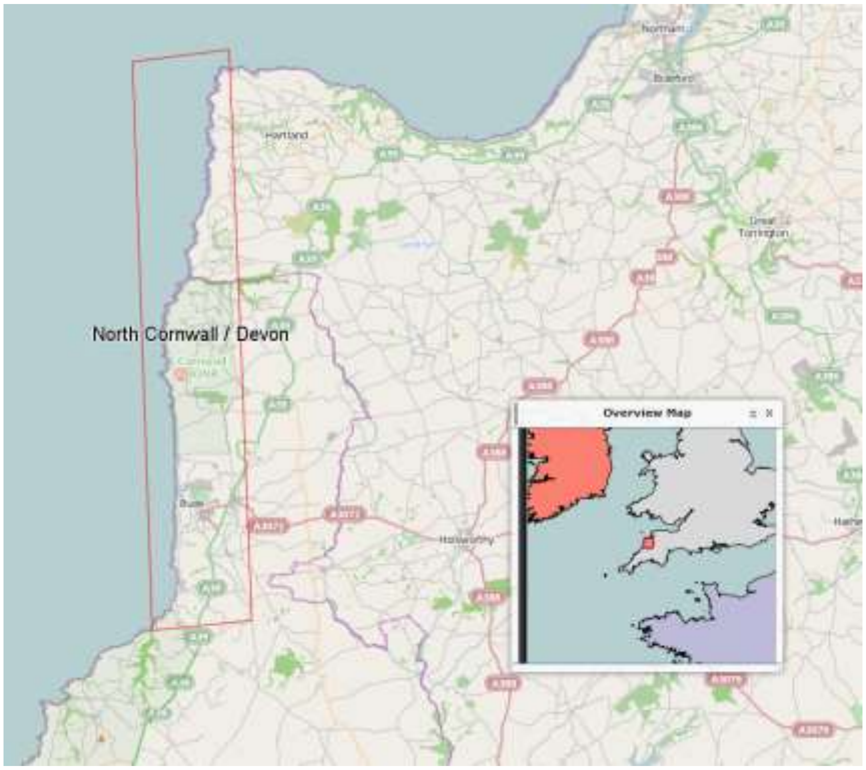

Figure 3G1. Map of the North Cornwall and North Devon case study area

3G.1 Introduction to the North Cornwall & North Devon Study Area

The archaeological study area of North Cornwall and North Devon includes the coast from Widemouth Bay in the south to Hartland Point in the north (see Figure 3G1). It incorporates the west facing coastline at the northern-most point of Cornwall and the most north-westerly coast of Devon, in the area around Hartland. The coastline consists of high cliff faces with small natural harbours opening onto sandy beaches (the largest being Summerleaze Beach at Bude) in the north and centre of the study area, while in the south the land is more low lying and runs down to a mile long beach at Widemouth Bay.

The study area was chosen due to the variable coastline, with hard cliffs in some areas and low-lying sandy beaches in others. Several submerged, intertidal prehistoric landscapes are also known from this region.

3G.1.1 Summary of the Geomorphology of the Area

The case study area has a distinct north-south orientation with a foreshore dominated by rocky ledges and outcrops of resistant sandstone exposed to the full force of Atlantic swells (Cornwall Council 2011, SMP). The area is renowned for its sheer cliffs, reefs and dramatic geology which is regularly battered by the Atlantic causing distinct wave-cut platforms as well as coastal waterfalls. The geology of this coastline is predominantly sandstones, shales, conglomerates, slates and limestones and is generally classed as a resistant coast, this is also partly due to the fact that the area was not glaciated under any Pleistocene glaciation (Buscombe & Scott, 2008:5).

After the Last Glacial Maximum (LGM) the sea level around this coastline was at least 120m lower than today, the early Holocene witnessed a rapid increase in sea level which became more stable around 6,000 years ago. Submerged forests are found in several places along this coastline which provide evidence from a period of lower sea levels. The cliffs have suffered many landslides as well as erosion but are still relatively hard and resilient, the beaches are also relatively stable with high sediment input from offshore resulting in low erosion rates (Buscombe & Scott, 2008:7).

3G.1.2 Summary of the Archaeology and History of the North Cornwall and North Devon Study Area

The geography and geology of Cornwall has meant that, relative to the rest of the UK, agriculture has been less intensive and many buildings and monuments have been built of stone. This means that it has an above average number of monuments and one of the largest Historic Environment Records (HERs) in the country.

The presence of significant sand dunes in the south of the study area means that there is potential for further archaeological material to be identified in the coastal area (Bell & Brown, 2009: 26). This section provides an overview of the currently known archaeology and history of the study area.

Early Prehistory (Palaeolithic and Mesolithic)

The coastline of the study area was once much further west than its present location. It is presumed that during the Pleistocene era, the coastline of Cornwall would have run almost continuously south west and so, Hartland Point would not have been definable as a point and Bude Bay would have been part of a river valley which exited at the coast some distance to the west. The ending of the last Ice Age led to rising sea levels around the coast; progressively the shape of the present coastline would have begun to materialise (Berridge & Roberts, 1986: 10). The remains of submerged prehistoric forests in the intertidal zone at Bude and Widemouth Bay (Bell & Brown, 2009: 26), as well as several other locations in the south west support this model. Although the only forests which have been definitely dated to the Mesolithic period so far are those at Westward Ho! (Berridge & Roberts, 1986: 11).

Webster 2007 outlines that “Overall, the Palaeolithic and Mesolithic archaeology of this [South West] region is generally rather poorly known, reflecting an absence of robust geochronological frameworks, the predominance of research into a handful of cave and open sites over the lithic scatter resource (whether located on the surface of deeply buried) and the absence of any major syntheses” (2007: 23).

For some time it had been presumed that there was no occupation of the Cornwall peninsula in the Palaeolithic period. A small number of individual finds of Lower and Middle Palaeolithic handaxes and flint tools, and some Upper Palaeolithic cave sites on the south coast suggest limited, sporadic activity in the area. Within the study area, the sole relevant find is a Palaeolithic axe head found in Bude. However, it is thought likely that many Palaeolithic sites on the coast have been lost on account of rising sea levels and erosion (Berridge & Roberts, 1986: 10). This suggestion is given further weight through research undertaken as part of the West Coast Palaeolandscapes Project (Fitch and Gaffney 2011), which extended to the North Devon coast. They outlined that “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” (*ibid.* 2011: ii). Modelling using marine survey data demonstrated that the previous landscape in the northern part of the study area has undergone significant change since the Palaeolithic.

The Mesolithic is often considered the first major period of human settlement in Cornwall and Devon, although this is largely based on a lack of Palaeolithic artefacts (Berridge & Roberts, 1986: 7). Several sites in Cornwall have been assigned a Mesolithic date on the basis of microlith types. In addition, numerous axeheads, scrapers and other tools have been identified in locations all across Cornwall and Devon. Several Mesolithic findspots have been found along the coast at Bude. One in particular, at Crooklets, has yielded a number of microliths that suggest a Mesolithic working site, most likely from the Later Mesolithic. In the 1970s and 1980s these were exposed by the slumping cliff face and, although this rapid erosion means that the site may already be lost (Berridge & Roberts, 1986: 27), further possible evidence of Mesolithic activity in the study area can be found in the flint scatters off the coast at Hartland Point, at Bude Bay, Widemouth Bay, Bethams, and Summerleaze Point (although these may represent Neolithic activity) (Cornwall and Devon HERs).

To the north of the study area there is well documented prehistoric evidence surviving at Westward Ho! which includes in-situ Mesolithic remains (Balaam et al 1987). These examples are further evidence of potential survival in the intertidal and near shore zones in areas of tidal estuaries, but also exposed coastal bays.

Later Prehistory (Neolithic, Bronze Age and Iron Age)
Neolithic activity in the area of Cornwall and Devon is well evidenced by a number of tor enclosures, megaliths and long barrows. None of these monuments are found within the study area, nor is there any evidence of settlements, although it is possible that any such evidence could have been impacted by more recent agriculture. However, numerous find spots suggest a Neolithic presence in the study area; Neolithic leaf shaped arrowheads have been found near Helebridge and at Crooklets Beach, as well as the many flint scatters which have been given a Mesolithic date, but may indicate Neolithic activity (Cornwall HER). For the Neolithic and Early Bronze Age there is well persevered evidence of prehistoric landscapes on the uplands of Bodmin Moor (Webster 2007: 45), however the nearby coastal zone territories are less well understood.

Cornwall has many areas of 'Anciently Enclosed Land' (a characterisation identified in the Historic Landscape Characterisation). These areas were most likely first cleared and used for farming in the Bronze Age, although successive periods of history have removed most traces of this land use (Cornwall County Council, 2007). The earliest evidence of settlement in Cornwall and Devon dates from this period; early farms have been identified in the upland landscape, as have settlements believed to be associated with managing animal herds.

A number of prehistoric field systems within the study area may date to the Bronze Age, although this is uncertain. Bronze Age burial mounds, traditionally found on areas of high ground, can be found extensively in the southern part of the study area, and there are many further inland in Cornwall and Devon. A number of these barrows are situated on the cliff tops around Bude and on a high ridge south of the town. Many of these survive as extant mounds, although a number are presumed and identifiable only as cropmarks. However, curiously none are recorded north of Morwenstow and so there are none on the high cliff tops around Hartland Point (Cornwall and Devon HERs).

The Iron Age is well evidenced in Cornwall and Devon by large numbers of hillforts, cliff castles and settlement sites. Within Cornwall, earth and stone ramparts of late prehistoric enclosed settlements (known in Cornwall as 'rounds') appear to have been subsequently used as field banks and survive in modern day field systems (Cornwall County Council, 2007). Within the study area, a number of fields on average 3km inland suggest that they were formerly rounds, either through existing or previously recorded evidence, or because their historical names incorporate 'round' (HER). The National Mapping Programme has identified extensive field systems, broadly dated to the Iron Age/Roman period (although this is based on morphology as opposed to absolute dating) suggesting an active area, possibly under the governance of Hartland hillfort or Embury Beacon hillfort. This hillfort, just north of the Cornwall/Devon border, was found to enclose several structures during a rescue excavation in the 1970s, before it succumbed to coastal erosion (Devon HER).

Roman Period

Perhaps because of the narrow peninsula or the terrain around Dartmoor and Exmoor, it has traditionally been believed that the Romans never extended much influence into Cornwall, although it is unlikely that the area was independent of their control. Roman documents suggest that Devon and Cornwall was as an area known as Dumnonia, and the land of the Cornovii and Dumonii tribes. There may have been active trade between the Romans and the tribes, particularly for tin (Cornwall Heritage Trust). However, recent discoveries of possible Roman forts suggests the Roman presence may have been more active than previously thought.

Accordingly, although several Romano-British features date to this period, there is little in the way of Roman archaeology in the study area. The most significant find was a coin hoard discovered in 1893, which contained Sesterii of Julius Ceaser, Augustus and Hadrian, Minimi of Constantine the Great and an Antoninianus of Carinus (Cornwall HER). A possible signal station at Oldwalls may also indicate a Roman presence at some point during the period, although this cropmark is hard to interpret. A number of finds, including hearths exposed by erosion at Duckpool, boundary banks and domestic refuse suggest that local tribes were still present in the area after the Iron Age (Cornwall HER).

Medieval Period (AD 500 – 1485)

Cornwall and Devon remained largely independent of the Saxon influx in the wake of the Roman departure from Britain. A separate 'Kingdom of Cornwall' evolved from Dumnonia, and the area seems to have some power in Brittany. However, by the 9th century, regular battles took place with the realm of Wessex, including a decisive battle in 825AD that might have been 25 miles south west of the study area. After losing this battle, the power of the Cornwall kingdom waned and by the 10th century, Devon had been incorporated into Saxon Wessex and Cornwall, its boundary now broadly similar to the present day county division, was a minor power (Cornwall Heritage Trust).

Although the Viking incursions of the period had little effect on the region, the arrival of the Normans in 1066 brought many Bretons to Cornwall. Although there was an acceptance of a separate region of Cornwall, the county was incorporated into the Norman kingdom (Cornwall Heritage Trust).

The area around Hartland was part of the larger Saxon Royal Holding in the west of Britain and passed through numerous generations until the Norman Conquest, at which point it was given to King William. The Manor of Hartland was subsequently gifted to the De Dinham family in the 12 century. The greater manor consisted of four smaller manorial areas that make up almost the entire Devon element of the study area. South Hole, Meddon and Stoke run along the coast, whilst Milford is further inland (Hobbs, 2009:9). As a result a number of medieval field systems can be found in the study area, many of which run right up to the present day coast. Other evidence of agriculture and subsistence includes an extensive area of rabbit mounds, including one extensive site known as 'The Warren' or 'Cliff Warren', established as a breeding area near Hartland Quay (Devon HER).

A number of medieval settlements, now abandoned fall within the study area. Many of these are farmsteads, but some, according to documentary evidence, appear to have been whole villages.

Several other monuments including wells, corn mills, farmhouses, manor houses and homes attest to the population settling here (Cornwall and Devon HERs).

Post-Medieval Period (1485 – 1901)

As industrialisation began to take place around the country, more significant changes began to occur in the study area. In the late 16th century, a quay was built at the natural harbour in the cliffs west of Stoke. Hartland Quay served to protect the harbour from the sea, but was itself washed away in 1887. The customs house and warehouses survive today and have been converted into a hotel and museum (Devon HER). Further to the south at Bude a small harbour was thriving by the 18th Century, with strong links with Ireland, Bristol and Wales. Warehouses, houses and business' then grew around the port, particularly after the mid 18th Century.

As maritime trade flourished, coastal traffic increased and so too did the number of accidents. Of the 78 wrecks listed off the Devon coast in the study area, approximately 60 date from the Post Medieval period (Devon HER).

In an effort to improve the infertile farmlands inland, landowners regularly used sand from the shore of the study area on their fields. Transporting such quantities was difficult and a canal was constructed from Bude to serve surrounding agricultural land. Completed in 1823, the canal ran from Bude, where a lock gate gave access to ocean going vessels to a wharf and basin. The canal ran inland as far as Launceston, and various wharfs along its route allowed cargo to be loaded and discharged. An extremely unusual feature of the canal was the use of incline planes rather than locks, which allowed the cargo 'tub boats' on the canal to be towed up and down the hills and inclines inland (Bude Canal and Harbour Society).

The canal was never profitable and developing technology eventually rendered it obsolete. In 1898 a railway line from Holsworthy to Bude was opened. A significant impact of the railway was the impact on tourist traffic, and Bude began to flourish as a coastal tourist destination (Cornwall HER).

Modern (20th Century)

The most significant development in this area during the modern period was the establishment of military defences during the Second World War. In the southern part of the study area, particularly around Bude where the beach represented a potential enemy landing site, numerous pillboxes and anti-tank obstacles were constructed in the early years of the war. Summerleaze Beach in particular was closely defended with pimples and concrete blocks. Around 60 of these are still extant (although they have been moved from their original positions) and many feature period graffiti (Council for British Archaeology, 2006).

In 1940, RAF Cleave was established four miles north of Bude. Although a grass airstrip, the site had numerous hard structures including perimeter tracks, barracks, offices and other buildings, dispersal pans, AA positions and numerous pillboxes and bunkers. Many of these remain extant and the main airfield itself was redeveloped in the 1960s to become a radar station that has since evolved into Government Communications Headquarters (GCHQ) Bude (Council for British Archaeology, 2006).

The site of GCHQ Bude may have been chosen because of its proximity to Widemouth Bay. The bay is the landing point for several submarine cables that originate in other countries and GCHQ Bude was used to monitor communications along the cables. The first Transatlantic Telecommunications Cable was laid between the USA and UK in 1963, from Widemouth to New

Jersey and to date eight such cables have been landed at Widemouth where they are connected to the nearby repeater station (Bamford, 2008:pp. 215–217).

3G.1.3 Current Environmental Impacts, Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the North Cornwall and North Devon coastline and reviews the current coastal management issues and approaches. Particularly relevant to this element of the report is the North Cornwall Shoreline Management Plan (SMP), Unit 7B-3 Widemouth Bay to Hartland Point.

Review of Key Contributors to Coastal Change

The coastline is dominated by cliffs and rocky headlands, with some low-lying beaches and coastal sand dunes. The cliffs along the southern parts of the study areas are generally fronted by sand, this decreases further north where there are more narrow shingle beaches. Many of the cliff sections have witnessed landslides, where large amounts of the material break down onto the beaches. However, it is not thought that the cliffs here will retreat significantly so littoral material resulting from cliff erosion will be minimal despite previous landslides (Cornwall Council 2011, SMP). The dominant westerly wave direction and the orientation of this coast means that little material moves along the shore, sediment movement is predominantly offshore-onshore.

As well as natural erosion the few low-lying areas of the coast around Widemouth, Crooklets and Summerleaze where there is good access to the shoreline, are impacted by tourism and developments, and many other parts of the coast are being affected by agricultural pressures. The coast here is internationally significant for its ecology, geology and archaeology and this is reflected by the various designations including SSSI, AONB, GCR and Heritage Coast.

The severe storms over the winter of 2013-2014 saw huge waves hitting the coastline. South of the study area witnessed dramatic changes with the iconic natural rock formation at Porthcothan Bay destroyed by waves, and huge amounts of sand lost from beaches at Newquay which exposed a shipwreck. Sand from the beaches within the study area was stripped by the waves during the storms, however, the natural on-shore off-shore sediment regime in the area means that much of this will slowly be pushed back to the beaches over time.

Summary of Current Coastal Management Approach

Four areas within the case study currently contain coastal defence structures, these are Widemouth, Crooklets Beach, Bude and Hartland Quay. The coastline has witnessed a long history of cliff erosion, the current shoreline management plan proposes that this natural regime of erosion and retreat should be allowed to continue, ‘this is a coastline where non-intervention is vital’ (Cornwall Council 2011, SMP), this is in order to maintain the diversity and richness of the coastal habitats. Currently these habitats exist in a narrow margin between the coastline and farmlands, in these areas the National Trust Management Plans are encouraging schemes for habitat recreation, alongside Natural England who are also introducing new grazing regimes to help restore the habitats.

Further south around Bude previous holiday developments have had a negative effect on the coastal landscape, recent work has been carried out to restore and re-vegetate the dunes at Bude. Other areas along this coast have also been affected by the pressures of tourism and agriculture, beaches at Widemouth, Crooklets and Summerleaze are popular tourist attractions as they are some of the few low-lying points in an area dominated by cliffs.

Widemouth includes important habitats and geology, where the entire Namurian succession of the Crackington Formation is exposed (Cornwall Council 2011, SMP) and areas are part of the Boscastle to Widemouth SSSI, the Heritage Coast and Cornwall AONB. The SMP also recognises the palaeo-environmental potential of Widemouth due to the submerged Neolithic forest remains. The coastal management strategy for Widemouth is to hold the existing line of defence, but in areas where there is no existing defence a strategy of do nothing will be implemented (Cornwall Council 2011, SMP).

From Widemouth to Bude the coast has a history of landslides and rockfalls, and again contains important habitats and geology reflected through its SSSI status. Roads along this coast and buildings such as the Coastguard lookout are at risk from coastal erosion. Archaeological monuments, mainly tumuli are located along the cliff top but are not thought to be at risk as they are quite set back (Cornwall Council 2011, SMP). The strategy here is to do nothing. In Bude itself where existing coastal defence structures are in place, this will be maintained, the undeveloped areas will be left which may result in the need to relocate the coastal footpath (Cornwall Council 2011, SMP).

From Crooklets to Hartland Point some buildings are at risk from coastal erosion, including the lighthouse and quay at Hartland along with archaeological sites at Duckpool. Again the area includes SSSIs, is an AONB and Heritage Coast. The SMP proposes that the assets are not at risk in the short to medium term, although the possibility of landslips should not be discounted, the preferred strategy here is to do nothing, although existing structures at Hartland Quay will be maintained.

Overall the current coastal management strategy for this study area is to do nothing, the SMP stresses the importance of natural erosion in maintaining the rich and diverse habitats as well as allowing new geological exposures to be opened up and coastal geomorphological features to evolve (Cornwall Council 2011, SMP).

3G.2 Archaeological and Palaeoenvironmental Ranking

This section outlines the results of the archaeological and palaeoenvironmental ranking from the North Cornwall and North Devon study area, followed by a discussion of the results. The ranking methodology applied is detailed in Section 2.

3G.2.1 Results of the Archaeological and Palaeoenvironmental Ranking

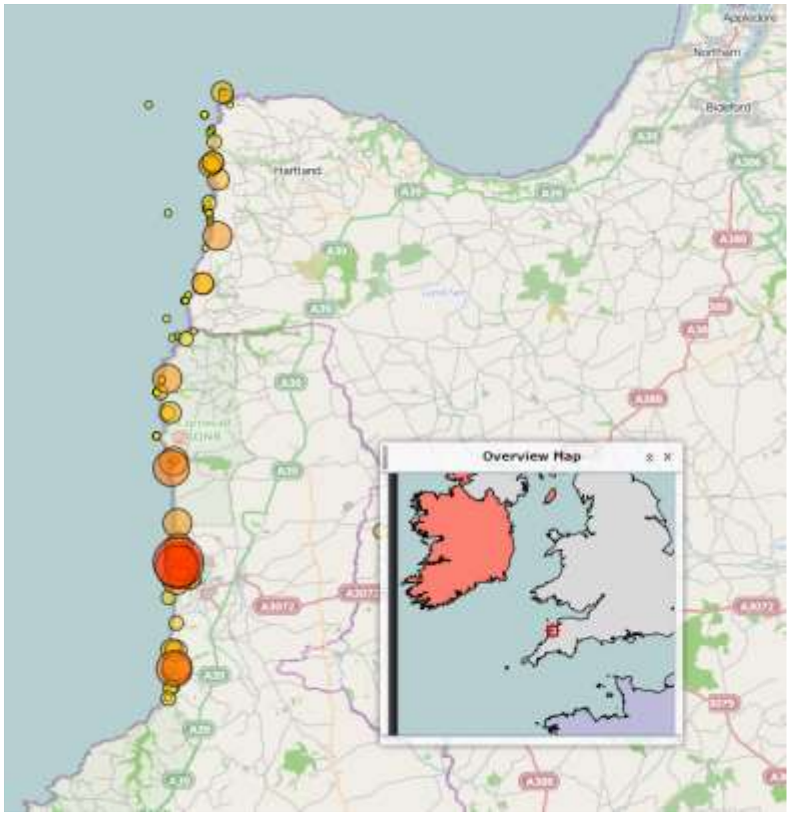

Figure 3G2 Map showing the distribution of all sites assessed within the North Cornwall and North Devon study area.

Within the North Cornwall and North Devon study area data was obtained from the local Historic Environment Records (HERs), the National Record of the Historic Environment (NRHE), the United Kingdom Hydrographic Office (UKHO) and the English Heritage Peat Database. It should be noted that the data obtained from the HERs was often limited, and where sites scored highly further research was then required in order to understand the full nature and extent of the site. Each data set went through a process of cleaning, in order to prevent the duplication of sites, this process is detailed further in the Methodology Section 2. A total of 240 sites and records were assessed.

The highest ranking sites are listed in the table below (Table 3G1), the total score has been normalised to give each site a score out of 100.

ID	Site Name	Site Type	Period	Score – Sea Level	Score – Environmental	Score – Temporal Continuity	Total Score	Coastal Context	Broad Environment type
27	Crooklets Beach – Prehistoric Forest	Submerged Landsurface	Prehistoric	High	High	High	100	Marine	Marine
36	Crooklets Beach – Peat Deposits	Submerged Landsurface	Prehistoric	High	Medium	High	88	Marine	Marine
37	Duckpool – Submerged forest	Submerged Landsurface	Prehistoric	High	Medium	Medium	77	Marine	Marine
12	Widemouth Bay – prehistoric forest	Submerged Landsurface	Prehistoric	High	Medium	Medium	77	Marine	Marine
39	Maer Lake – Submarine Forest	Submerged Landsurface	Prehistoric	High	Medium	Medium	77	Marine	Marine
24	Northcott Mouth – Bronze Age Barrow	Monument	Bronze Age	Medium	Medium	Medium	66	Above HW	Coastal

26	Duckpool Beach – Industrial Remains	Monument	Roman	Medium	Medium	Medium	66	Above HW	Coastal
11	Widemouth Bay – Romano British Site	Buried Landsurface	Roman	Medium	Medium	Medium	66	Above HW	Coastal
28	Vicarage Cliff – Medieval holy well	Monument	Post Medieval	Medium	Medium	Medium	66	Above HW	Coastal
30	Crooklets – Mesolithic flints	Buried Landsurface	Mesolithic	Medium	Medium	Medium	66	Unknown	Coastal
65	Mansley Cliff – Mesolithic flint working	Buried Landsurface	Mesolithic	Medium	Medium	Medium	66	Above HW	Coastal
703	Maer Lake – Core Sample	Other	Unknown	Medium	High	Low	66	Unknown	Unknown
704	Widemouth Sands – Core Sample	Other	Unknown	Medium	High	Low	66	Unknown	Unknown
14	Bude - Barrow	Monument	Bronze Age	Medium	Medium	Medium	66	Above HW	Coastal
19	Earthquake - Barrow	Monument	Bronze Age	Medium	Medium	Medium	66	Above HW	Coastal

Table 3G1: Highest ranking archaeological and heritage sites within the North Cornwall and North Devon study area

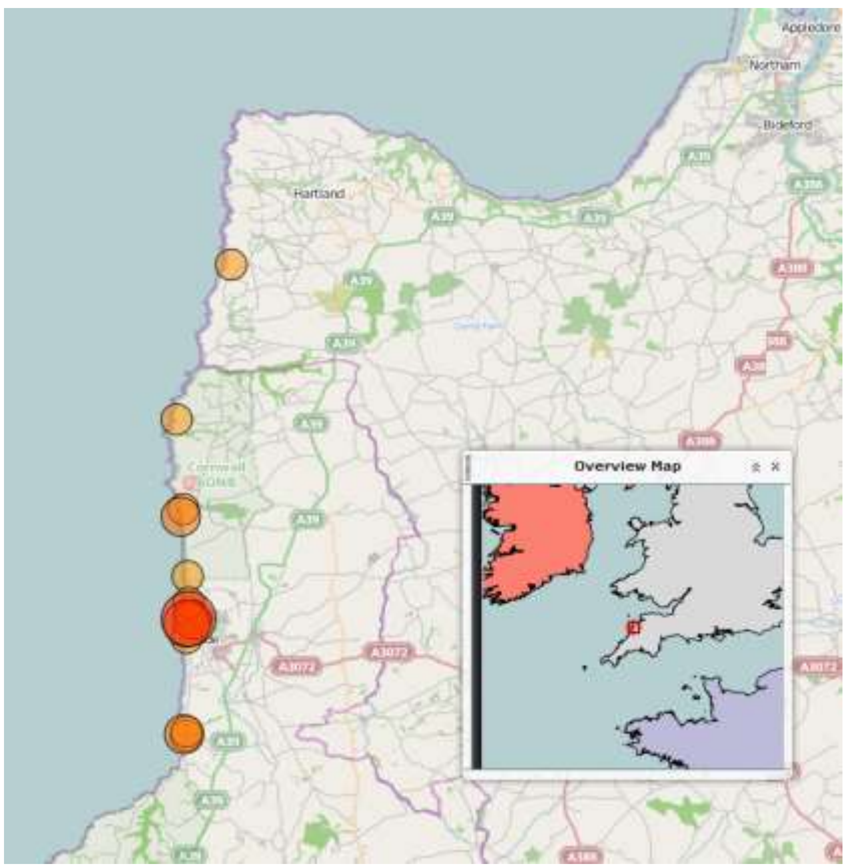

Figure 3G3 Map showing distribution of highest ranking archaeological and palaeoenvironmental sites within the North Cornwall and North Devon study area.

The following tables provide the breakdown of numbers of sites ranking ‘high’, ‘medium’ and ‘low’ for each category within this study area.

Ranks for sea level change

	High	Medium	Low

Number of sites	5	38	197

Ranks for environmental change

	High	Medium	Low
Number of sites	3	20	217

Ranks for temporal continuity

	High	Medium	Low
Number of sites	2	26	212

Table 3G1. Results of the three archaeological and palaeoenvironmental ranking categories

3G.2.2 Discussion of the Ranking Results

High ranking sites (Table 3G1) from the study area range from the Mesolithic to Modern periods. The sites with the highest ranks were submerged prehistoric forests, particularly around Bude, Crooklets Beach and Widemouth Bay. At Crooklets Beach core samples taken in 2002 provide detailed information on the Holocene environmental sequence, the site also contains evidence of Mesolithic and Neolithic occupation. Two sites containing large amounts of worked Mesolithic flints have also been found eroding from the cliffs at Crooklets and Mansley Cliff. These sites can provide detailed information on sea level and environmental change, and Holocene cores like those taken from Crooklets can also provide a detailed running chronology.

Other high ranking sites include Bronze Age barrows, particularly around the cliff tops at Bude including some which have partially eroded. A Romano-British site has also been exposed by erosion and includes several hearths. Medieval and Post-Medieval sites also ranked highly, these include wells, the quay and pier at Hartland which is still partially visible although much was destroyed in the late 19th century, and wreck sites. More modern sites include the canal, breakwater and pier at Bude, and even WWII defence structures, although many of these are not included in the list of highest scoring sites they still ranked medium for sea level change, one site at Northcott Mouth has partially collapsed due to erosion by the sea.

3G.3. Analysis

The North Cornwall and North Devon study area contains a wealth of archaeological and palaeoenvironmental evidence which can improve our understanding of past sea level and environmental change. Evidence from Crooklets Beach was ranked the highest, the site contains a submerged forest, peat deposits containing timber fragments, and a Mesolithic flint working site nearby. The forest was first recorded on a map in 1848, it is also shown on the 1880 Ordnance Survey map just below mean high water (see Figure 3G4). Environmental analysis of further material recovered during cable works in 2000 revealed that the environment of Crooklets Beach was predominantly woodland with swamp and freshwater pools dating to at least 3750-2200 BC (Kirkham & Herring, 2006:172). The submerged forest was mainly oak and alder with some ash and willow and has been radiocarbon dated to between 3750-3500 BC, open water pools also existed as evidenced by finds of aquatic plants and the Crooklets stream is said to have flowed through swampy environment, then woodland on the lower slopes of the bay and then out to sea (Kirkham & Herring, 2006:172). Although no evidence of human activity was found in this area a flint knapping site from the late Mesolithic was recorded inland from the beach, flints were first discovered eroding from the cliff in 1972. This data can help to reconstruct the prehistoric landscape, and to understand the change in sea level since this period.

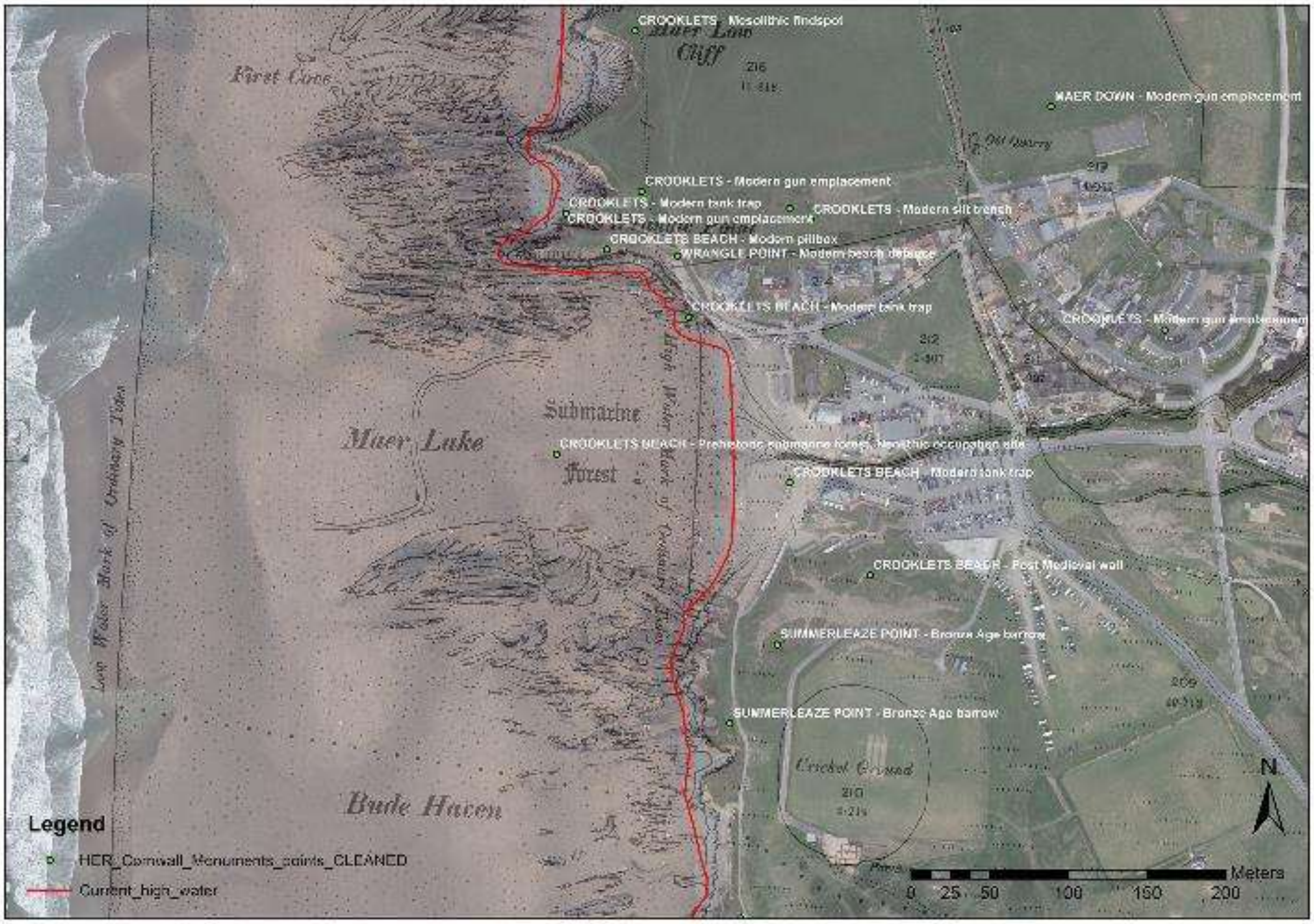

Figure 3G4. Map showing the location of the submerged forest at Crooklets Beach from the 1880 Ordnance Survey Map overlain on 2013 Aerial Photography (CCO). The red line shows the current high water mark, which in the centre of Crooklets Beach is 24m further inland than then HW mark on the 1880 map. The green dots show site data obtained from the Cornwall HER.

3G.4. Conclusions and Recommendations

For the Arch-Manche project the focus of the North Cornwall and North Devon study area has been on the archaeological and palaeoenvironmental evidence. However, results from other case study areas has shown that valuable information can also be gained from the use of historic maps, charts, photos and historic artworks. Although this report has demonstrated the value of archaeology in improving our understanding of coastal change, particularly through the evidence of submerged prehistoric forests, maps, charts, photos and paintings could help to refine our reconstruction of the coastline from the last few hundred years. A brief review of the 1880 Ordnance Survey Map, overlain on 2013 Aerial Photography (courtesy of the CCO), has helped us to see change in the last 123 years (see Figure 3G5), such maps also include information on the high water mark which can be compared with today.

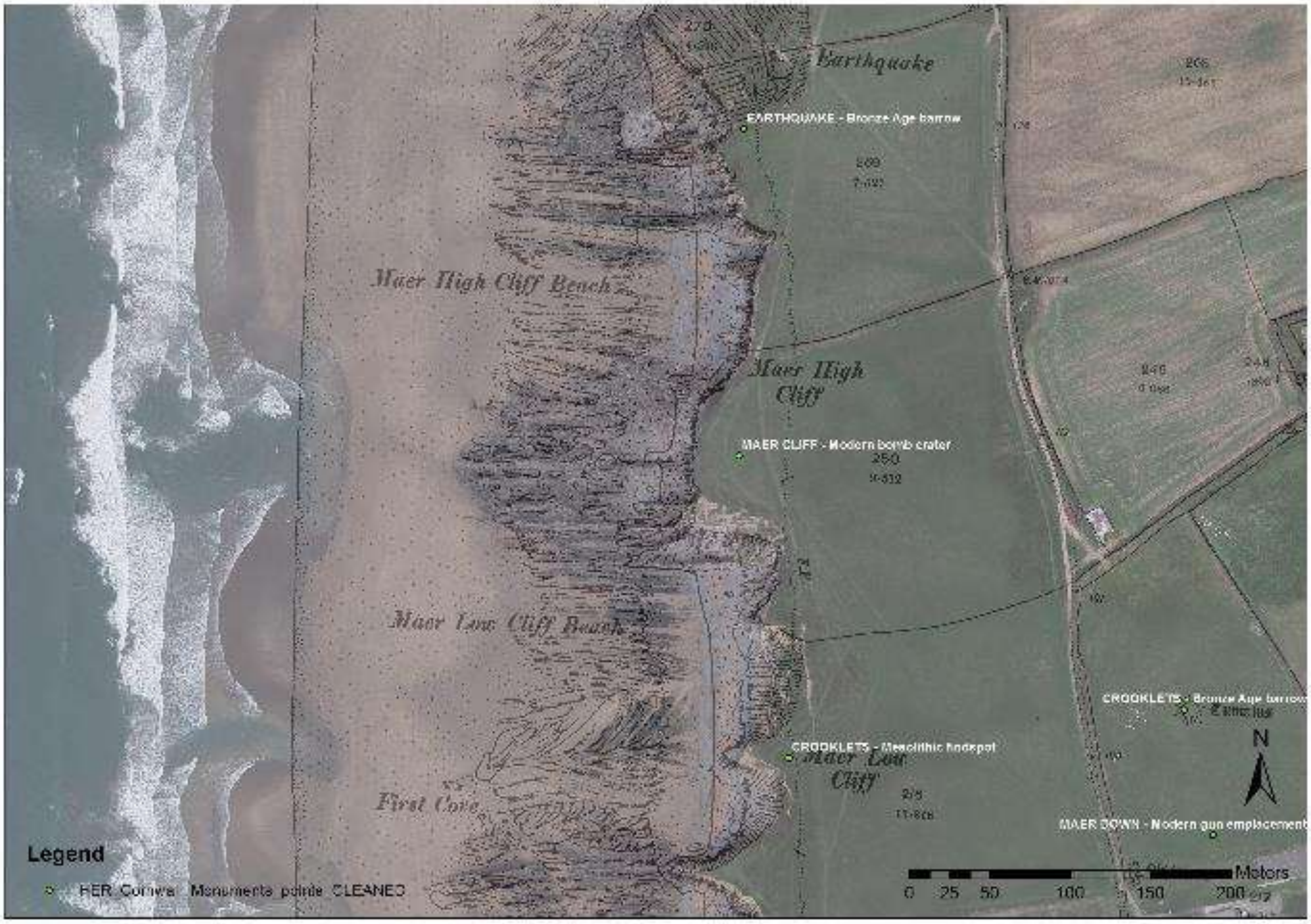

Figure 3G5. Map showing the 1880 Ordnance Survey overlain on 2013 Aerial Photography (CCO) around Maer Cliff. The cliff shows very little change over this 123 year period.

There is no shortage of available works of art from within this case study area. The 'wild' nature of the coastline here, and development of Bude as a tourist destination drew a number of established artists to the area. Just one example is shown in Figure 3G6 which shows a view of Nanny Moore's Bridge in Bude which is a grade II listed structure, painted by Joseph Stannard who was a prominent member of the Norwich School of artists. The history of the bridge can be traced through historic photographs up until the situation in the present day.

The geology of the North Cornwall and North Devon coastline is relatively resistant, dominated by hard cliffs and rocky outcrops. However, the area has witnessed a number of landslides and continual natural erosion, with the current shoreline management plan favouring a policy of no intervention along the majority of the coast. These processes have revealed archaeological material which has the potential to inform coastal managers on the rate and scale of past coastal change to help with planning for the future. However, much of this material may be lost before it is fully recorded. Evidence all along the coast can tell us about the environment and coastline both over the long and short term, with material from the Mesolithic and Neolithic up to WWII.

Figure 3G6: Painting by Joseph Stannard c. 1830 showing Nanny Moore's Bridge in Bude (Reproduced with permission of Newport Museum and Art Gallery)

Further work is required in order to reconstruct the prehistoric landscape, combining the environmental data obtained from sites like Crooklets Beach, with information on relative sea level rise it would be possible to demonstrate how this landscape looked in the Mesolithic and Neolithic periods. Combining this with data from later periods including Bronze Age, Iron Age, Medieval and more modern sites would allow us to understand how this coastline has changed over thousands of years, as well as the rate and pace of change. The incorporation of artistic images, maps, charts and historic photographs from the last two to three hundred years would increase the resolution of understanding of change during this period.

This report is a section of the Technical Report for the Archaeology, Art and Coastal Heritage – tools to support coastal management and climate change planning across the Channel Regional Sea (Arch-Manche) Project. To cite this report please use the following:

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3G.5 Case Study References

Balaam, N, Bell, M, David, A, Levitan, B, Macphail, R, Robinson, M. and Scaife, R. 1987 'Prehistoric and Romano-British sites at Westward Ho!, Devon: archaeological and palaeoenvironmental surveys 1983 and 1984' in 'Studies in palaeoeconomy and environment in south-west England. BAR British Series 181', (eds) Balaam, N, Levitan, B. and Straker, V, 163-264, Oxford: British Archaeological Reports.

Bamford, James. 2008. *The Shadow Factory*. New York, USA: Anchor Books.

Berridge, P, and Roberts, A., 1986. The Mesolithic Period in Cornwall. In: Cornish Archaeology, 25.

Bell, M. and Brown, A., 2009. Southern Regional Review of Geoarchaeology: Windblown deposits. English Heritage.

Bude Canal and Harbour Society. 2013. *History.* Available from: http://bude-canal.co.uk/Bude%20Canal%20History.htm. [Accessed December 2013].

Buscombe, D., and Scott, T.M. (2008) Coastal Geomorphology of North Cornwall: St Ives to Trevose Head. Internal report for Wave Hub Impacts on Seabed and Shoreline Processes, University of Plymouth. 170pp.

Cornwall Heritage Trust. 2013. *Cornish History.* Available from: http://www.cornwallheritagetrust.org/page_history.php. [Accessed December 2013].

Cornwall HER

Cornwall County Council. 2007. *Cornwall and Isles of Scilly Mapping Project: A report for the National Mapping Programme*. Cornwall County Council.

Cornwall County Council, 2011, Cornwall and Isles of Scilly Shoreline Management Plan Review.

Council for British Archaeology (2006) *Defence of Britain Archive*. York: Archaeology Data Service (doi:10.5284/1000327)

Devon HER

Finch, S. and Gaffney, V., 2011, West Coast Palaeolandscapes Survey, Visual and Spatial Technology Centre, University of Birmingham.

Hobbs, Stephen. 2009. The Manorial and Monastic Estates of Hartland. In: *Results of an Archaeological Investigation of Hartland*. The Hartland Society.

Kirkham, G and Herring, P (eds). 2006. *Cornish Archaeology*. Cornwall Archaeological Society.

Webster, C. J, (ed), 2007, South West Archaeological Research Framework: The Archaeology of South West England, Resource Assessment and Research Agenda. Somerset County Council, Taunton.

CASE STUDY 3H – CÔTE D'EMERAUDE, FR. (Brittany)

Case study area: Côte d'Emeraude, Brittany, France

Main geomorphological types: Rocky cliffs, sandy beaches, dunes, islets and estuaries.

Main coastal change processes: Coastal erosion, cliff instability, beach change.

Primary resources used: Art and archaeology.

Summary: The study area comprises extensive cliff lines, sandy dunes and beaches which are subject to erosion and instability. Archaeological records and artistic depictions have enabled us to see the rate and scale of this erosion over the last millennium. The palaeoenvironmental and archaeological records demonstrated these changes, particularly from the Iron Age period.

Recommendations: Coastal managers should use these resources when predicting future rates of erosion, they provide hundreds of years' worth of data to assist in the understanding of the rate of change. Further work into historic maps and charts is recommended as this can provide even more detail particularly from the 19th Century.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

The Côte d'Emeraude area is one of four case studies within the Brittany area of France. This case study report introduces the study area and why it was chosen as part of the project. This report presents the results of the detailed art study. No specific archaeological or palaeoenvironmental field work has been carried out, however, former archaeological field studies have provided data regarding the coastal evolution in this area. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. Further details about the project methodology applied can be found in Section 2.

Within the Côte d'Emeraude area, the archaeological and palaeoenvironmental resource and the available art resource have been researched, scored and analysed. The extents of the detailed study areas are shown in Figure 3H1 below. The area considered for archaeology and palaeoenvironment has been selected to provide a representative range of types of evidence across a range of periods spanning from Palaeolithic through to more modern coastal heritage. The art, photograph and map case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time.

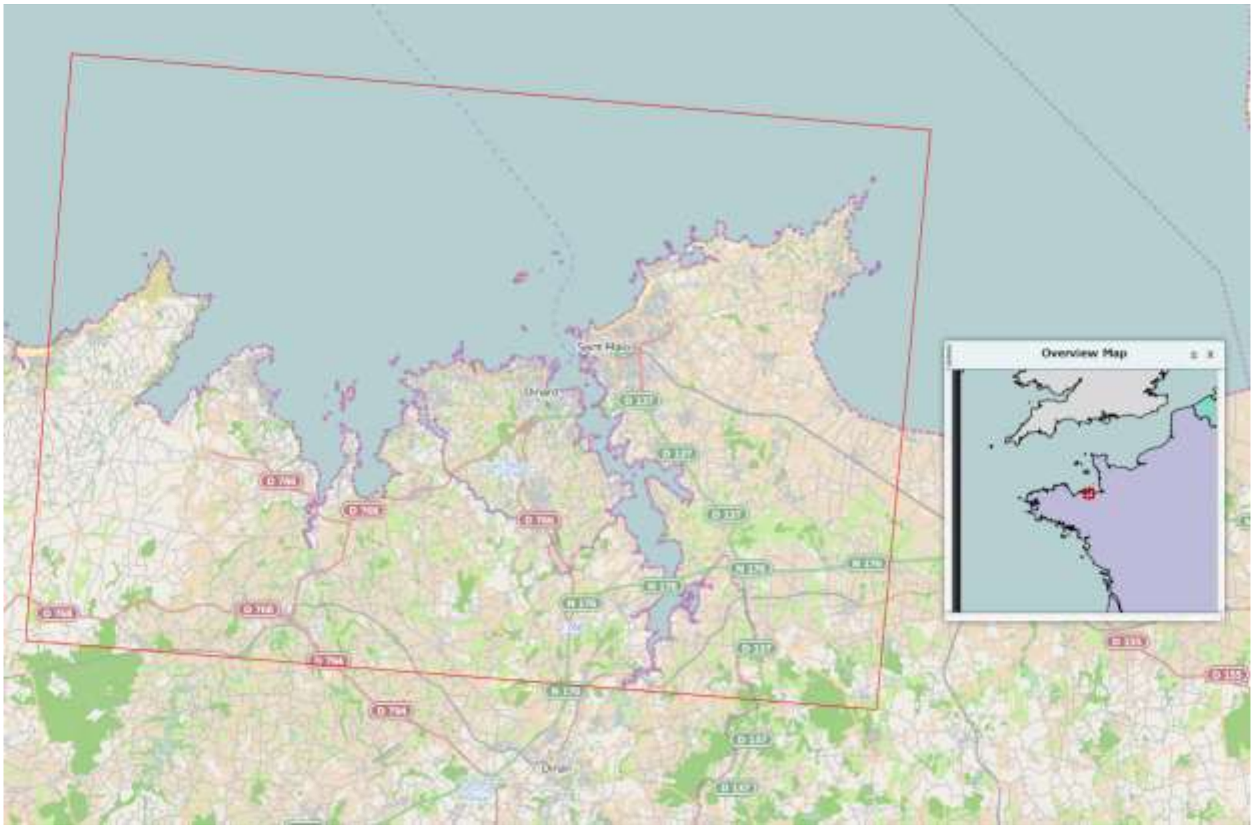

Figure 3H1. Map of the Côte d'Emeraude study area.

3H.1 Introduction to the Cote d'Emeraude Study Area

In Northern Brittany, the "Côte d'Emeraude" is located on two departments: Ille-et-Vilaine (with Cancale at its eastern limit) and Côtes d'Armor (Cap Fréhel being the western limit), and represents just under 100 km of coastline. The name 'Côte d'Emeraude' is quite recent, dating to the end of the 19th century it corresponds to a tourist area without any proper cultural or political identity. Located along the English Channel, the Côte d'Emeraude comprises numerous bays and capes as well as peninsulas, islands and islets, in addition to important geographical features such as the Rance and Arguenon rivers estuaries.

Tourism has developed very quickly in this area since the middle of the 19th century, with various coastal constructions such as dykes, embankments, roads and buildings having created an 'artificial' coastline. The economy of this area mainly relies on tourism, with an important demographic development along the coastal belt. Beyond the buildings occupied by inhabitants, there are many secondary residences and establishments dedicated to tourist activities such as hotels, a casino and spa. This tourist economy is based on the coast and the attaction o fhte maritime environment. In spite of the attempts to manage the position of the coastline with dykes and embankments, it is important to remember that the shoreline has changed. Sedimentary and climatic changes have played a great part in these changes, as well as storms.

Recently, new mesures have been taken to protect populations and installations, mainly after the Xynthia storm (in 2010), when the prescription of a Risk Prevention Plan – Marine Submersion (PPR-SM) has been set up for all the coastal parishes (Collective, 2009 and 2013), governed by the Environemental code (since 1995). Frequenlty, coastal protection structures are damaged during storms due to a combination of waves, high tides and a storm, e.g. in 1905 when the Saint-Malo dike was partly damaged. Nowadays, private structures along the Saint-Malo dike are regularly damaged by climatic events.

3H.1.1 Geomorphology of the Area

This section outlines the key geological and geomorphological features and processes of the study area. These factors have a significant impact on the on-going changes to the coastline and associated sites, deposits and features preserved related to the archaeological and heritage resource, in addition to being depicted through a range of art sources.

Geological History

The geology widely explains the shapes, structures and landscapes of the coastal areas. Since the formation of the geological features, the erosion and the long term resistance (several millions years) have underpinned the present landscapes. Erosion acts differently according to the geomorphology (cliffs, beaches) and the bedrock material (limestone, granite). Within the general geology of the area, there are metamorphic rocks to the east (from Cancale to Saint-Jacut), Precambrian sediments [top of Earth-590 Ma] (Saint-Jacut Fort La Latte) and magmatic cadomian rocks and Paleozoic sediments (Fort La Latte in Cape Frehel) (Graviou 2012: 14-18; Plaine and Jegouzo 2012: 14-17; Le Goff *et al*., 2009, Cogné *et al.,* 1980).

One of the main geological features in this area is the Massif of Saint-Malo (Jonin 2008 : 50-53), which is ‘cut’ by the Rance river estuary. The Massif de Saint-Malo has a ‘*metamorphic continuum*’ from micaschist and gneisses green schist features (south) to anatectic granites (north) through the rocks of amphibolite 'facies', which makes this zone, among other things, of major interest within geology education. Originally it was silty or more sandstone, rich in alumina, sometimes more calcium, the base of the sedimentary pile lying north in the current part migmatitic. All these sediments of Brioverian lower age (590-600 million years? were affected by metamorphism ‘Low Pressure - High Temperature’, within the Cadomian chain, around 540 million years ago. They also recorded several episodes of deformation, probably three, more or less easily identifiable on the outcrop or that are deducible from regional measures of 'schistosity' or foliation.

Geomorphologic Processes and Human Intervention

The sedimentary superficial deposits of the northern coast of Brittany, between cap Fréhel and Saint-Malo, were recently studied using side-scan sonar data, sediment analysis of subtidal and tidal facies, and morphological analysis of intertidal and shallow-water areas (Bonnot-Courtois *et al*. 2002). The tidal range in this area reaches 14 metres during high spring tides, giving rise to strong tidal hydrodynamics. The intertidal sedimentary deposits have a complex distribution linked to the wide range of coastal geomorphology.

The subtidal zone is dominated by coarse-grained deposits, which are the main offshore sediments. Grain-size progressively decreases until close to the shore where sandy sediments overly the bedrock. The superficial sand cover in places shows various bed forms at water depths of 5 to 15 metres. The coastal zone is characterised by numerous rocky outcrops and very coarse grained sediments distributed widely over the mapped area; it is an abrasion platform that evolves under very high hydrodynamic conditions and consequently has a poorly developed sedimentary prism.

The shoreline of the coast has undergone many changes. In the eastern part, strong tides (among the largest in Europe) have caused long term landscape change, eroding cliffs and bringing sediment into bays. Climatic events such as storms and tidal waves have an undeniable impact, they can alter the coastline either temporarily or in the long term (storms can fill bays). More than 40% of the erosion is caused by storms and marine activities such as wave action or flooding of low-lying areas (Hénaff *et al* 2007). This change in the coastline may cause changes in human activities (fishing, sailing).

The erosion is exacerbated by humans, with actions such as the modification of river banks, aggregate extraction in river beds and sea drainage of coastal marshes, and planting work impeding natural transit of sediment. The construction of beach frontages, followed by the building of sea defences against erosion, often accelerate erosion. The extraction of sand near sea sedimentary shores further accentuates this erosion.

In the Rance river estuary, the building of the Rance Tidal Power Station in 1966 (which takes advantage of the huge tide potential) had a great impact on the estuary and river landscape and activities; the dam provides electricity to the surrounding cities but deeply impacted the sediment budget of the river and of the estuary. Indeed, there are significant sediment supplies with artificial immobilisation of several hours of sea water upriver, promoting sedimentation of fine particles. Then, there is a silting of the Rance, with an extension of mudflats (accumulation of up to 3m). This brings various consequences: reducing the width of the channel (which decreases the flexibility for use by ships), modification of wildlife since some fish only reproduce in the sand. The estuary of the Rance River is now entirely shaped by human actions (Bréhier *et al*. 2009-2010).

In order to protect the main tourist coastal cities, such as Saint-Malo, against erosion, numerous dykes have been built along the coasts, even when some geomorphologists had pointed out that such structures may speed the erosive and sedimentary processes. During the early 19th century, the northern coast of the municipalities of Saint- Malo and Paramé consisted of dunes occupied by windmills and industries. The first works to build a dyke were achieved in 1854 in the municipality of Saint-Malo at the east end of the furrow between the wedge and the Piperie mill belonging to MM. Challah and Le François. In 1856, M. Palmié completed a defensive wall 270 meters long, continuing from the first dike (called "*dike Tourou*"), to protect its lime kilns and other industries. In 1853, a violent storm seriously damaged the existing defenses. In October 1856, the government approved the draft continuation of the dyke, increasing its length to 449 meters. The work of the "Dunes dykes" was completed in 1858. After several additions and recognising the importance of the dyke to the emerging tourist seaside resort of Paramé, the Société des Bains de Mer decided to fill the gap of 3 meters from the dike Lemoine to align it with the dike Dunes. Stairs were built in 1887 for access to the beach. Benches were installed by 1900, street lights in 1909. To protect the new villas, the dam was repaired in 1887 by the State. In 1903, the project to repair the dam Lemoine to the rear of the Hoguette was achieved through management. The dam in its current state extends over 900 meters between the wedge and the Piperie Rochebonne and has been fully built or rebuilt by the state between 1854 and 1905 (Figure 3H2).

Coastal evolution is sometimes said to be forced by storms, sometimes by average meteorological conditions; this point has been documented by geomorphologic studies (Regnauld *et al*., 2010), especially on the Verger Bay site. The exact role of very strong storms is therefore a widely debated issue. On the northern coast of Brittany, a site located in the eastern part of the Côte d'Emeraude, Verger Bay, has been surveyed for the last 20 years and has evolved under the control of human management, long periods of calm weather and three large storms. The weight of each of these agents on coastal evolution has been examined. Their respective impact is highly variable in time and in space, thus making it very difficult to understand coastal behavior with a simple conceptual model of forcing, controls and resilience.

These notions do not have the same meaning depending on where they are applied but storms appear as the main forcing agent on a large extent of the studied coastline.

Figure 3H2. The Saint-Malo/Paramé dyke after the 1905 storm (ancient postcard H.L.M ed.)

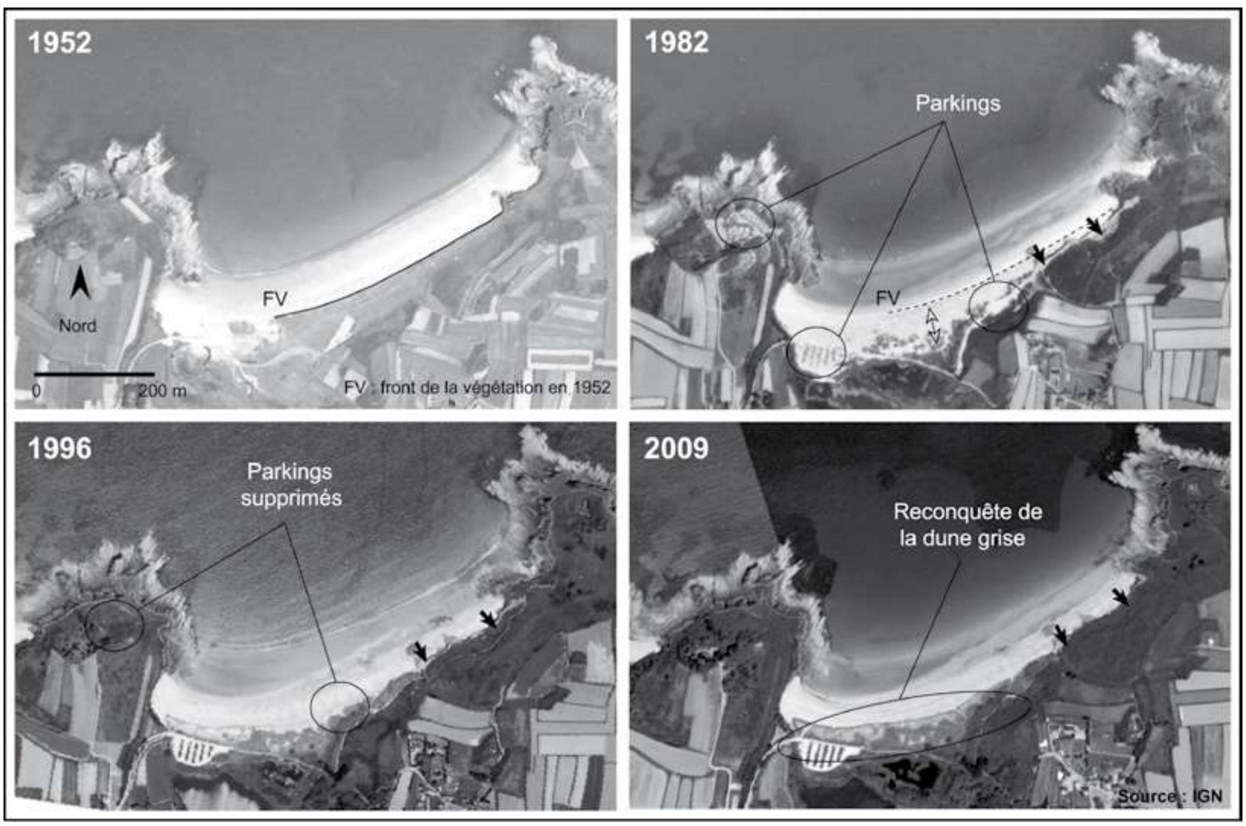

Figure 3H3. Evolution of the Verger Bay case study site, based on IGN (Institut Géographique National) air photos, showing the coastline changes and the main natural and anthropic causes (building then removal of the car parks) (after Regnauld et al., 2010)

In northern Brittany, an important geomorphological response to Holocene sea level rise has been the development of coastal dunes with associated lagoons and marshes. At Verger Bay (Figure 3H3), a marsh has formed behind a dune system which has been developing *in situ* for the last 4000 years. The litho-stratigraphy of the marsh comprises extensive peat formation, with sands, silts and occasional sand lenses, the latter probably associated with storm surges. The sequence dates from 10,320±120 BP. After 3000 BP, flood episodes on the marsh are more common, while the upper marsh deposits can be correlated with the recent period of dune building. Prehistoric artefacts (remains of cooking implements) have been found on a cliff to the east of the marsh and are buried by wash over deposits, which indicate a sudden abandonment of a settlement possibly due to a storm surge soon after 2460±80 BP. Surge levels are proposed as a controlling factor on dune crest elevation (Regnauld *et al*., 1996).

3H.1.2 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for Project

The archaeological and palaeoenvironmental data has been obtained from the Atlas des Patrimoine (Culture Ministry), available online (http://atlas.patrimoines.culture.fr/atlas/trunk/), and from the databases of scientific research groups: AMARAI (Association Manche Atlantique pour la Recherche archéologique dans les Îles) and CeRAA (Centre regional d'Archéologie d'Alet, Saint-Malo). Extensive documentation was also provided by the Archéosciences laboratory of the Rennes1 University, which is a component of the federative research group Unité Mixte de Recherche 6566 du CNRS- CReAAH (Centre de Recherche en Archéologie, Archéosciences, Histoire). Another important resource centre for historical periods is the 'Society of archaeology and History of the Saint-Malo area'; dedicated to maritime history, and especially shipwreck studies, the ADRAMAR (Association pour le Développement de la Recherche en Archéologie MARitime) provide an important documentary set, now available online (Atlas Ponant et Atlas des 2 mers: http://adramar.fr/atlas/). Several books concerning the history of the region have been consulted and used (Giot *et al*., 1995 and 1998; see also References Section 3H.7 below), as an abundance of historical literature exists for this region, due to the richness of its past history and stimulated by the importance of the tourist industry.

3H.1.3. Summary of the Archaeology and History of the Côte d'Emeraude Study Area

The archaeological and palaeoenvironmental study area is quite well known, thanks to the research carried out by two research groups:

- The 'Centre Régional d'Archéologie d'Alet' (Ce.R.A.A. created in 1974) which enabled the discovery, excavation and study of several major archaeological sites in this area, situated on the coast as well as inland; and
- The 'Association Manche Atlantique pour la Recherche Archéologique dans les Iles' (AMARAI, created in 1988) is more specifically focused on coastal and island archaeology.

Numerous archaeological sites are known in this area, but many of them have been damaged or destroyed along the coasts, due to various reasons: natural erosion, climatic events, or anthropic pressure. WWII had a particular impact as the city of Saint-Malo and the surrounding area was considered as a strategic area; the Atlantic Wall was built along with numerous concrete structures built on places where archaeological remains had been formerly foun. Many archaeological sites also suffered from bombing, e.g. on Cézembre island where a famous pre-roman settlement was destroyed in 1944.

Early Prehistory (Palaeolithic and Mesolithic)

Some Paleolithic sites are currently on the foreshore, showing the rise in sea level since their construction (e.g. Port-Briac Cancale). Paleolithic sites have existed on the islets and islands of the Côte d'Emeraude, however, some of them were destroyed by military structures, particularly during WWII (an example being the Grand Bé site (Saint-Malo) where bunkers were built). Many islets and islands are accessible at low tide, especially between Dinard and Saint-Malo. The presence of archaeological remains on these sites, suggest that with the rise in sea level, many other remains are now submerged or missing (source: CeRAA - Centre Régional d'Archéologie d'Alet).

The Gastines site at Saint-Marc-en-Poulet (Ille-et-Vilaine), on the western bank of the river Rance, lies on the beach. It consists of an open camp dated from the middle Palaeolithic period, located near a rocky cliff. The site provided evidence of lithic industry (flint), but no bone remains or charcoals were preserved. No anthropic structure was visible and the archaeological interpretation is only based on the lithic industry. However, the main part of the site has probably been destroyed by erosion (Monnier 1988).

At present, there has not been any archaeological excavation of any Mesolthic sites in the area, however, some prehistoric layers containing microlithic flint remains have been identified through fieldwalking surveys. The Mesolithic layer at the la Varde peninsula is associated with a contemporary fishtrap, making this site one of the most significant in the area.

Later Prehistory (Neolithic, Bronze Age and Iron Age)

These periods are illustrated by several archaeological sites. On Verger Beach (Cancale), an important shell midden at la Moulière is included in the small sandy cliff and has been seriously eroded by the waves and the pedestrian path leading to the beach. According to the radiocarbon dating, the site was occupied between the early Bronze Age and the early Iron Age. Next to this, a metal age layer has been found on the beach, characterised through ceramic sherds (Cocaign *et al.* 1996 : 71-81).

For the Iron Age, the main site is the coastal cliff castle of Alet (Saint-Servan), located on the right side of the Rance river mouth, and studied since the 1970's, with an intensive excavation program (Langouët, 1996: 31, 34). It consists of a pre-Roman town, densely settled and largely focused on commercial activities as a port of trade (*Reginca*) which was closely linked to Hengistbury Head (Dorset, UK). This pre-Roman town is located at a strategic crossing point for river, land and maritime routes, the exchange networks and long distance trading are illustrated by the numerous finds of goods coming from the Mediterranean area as well as from across the English Channel.

Roman Period

Even if the city of Alet had been partly abandoned after a great fire c. 20-25 A.D., the site was still occupied during the Roman period (Figure 3H4); at the lower edge of the city, some port installations have been found in the tidal and underwater area, including a basin and a wooden pump used to supply fresh water to the ships which were moored at the quay. Intensive underwater excavations in the estuary enabled the port to be located. The main landscape changes since the Roman period date to the 4th century when the topography was transformed by breaking through the alluvial bank, which was isolating Solidor Bay from the sea (Langouët, 1996). Such environmental changes explain the discovery of a Roman cemetery at the foot of the Solidor tower, during the building of a new quay in the 19th century.

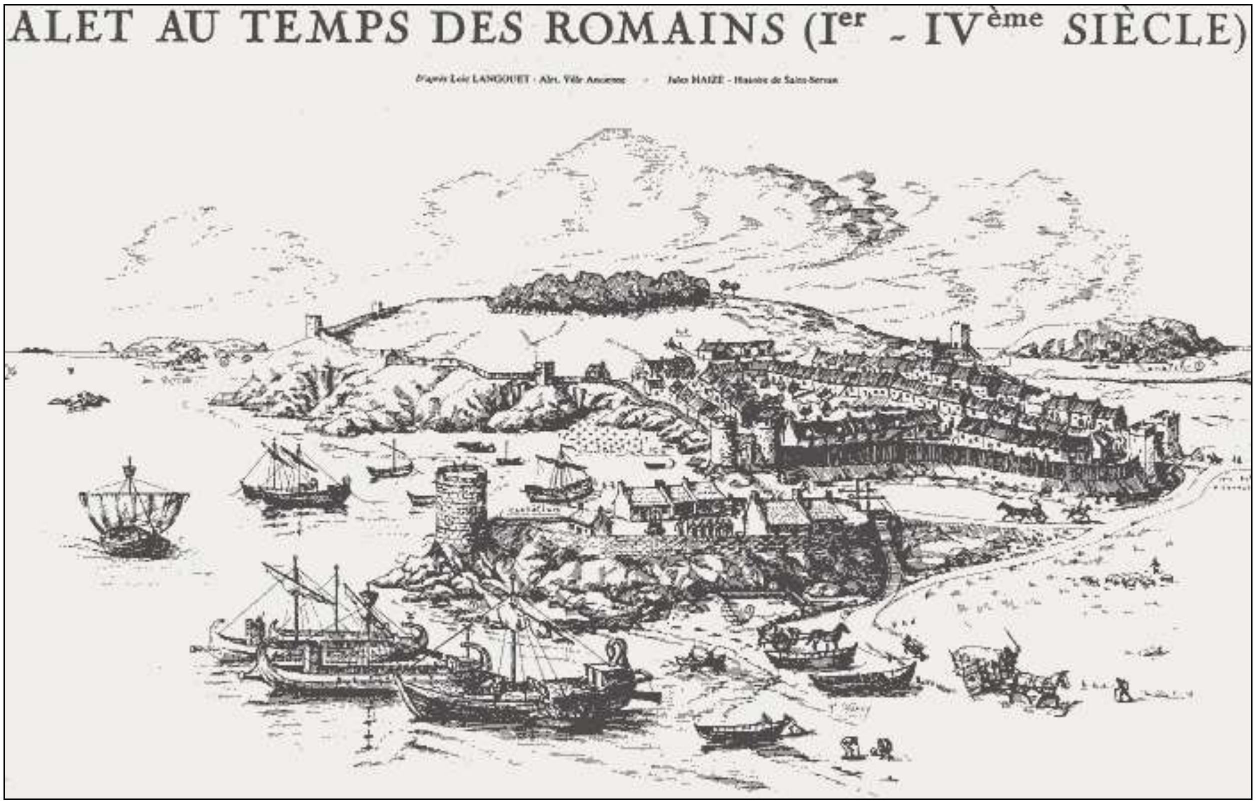

Figure 3H4. The Alet (Saint-Servan, Saint-Malo) castellum and harbour, during the Roman period (after Langouët and Haizé).

Medieval Period (500AD – 1485AD)

During the Medieval period several castles and fortresses are built at various strategic points on the coast. At the foot of Mont Garo (Saint-Suliac), the ‘Viking’ camp named ‘Gardaine’ provides a good illustration of sea level evolution and coastal changes (Figure 3H5). Located in the river Rance estuary and probably built after the 10th century AD, this earth camp is currently partly submerged. Since the building of the Rance Tidal Power Station in 1966, the amount of sediments deposited around the site increased, which is now more easily reachable on foot. This camp was originally a defensive installation, consisting of several lines of wooden posts. During the 19th century the site was damaged and some parts of the banks were destroyed, allowing sea water to invade the inner part of the enclosure. Among the various materials found in the camp are animal bones and iron weapons. The strategic position offers some landing possibilities, as well as control of the fluvial and maritime circulation of ships. Located next to the Châteauneuf-d’Ille-et-Vilaine isthmus, the only way to cross the marshes and gain access to the Clos-Poulet area, the Gardaine camp is also likely to have played a role in controlling land transportation and movement (Langouët 1991).

Figure 3H5. The "Viking camp" of Gardaine, Saint-Suliac (cl. L. Langouët).

Another site from the later medieval period is Fort Lalatte (Plévenon), this military construction was built around the mid 14th century AD, with significant later additions, particularly in the 17th century. It is one of the best examples of coastal medieval fortification with its main fortified tower still preserved. Located on a cape, this fort is linked to the control of the Bay of la Fresnaye (and then of the Saint-Malo port). Other fortified sites include the Chêne vert castle (Plouër-sur-Rance), built on the remains of a medieval fortress (13th-15th centuries) along the Rance river. The Guildo castle (Créhen) is built on a rocky promontory dominating the Arguenon river estuary. The remaining visible structures date from the 14th-15th centuries, however, according to the results of archaeological excavations, the first occupation of the site goes back to the Iron Age.

Several chapels and churches have been built along the coastline during the medieval period, e.g. on the Cézembre island, where a chapel was built during the early 15th century, dedicated to saint Brandan. Later on, a monastery existed on the same island.

In the Rance river estuary, there is a tide mill which consists of a dam and associated channels which utilize the tidal movement of sea water to create energy to run the mill. While millers used this natural energy to grind grain, the process of the installation of dikes changed the sedimentation of the estuaries. Many of these mills date from the late Middle Ages to the Modern period, but most of them were abandoned during the 20th century.

Post-Medieval Period (1485AD – 1901AD)

A significant feature of the Post-Medieval period in this case study area is the building of coastal military defences, most of them belonging to the group known under the general name of 'Vauban' fortifications, which generally lie over former structures: islets of Petit Bé, la Conchée, Harbour, Cézembre island, off the city of Saint-Malo and the Alet fortification, are all dedicated to the protection of Saint-Malo.

In addition, numerous shipwrecks line the bay of Saint-Malo and reflect the rich maritime history of the city (Feige 2005). From 1590–1593, Saint-Malo declared itself to be an independent republic. Saint-Malo became notorious as the home of the corsairs, French privateers and sometimes pirates. The corsairs of Saint-Malo not only forced English ships passing up the Channel to pay tribute, but also brought wealth from further afield. Jacques Cartier, who sailed the Saint Lawrence River and visited the sites of Quebec City and Montreal – and is thus credited as discovering Canada - lived in and sailed from Saint-Malo. The maritime and military history of Saint-Malo is one of the richest of the region.

In the 19th century, the reputation of Saint-Malo and, more generally speaking, the Côte d'Emeraude area, is basde on the development of seaside resorts, particularly since 1830. This lead to the development of the marina, dykes, and paths along the coast and on the beaches. These port and tourist developments often caused a reduction of erosion on the nearby beaches. Due to these developments, traditional human activities on the foreshore such as seaweed farming, collecting sand, and sea life collection disappeared progressively in favour of the tourist economy. For example the ancient fishing port of Dinard became exclusively a beach resort and a sailing port.

The natural landscape has been totally modified, not only by the building of numerous holiday houses, but also by the planting of exotic and imported trees such as acacias, Chinese palm trees, and cedar from Atlas. Some promenades are arranged along the water side, such as in Saint-Malo where there was a path from as early as 1767; the promenades often reused former coastal control paths.

There is a regional tradition of the exploitation of marine products along the coasts, especially with fish traps (Langouët and Daire, 2009, for more details, see the Trégor case study (Section 3I)) and fishing remains an important economic resource for local communities. The exploitation of seaweeds developed with industrial use of soda (especially in gall industry), and is currently marked by the remains of dedicated kilns. The exploitation of clay along the coast (e.g. Sillon beach in Saint-Malo) is linked to industrial activities such as pipe productions, which were then sold locally and also overseas.

Most of the cities of the Côte d'Emeraude area have an economy based on marine fishing (fish and crustaceans) and coastal collection of seafood at low tide. Saint-Malo also developed wider trading activity, with the building of dedicated structures (harbours, ports areas) and shipyards which evolved, mainly since the 16th century, linked with colonial trade and offshore fishing.

Modern

Since the middle of 19th century the emergence of tourist resorts is closely linked to the birth and development of the national railway networks (Clairay and Vincent 2008). Once the preserve of the aristocrats, visiting the seaside for enjoyment and health became more widely available to the population from the mid 1930s (Delignon, s.d.), and fuelled the need for coastal structures such as promenades, hotels and spas. New eating habits emerged with a growth in demand for seafood; oysters farms, some of them exiting since the 16th century, rapidly developed, especially in Cancale bay and the Arguenon estuary, and are still very productive.

The majority of sites from the 20th Century comprise WWI and WWII defence systems. The construction of the Atlantic Wall along the coast, in the 1940s, had various consequences. Concrete military installations along the shore included bunkers, batteries, guns etc, many of which were situated in strategic areas, transformed the coastal landscape. However, the destruction of these installations during the Liberation (through blasting and disassembly, e.g.

bombing of Cézembre island, Cardin 2003-2004) also caused the complete destruction of archaeological and historical sites.

Figure.3H6. Saint-Servan harbour in the early 20th century (cl. Gauthier).

3H.1.4 Art History of the Area

This section presents the background to artistic representations within the area including key schools and individual artists. This provides the background to the broader consideration of individual artworks within the study area. In this area, the priority has been given to the analysis of art works as there is extensive documentation available to illustrate historical changes within the coastal landscape. The analysis includes paintings, watercolours, engravings, photos and ancient postcards.

The variety and richness of the types of coast in the area has attracted artists which have created large numbers of depictions (paintings, prints, watercolours, photos etc), especially since the nineteenth century, which was marked by the rise of seaside tourism especially along the Côte d'Emeraude.

Introduction

The art study area extends for a distance of a bit less than 50km, from Cancale in the east to the cap Fréhel in the west. The approach for the coastal study site aimed to demonstrate the role that historical works of art (oil paintings, watercolours, and prints) can provide in terms of supporting understanding of long-term coastal change and assist in understanding of the chronology of coastal change in the Côte d'Emeraude. A number of examples are provided of those artists' works which form reliable records of coastal conditions at the time they were painted.

Literature Review

The coastline of Côte d'Emeraude benefits from a rich landscape art heritage, closely linked to the touristic history of the area during the 19th century. Some of the most notable specialists in the study of the history of Breton paintings and painters are D. Delouche (Delouche 1996 and 2003) and A. Cariou (Cariou, 2011), who have considered the tradition of general landscape representations inland as well as along the coasts. Recently, some authors drew attention to the pictures of humid zones, which are currently under the attention of ecologists (Goeldner-Gianella *et al*. 2011), especially in the coastal area.

Cotes d'Emeraude Art Resource

The main are collections are located in regional museums such as Musée des Beaux Arts de Rennes, and local art galleries such as the Musée Yvonne Jean-Haffen (Dinan), the Musée Mathurin Méheut (Lamballe), as well as private art galleries which are especially numerous in the city of Dinard. However, concerning this specific area (Côte d'Emeraude), the main resources for researches were illustrated books, with a wealth of paintings and drawings that form the largest number of illustrations of the study area coastline.

The most prominent artistic figure is Eugène Louis Gabriel Isabey (1803-1886) who was a French painter, draftsman, and printmaker (Leribault, 2012). Born in Paris, the son of Jean-Baptiste Isabey, a painter as well, Eugène Isabey studied and worked at the Louvre Museum. Early in his career his paintings consisted of mostly watercolor landscapes. In 1820, he travelled to Normandy and Britain painting land and seascapes, especially in the Côte d'Emeraude area (Figure 3H7). After 1830, he switched to narrative and historical painting. He was later selected to become one of Louis-Philippe's court painters.

Another important artist is Emmanuel Lansyer (1835-1893), considered as one of the best landscape painters of his time, with Corot; his work includes more than 1,500 paintings, including many Breton landscapes with numerous views of Saint-Malo and the Ellé river. Lansyer settled in Douarnenez during his summer holidays which helped draw other artists to the town during the late 19th century.

Figure 3H7. The Grand Bé island, at low tide, Saint-Malo (watercolour by E.L. Isabey, c. 1820). Source Joconde, Ministère de la Culture. http://www.culture.gouv.fr/public/mistral/joconde_fr.

3H.1.5. Cote d'Emeraude Art Resources Consulted for the Project

For the Côte d'Emeraude area, the art ranking and analysis benefited from an academic study (Master2) led in the Rennes 2 University (Motte 2013), under the direction of H. Regnauld, with help from M.-Y. Daire and R. McInnes. The theme of the dissertation was: *Representation and Evolution of the Shoreline: What do regional paintings can teach us about the Breton coastal environment*? In order to establish the art resource available for this study, it was necessary to review the topographical paintings, drawings and prints held by the principal national, region and local collections. The analysis has questioned the scientific value of iconography when it is used as a source for understanding the evolution of coastal landscape. From a corpus of ancient illustrations representing shorelines in Brittany, a study of coastal change during the last centuries is proposed. The points from which the artists were painting were relocated and photographs taken. A comparison of the two images allowed an assessment of the exactness of the work of art as an objective source of knowledge. Then detailed study of the images highlights specific landscape changes, which are recorded through a consistent methodology. A synthesis of results is compared with other available historical data enabling conclusions over whether a set of paintings provide accurate representations of landscape changes in Brittany. This research work aimed to exploit these representations as a source of scientific information able to increase knowledge about physical evolution of the coastline, particularly offering an approach over a longer period than it is possible with visual materials traditionally used in geography such as photographs and satellite images.

3H.2 Current Environmental Impacts/ Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the coastline and reviews the current coastal management issues and approaches.

3H.2.1. Review of Key Contributors to Coastal Change

Along the coasts of Côte d'Emeraude the natural erosion combines with a strong anthropic pressure. The coastal evolution of this area can be explained by a combination of several factors:

- There are many human developments, especially around the major tourist cities where buildings have changed the shoreline (e.g. port of Saint- Malo), land has been reclaimed from the sea and new dykes have modified the sedimentation process.
- Significant weather events (storms, tidal waves) can set back the coastline for a few hours or permanently mark the landscape.
- Natural erosion can be hastened by human activities (especially intensive agriculture).
- Exotic plantations near the coast of trees that are not normally suitable for this type of land (due to wind, rain, salt); e.g. intensive plantation of pine trees along the coasts proves to be disastrous as under the trees secondary short vegetation disappears; consequently the land becomes vulnerable to rain water streaming and erodes much faster.
- Intensification of coastal occupation leads to a strong urban pressure (economic attractiveness), pressure from tourism (with mass tourism, camping, etc), and the development of many activities (aquaculture, seaweed exploitation, biochemistry, etc) which require infrastructure.
- A particular example in this area is the use and extraction of silica sand and gravel in the Gulf of Saint-Malo which can change the seabed. These human activities change the coastline, impacting sediment exchange and current sediment levels.

Coastal evolution is sometimes said to be forced by storms, sometimes by average meteorological conditions; this point has been documented by geomorphological studies (Regnauld *et al*., 2010), especially at the Verger bay site (see below). The exact role of very strong storms is therefore a widely debated issue. On the northern coast of Brittany, a site located in the eastern part of the Côte d'Emeraude, Verger bay, has been surveyed for the last 20 years and has evolved under the control of human management and the impacts of long periods of calm weather and of three large storms. The weight of each of these agents on coastal evolution has been examined. Their respective impact is highly variable in time and in space, thus making it very difficult to understand coastal behavior with a simple conceptual model of actions, controls and resilience. The coastal response to each of the actions is not the same in different areas, however, storms appear to be the main shaping force on a large extent of the studied coastline.

3H.2.2 Summary of Current Coastal Management Approach

Coastal risk management is a responsibility of coastal local authorities in partnership with the the regional and national environmental agencies. The Natura 2000 (EU, ratified by French government in 1996 ; Ministère de l'Ecologie, Cartographie de l'Inventaire National du Patrimoine Naturel) protects several zones in the Côte d'Emeraude area, such as the Arguenon estuary, Saint-Malo and Dinard archipelagos, the Cap Fréhel, the coastline between Cancale and Paramé, and the Rance river estuary with the islets of Notre-Dame et Chevret. This legal control tool limits human building and structures, taking account of two key features: birds and natural habitats. The main goal of this network is to maintain or to bring back a stable situation, favorable to the preservation of natural habitats, especially for wild fauna or plants recognised as of community interest.

In the Côte d'Emeraude area (Figure 3H8), the Conservatoire du Littoral owns several properties: Verger bay, Besnard islet, des Landes island, and several capes: la Varde, le Décollé, Meinga and Nick. In these areas access is limited (and forbidden during bird nesting season), the paths have been marked out in order to keep large areas of land free of human presence (stamping) and to favor the progress of natural formations (e.g. dunes).

The Rance estuary is protected as a 'Zone Naturelle d'Intérêt Ecologique, Faunistique et Floristique', meaning that no structures can be built in this area (thanks to a law adopted in 1982 and reinforced in 1983; Inventaire National du Patrimoine Naturel, Cartographie de l'Inventaire National du Patrimoine Naturel). The 'ZNIEFF' consists of an inventory plan of the natural and scientific resource, describing and identifying the zones of high biological potential.

In the wake of the Xynthia storm in 2010, the building of new houses is not permitted in the eastern part of Côte d'Emeraude (Saint-Malo, Cancale, Saint-Coulomb) if the soil level is equal or lower than the sea level (urbaplu). The general councils of Côtes d'Armor and Ille-et-Vilaine departments have bought some areas, in order to manage and protect them in cooperation with European structures.

Some additional rules concern important areas for the protection of wild birds (EU since 1979), or the creation of regional nature parks, e.g. the 'Rance Côte d'Emeraude park' (since 2008) for the preservation of natural maritime and coastal heritage.

Figure 3H8. Map of the Côte d'Emeraude study area, featuring the protected zones (after Geoportail, 2013).

3H.3 Ranking Artistic Depictions

The ranking systems developed for artworks, historic photographs, maps and sea charts were applied to each of the selected depictions, the results are described in more detail below.

3H.3.1 Art Ranking

Compared with the state of the art on the other side of the English Channel, and referring to R. McInnes works within the UK case study areas, for the French side there was a slight adaption of the methodology to make it applicable specifically to the Brittany coast (type of coast and different artistic tradition).

The art approach benefited from the academic work of E. Motte (Motte 2013). Research on the painters of the Emerald Coast region used the database of the Ministry of Culture. Here, we mainly considered Eugène Isabey (1803-1886), who represented many landscapes of Brittany and Normandy, and Théophile Busnel (1843-1908) who was an illustrator, including work for newspapers. It is also important to highlight Felix Benoit as one of the most accurate artists for the depiction of the coasts, as he produced very fine and precise engravings of several areas of the Côte d'Emeraude.

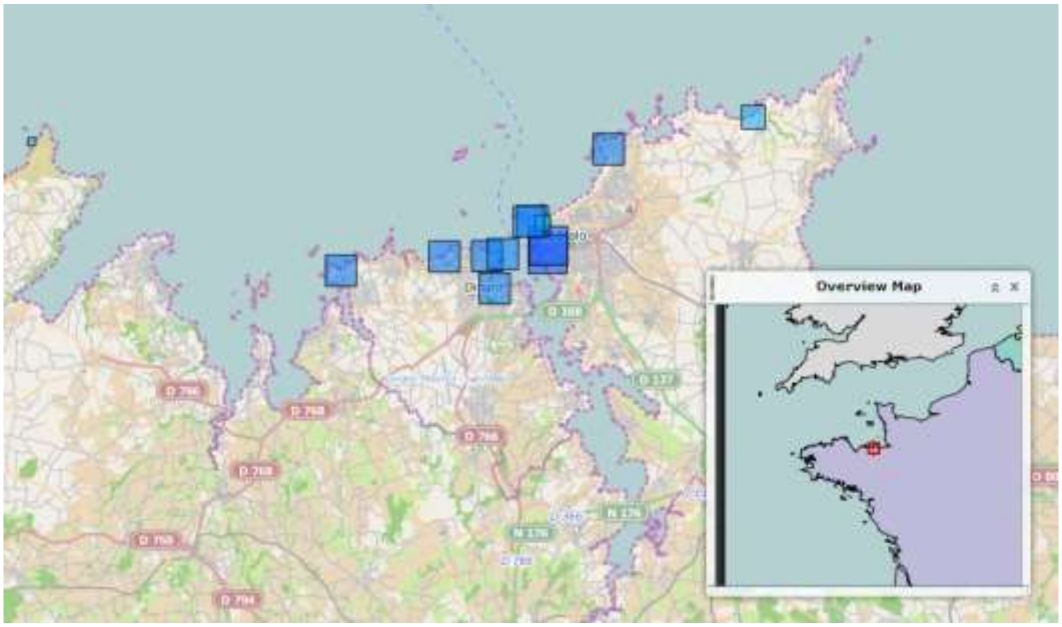

Figure 3H9. Location of art images (paintings) in the Côte d'Emeraude case study area.

The development of the ranking system is described in Section 2. By entering the data on artwork type, medium, subject matter, time period and other parameters, the database was then able to calculate the ranking scores for ten works of art from the case study site.

Artists tended to represent either the landscape as it is or from a certain perception providing their interpretation. They mostly focussed on the Rance river estuary, i.e. Saint-Malo and Dinard areas (Figure 3H9), which were the main attractive zones popular with tourists. Analysis of the accuracy of artists reveals that most ‘liberties’ taken with depictions involve changes to forms and proportions. However, the paintings generally give good indications of the geomorphology and vegetation.

The highest ranking, a painting by E. L. Isabey, scores 74; he was one of the most accurate painters for the visual depiction of coastal landscapes. However, due to the cohesion of the painters' styles, all the scores reach a (more or less) medium rank, without great difference between the total values. The main category of artwork consists of watercolours, which generally permit more nuances within views and perceptions. Due to different backgrounds and techniques, the works of artistis do not reveal the same sensitivities. E. Isabey willingly represents landscapes while T. Busnel depicts characters.

Table 3H1 include the 13 paintings reaching the highest scores. A more detailed explanation of some case study sites and the interpretation of the individual artworks is provided below.

ID No	Location	Artist	Date	Score type	Score style	Score environment	Total Score
113	Baie de Dinard	Eugène Isabey	1864	Water-colour	Topographical	Detailed view	66
118	Baie de Saint-Servan (Saint-Malo)	Eugène Isabey	1850	Water-colour	Topographical	Detailed view	74
109	Fort Duguesclin (Saint-Coulomb)	Théophile Busnel	1913	Chromolith o-graphie	Picturesque	General view	55
	Saint-Enogat	Eugène	1850	Water-	Topographical	General view	59

114	(Dinard)	Isabey		colour			
119	Plage de Saint-Servan (Saint-Malo)	Eugène Isabey	1850	Water-colour	Topographical	Detailed view	74
110	Remparts de Saint-Malo	Eugène Isabey	1870	Water-colour	Topographical	General view	66
115	Baie de Saint-Enogat (Dinard)	Eugène Isabey	1850	Water-colour	Topographical	General view	59
111	La Grande porte de Saint-Malo	Unknown	1820	Oil	Picturesque	Detailed view	48
116	Baie de Saint-Malo	Eugène Isabey	1850	Water-colour	Topographical	General view	59
117	Le Grand Bé (Saint-Malo)	Eugène Isabey	1864	Water-colour	Topographical	General view	59
258	Port Hue Beach (Dinard)	Alexandre Nozal	End of the 19th cent.	Water-colour	Topographical	General view	59
259	Pointe du Moulinet (Dinard)	Duroy-Bateau	1850-60	Drawing	Picturesque	Detailed view	59
260	Cap Fréhel (Plévenon)	Felix Benoit	1865	Engraving	Picturesque	General view	29

Table 3H1. Top art ranking results for the Côte d'Emeraude study area.

3H3.2 Historic Photograph Ranking

The historic photograph resource, particularly of old postcards, available dating from the 19th century onwards is very rich for the study area, mainly due to its popularity for tourism. The photograph ranking system was applied to images primarily chosen from locations along the coastline where historic paintings and archaeological sites were also known. Hundreds of historic images exist for this stretch of coastline, it should be noted that this study was not intended to be exhaustive, it aimed to highlight the potential for historic photos to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums and galleries, as well as private collections has the potential to provide many more.

The majority of photos assessed were of heritage views, containing features which can be identified today, the oldest photo assessed was taken in 1853. For the Côte d'Emeraude area, where available photos were very numerous it was necessary to select the most informative ones relating to coastal change. The photographs reaching a total score of 100 were selected as being the most representative for the assessment of coastal change or illustrating the presence of heritage sites along the seashore. In this area, archaeological heritage is scarcely represented within photos. Geological features are illustrated by L. Collin, who was a geologist of the Rennes University during the first half of the 20th century.

For this case study area, 317 photos were selected. The existence of such an important set of pictures is clearly linked to the touristic attraction of the region. This goes in parallel with the development of the tourist postcard tradition.

Figure 3H10. Location of historic photos in the the Cote d'Emeraude case study area

The most ancient photos date from the mid 19th century (1853), with the majority dating from the first quarter of the 20th century, a period when photography became more widely available to the population. These pictures generally depict the most popular tourist places, either wild landscapes such as Grouin Cape near Cancale, Cape Fréhel in Plévenon, or places of interest (grottos, historical monuments, castles, churches); but the main interest is generally the seaside resorts (Saint-Malo, Dinard, Saint-Lunaire). Thanks to this photography, it is possible to follow the landscape evolution of some places of the Côte d'Emeraude, revealing diverse changes and infrastructures (dykes, quays, etc).

The largest available photographic documentation is through the tourist postcards of the late 19th and early 20th centuries. The postcards have at two distinct objectives:

- to witness that the tourist wwas really 'there', which is why they often represent a hotel, a spa, a castle, a garden, etc; and
- to show the beauty of natural landscapes.

Many of these postcards picture the former situation of some places, before constructions on or arrangement of the shore through harbour installation, etc. These examples can often help in the reconstruction of coastal changes during the last decades and across the century.

Most of the postcards concern seaside resorts and cities (around 200). They inform us about the coastal arrangement along the coastline, and on the threats due to anthropic pressure and climatic events (e.g. the photos showing the destruction of the Paramé-Saint-Malo dyke in 1905 when a storm combined with high tides). Some ancient photos of the fortified city of Saint-Malo *intra-muros* (within the walls) exist, dating from 1853, showing the city before the harbour arrangement of the 20th century and the construction of pools and quays, at a time when the enclosed town was only reachable at low tide.

Sometimes, the photos help to rediscover some structures that no longer exist, e.g. lobster basins, formerly situated between the beach and Fort National. Some ancient postcards picture places where access is now impossible (forbidden), e.g. Cézembre island, where due to the bombing during the WWII it is still dangerous even now.

Img_ uid	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
135	Saint-Malo Intra-muros	1853	Medium		Poor	55
136	Saint-Malo Intra-Muros	1853	Medium		Poor	55
180	Fort National (Saint-Malo)	1952	High		Good	100
181	Le Chêne Vert (Plouër-sur-Rance)	1900-1925	High		Good	100
186	Le château du Guildo (Créhen)	1900-1925	High		Good	100
411	Cap Fréhel (Plévenon)	1900-1930	Poor		Good	55
660	Cale de l'épi (Cancale)	1900-1925	High		Good	100
671	Pointe du Grouin (Cancale)	1900-1925		High	Good	100
701	Moulin du Lupin (Saint-Coulomb)	1900-1920	High		Good	100
708	Le Hâvre (Saint-Malo)	1900-1905	High		Good	100
724	Digue après le raz-de-marée (Saint-Malo)	1905	High		Good	100
744	Cale de Dinan (Saint-Malo)	1900-1923	Medium		Good	100
750	L'île Cézembre (Saint-Malo)	1900-1925		Medium	Good	77
756	Parcs à homards (Saint-Malo)	1900-1925	High		Good	100
760	Débarcadère du Petit Bé (Saint-Malo)	1900-1925	Medium		Good	55
779	Rocher Bizeux (Saint-Malo)	1900-1925		Medium	Good	100
781	Hôtel Victoria (Saint-Malo)	1900-1925	High		Good	77
793	Pointe de la Malouine (Dinard)	1900-1911	High		Good	77
794	Pointe du Moulinet (Dinard)	1900-1925		High	Good	100
795	Plage de Saint-Enogat	1900-1925	Medium		Good	100
855	Digue de la Banche (Saint-Jacut-de-la-Mer)	1900-1902	High		Good	77
871	Pointe de la Garde (Saint-Cast-le-Guildo)	1900-1925		High	Good	100
884	Le Bec Rond (Saint-Cast-le-Guildo)	1900-1925		Medium	Good	77
902	Le fort Lalatte (Plévenon)	1900-1925	Medium		Good	55

Table 3H2. Top ranking photographs within the Cote d'Emeraude case study area.

Regarding the distribution, the whole case study area is covered by ancient photographs and postcards. But the highest scores (Table 3H2) seem to be linked either to the existence of a seaside tourist resort (Saint-Malo, Dinard) or to some wild landscapes, e.g. Fréhel cape.

The Table 3H2 outlines the results of the ranking; note that photographs were ranked as either a heritage view or a non heritage view. Not all the photos are equal in quality and in their informative ability. Some show very large areas of landscape in a general view which does not provide much detail on the geomorphology, but can show the general state of the landscape in a given time. In the Côte d'Emeraude area, the photographs generally feature large views.

3H3.3 Maps/Charts Ranking

Several historical maps exist of the coastline, with dating back over 400 years. These maps were assessed as part of the project using the methodology outlined in Section 2. The study of maps in this case study area was not exhaustive, it aimed to highlight the potential for historic maps and charts to provide information on coastal change.

Most of the ancient maps that we know of for the Côte d'Emeraude area were drawn for marine purpose. They are related in particular to trade, but also to military defenses. They often depict harbours, shelters, watering places, but also marine features such as anchorages, rocks and major landmarks for navigation (e.g. coastal shipping). Defensive points along the coast are highlighted on the maps, particularly during the wars (e.g 17th and 18th century, with St-Malo) and periods of major offshore sailing (especially in the 19th century). Shipping information is focused on the depth of the seas, currents or the nature of the seabed (Collectif 1992). Finally, with the establishment of the Napoleonic "cadastre" (19th century mapping based on registering property), the plots are shown in more accurate maps and include the coastline.

Figure 3H11. Map of Saint-Malo "island" (1758) featuring the limits of low and high tides and the limited access to the fortified city. Source : gallica.bnf.fr/Bibliothèque NAtionale de France. http://gallica.bnf.fr/ark:/12148/btv1b53016834n

The focus of this documentary research was on the baie de Saint-Malo but the majority of maps consulted depicted the whole Brittany region. The maps were gereally obtained in a digitised format and were later combined with all other data sources. However, as the maps and charts studied for the Côte d'Emeraude area were not very numerous (only 6 were ranked – detailed in Table 3H3), so the interpretation of the rankings is based on a limited dataset.

MAP_ uid	Title	Year	Score Chronometric Accuracy	Score Topographic Accuracy	Score Detail in non-coastal area	Score Geometric Accuracy
88	Carte particulière des côtes de Bretagne : Depuis Granville jusqu'au cap Fréhel	1756	73.33	25	66.66	83.33
89	Plan du terrain au dessus du moulin du Boschet	1756	100	50	100	100
101	Carte de la rade de Saint-Malo et d'une partie de la rivière de Dinan	1600	73.33	38.88	33.33	66.66
93	Saint-Malo	16th / 17th	20	50	33.33	66.66
102	Plan du port de Saint-Malo tel qu'il paroit de mer basse	1754	66.66	27.77	33.33	66.66
100	Carte particulière des entrées du port de S. Malo, et de la riviere de Dinan. Comme elle paroissent aux plus basses marées des equinoxes	17th	20	36.11	33.33	50

Table 3H3. Top ranking maps within the Cote d'Emeraude case study area.

3H.4. Art Field and Research Studies

No dedicated archaeological or palaeoenvironmental fieldwork was carried out within the Côte d'Emeraude case study area as the available documentation on the historic resource was already detailed enough to analysis of some sites. However, field studies were undertaken in support of the art research, demonstrating the need for studies related to the different evidence types (paintings, photos and maps).

In addition to natural evolution, due to the tourist activity in this area, some parts of the coastline or this area have been severely transformed during the last century. For example, in the Saint-Briac area, as shown in the paintings of the great painters of the late 19th century and contemporary photographs, the coast, before the establishment of resorts, was devoid of trees. It was the new summer residents who planted all kinds of plant species to embellish the site.

3H.4.1 Key Research Questions

The research questions to be answered through the art representations, maps and photos concerned:

- the visualisation of coastal changes in a selected area
- the time scale and rhythms of the changes; and
- the process and origins of the coastal transformation.

All these questions aim to contribute to a better understanding of the issues and help put forward solutions to the managers of the coastal areas.

3H.4.2 Approach to Information Gathering and Fieldwork

Where possible, fieldwork has been undertaken to assess the informative value of paintings, maps and photos illustrating coastal changes. The sites selected for fieldwork were: the medieval Château du Guildo, Saint-Malo town and harbour, the Moulinet cape on Dinard, the Port Hue beach in Saint-Briac and the Fréhel Cape.

3H.4.3 Art Field Data Gathering Results
Five sites were selected for more detailed analysis, these are presented below.

H1. Château du Guildo (Figure 3H12)

Location
The Guildo castle is located in the western part of the Côte d'Emeraude, in the mouth of the Arguenon estuary, Créhen town (Côtes d'Armor).

Why was the study site selected?
The photos (postcards) feature historic buildings threatened by coastline retreat.
Ruins of an ancient castle which originated in the 12th century are shown. This building has a number of developments until the 14th century. As the castle is pictured several times in photos and paintings it was possible to analyse the coastline evolution of this specific place during the period of the 18th - 21st centuries.

Geomorphologic setting
The castle occupies a rocky outcrop consisting of mica schist and crossed by a bench of dolerite, bordered to the north and west by the Arguenon.
The views (postcards, upper part of the Figure 3H12) show how close the sea water comes to the castle, revealing a probable sea level rise since the time of its building. The comparison between the Blin painting (Figure. 3H12 lower left) and a recent photo taken from the same angle (Figure.3H12 lower right) show a sedimentary accretion process (with the development of silty vegetation) at the foot of the castle.

How the site can inform coastal risk management?
The images show that the castle is exposed to high tides (as demonstrated by sea weeds beneath the walls). It is certainly much closer to the shore than when it was inhabited. The analysis of the documents gives potential information on coastline retreat during historic periods.

Blin François, Ruines du château du Guido, marée basse, 1866 (Lille, Musée des Beaux arts, inv. n° P689).

Ruins of the Guido castle, to compare with Blin painting (after C. Feiss-Jehel, In Goeldner-Gianella et al., 2011).

Figure 3H12. Various views (postcards) and painting of the Guildo castle (ancient postcards, painting from Lille Musée de Beaux-Arts and photo after Feiss-Jehel 2011).

Key coastal risk management issues for the location

The archaeological investigations and restoration of the castle recently gave an opportunity to underline the threats to the coastal heritage in this area. The local authorities (Créhen parish and Côtes d'Armor department) have been fully informed and are now aware about this situation.

Chateau du Guildo Castle - Ranking score achieved: 100

H2. Saint-Malo harbour, ancient map (Figure 3H13).

Location
Saint-Malo city and harbour is located on the northern coast of Brittany, Ille-et-Vilaine department, and is situated on the right side of the Rance river estuary.

Why was the study site selected?
This site has been selected as representative for the impact of anthropic pressures and urbanization on the coasts.

Geomorphological settings
Saint-Malo city and harbour are located in the middle of the Massif de Saint-Malo, a '*metamorphic continuum*' cut by the Rance river estuary. The site was originally composed of several islands, some of them being now artificially connected to the main land (e.g. Saint-Malo island), maritime and estuarine bays, and sandy slopes combining with rocky cliffs (e.g. Alet/Saint-Servan). In this area, the tidal range, which is the largest in Europe, reaches 14 metres, it means that the shoreline has been shaped by the tides and the sea.

How the site can inform coastal risk management?
The site of Saint-Malo reveals a long history of managing risk from the sea. The architectural history of the city reveals building of dykes along the most exposed part (le "Sillon") that started in the early 17th century. During the following centuries, the dykes were extended or rebuilt several times, while they were regularly damaged by storms, and the local authorities are aware of this.

Key coastal risk management issues for the location
Comparing the views in Figure 3H13, it can be seen that the main risk to be managed is pressure from human development. Some areas of land around the harbour, which were wild and free of constructions during the 16th-17th century are now densely settled.

Saint-Malo ancient Maps - Ranking Score achieved: 20 to 66

Figure 3H13 . Saint-Malo, ancient map (16-17th century) (Source : gallica.bnf.fr/Bibliothèque Nationale de France) and present view (cl. G. Cazade, Le Pays Malouin).

H3. Dinard city, Pointe du Moulinet by Duroy Bateau 1850-60 (Figure 3H14).

Location

Dinard is a town located on the northern coast of Brittany, Ille-et-Vilaine department, and is situated on the left side of the Rance river estuary, west of Saint-Malo.

Why was the study site selected?

Dinard is a typical seaside resort, with an economy which has been based on tourism for a long time and is reflected in features such as beaches, hotels, spa and casino. The evolution of the represents an important issue here due to the touristic economy and for local inhabitants who have houses along the seashore.

Geomorphological settings

Dinard settles on a rocky promontory, dominating the Channel on its northern sea side and a more protected façade on its eastern side, turned to the Rance river and facing Saint-Malo harbour. Here, rocky coats sections alternate with large sandy beaches.

How the site can inform coastal risk management?

The comparison of the pictures (Figure 3H14) shows that the site is subject to natural erosion which causes a retreat of the coastline, even in rocky parts.

Key coastal risk management issues for the location

Taking into account the density for habitation along the coastline, the major risk inferred by erosion concerns the more exposed private and public buildings.

Dinard City Painting - Ranking score achieved: 59

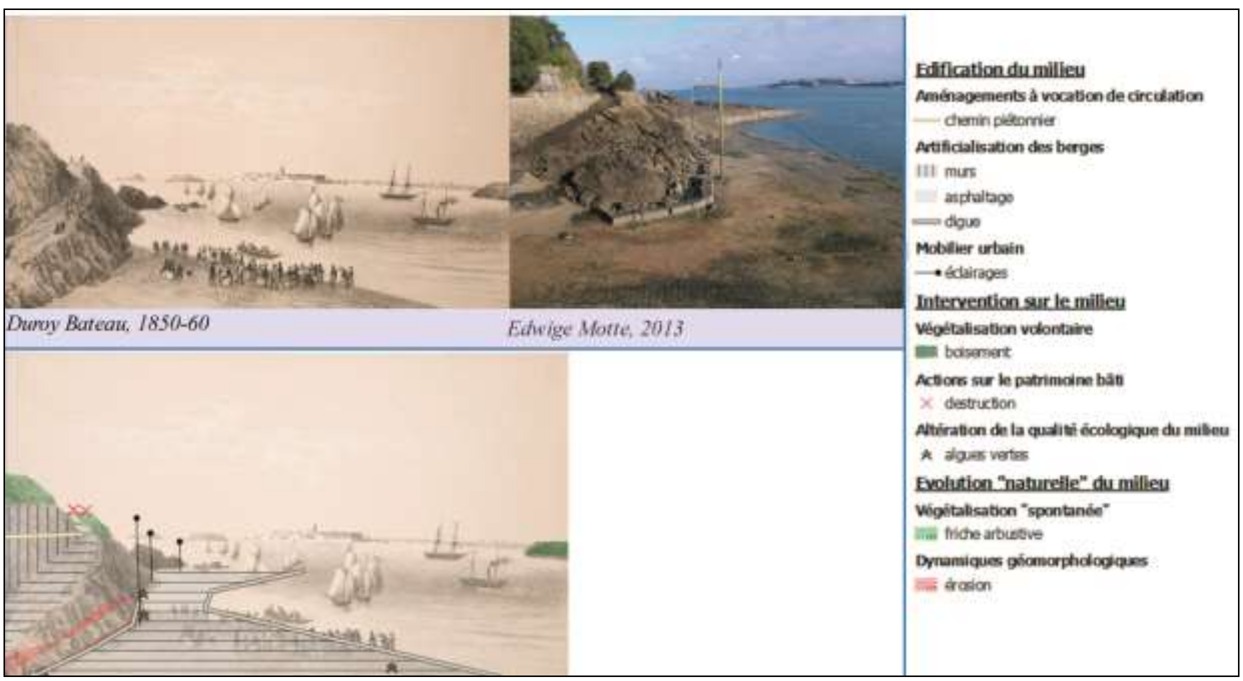

Figure 3H14. The town of Dinard, view of Saint-Malo since the Moulinet cape, (after Motte, 2013).

H4. Saint-Briac, Port Hue beach by A. Nozal (end of the 19th century) (Figure 3H15).

Location

Saint-Briac is a small seaside town, located at the present limit between Côtes d'Armor and Ille-et-Vilaine departments. Its territory is limited to the west by the Frémur river. The Port Hue beach is facing to the north.

Why was the study site selected?

The site has been selected because, despite of the tourist development of the town, it has long benefited from coastal management measures, especially the wild parts of its territory.

Geomorphological settings

The Saint-Briac territory shows a diversity of features, with large sandy beaches alternating with rocky sections, e.g. the Garde Guérin cape. This painting shows the Port Hue beach, in the foreground and the Garde Guérin cliff castle in the background.

How the site can inform coastal risk management?

This site shows interesting evolutional features of the coast: first, we notice that some elements of the “built” heritage (houses on the Garde Guérin cape, and bath cabins) have recently been dismantled, due coastal management decisions. Due to the protection measures recently taken, some wooden barriers, "ganivelles" have been installed in order to prevent from people from walking over the site, and to promote stabilisation, then progression, of the dunes (Figure3H15).

Key coastal risk management issues for the location

The coast line of Saint-Briac is located in a Natura 2000 protection area. Nevertheless, the natural erosive process is very active in some parts.

Saint-Briac Painting - Ranking score achieved: 59

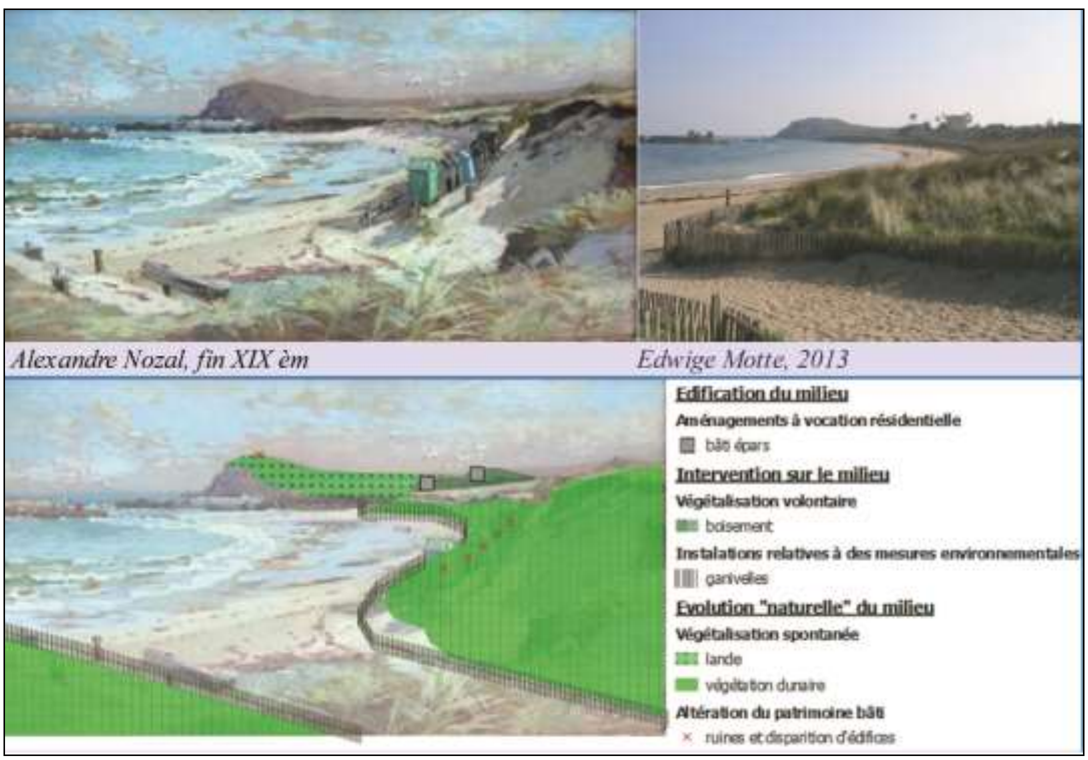

Figure 3H15. Saint-Briac, Port Hue beach (after Motte, 2013).

H5. Cap Fréhel by F. Benoist, 1865.

Location

Cape Fréhel is a peninsula in Côtes-d'Armor, in northern Brittany, France which extends off the Côte d'Émeraude into the Golfe de Saint-Malo. The Cape is located 8.5 km from the town centre of Fréhel, although, administratively, it is located within the territory of the commune of Plévenon.

Why was the study site selected?

Overlooking the sea for more than 70 meters, the shale cliffs and pink sandstone of Cape Fréhel offer one of the most beautiful views of Brittany. It is considered one of the greatest tourist sites of interest in the Côte d'Emeraude.

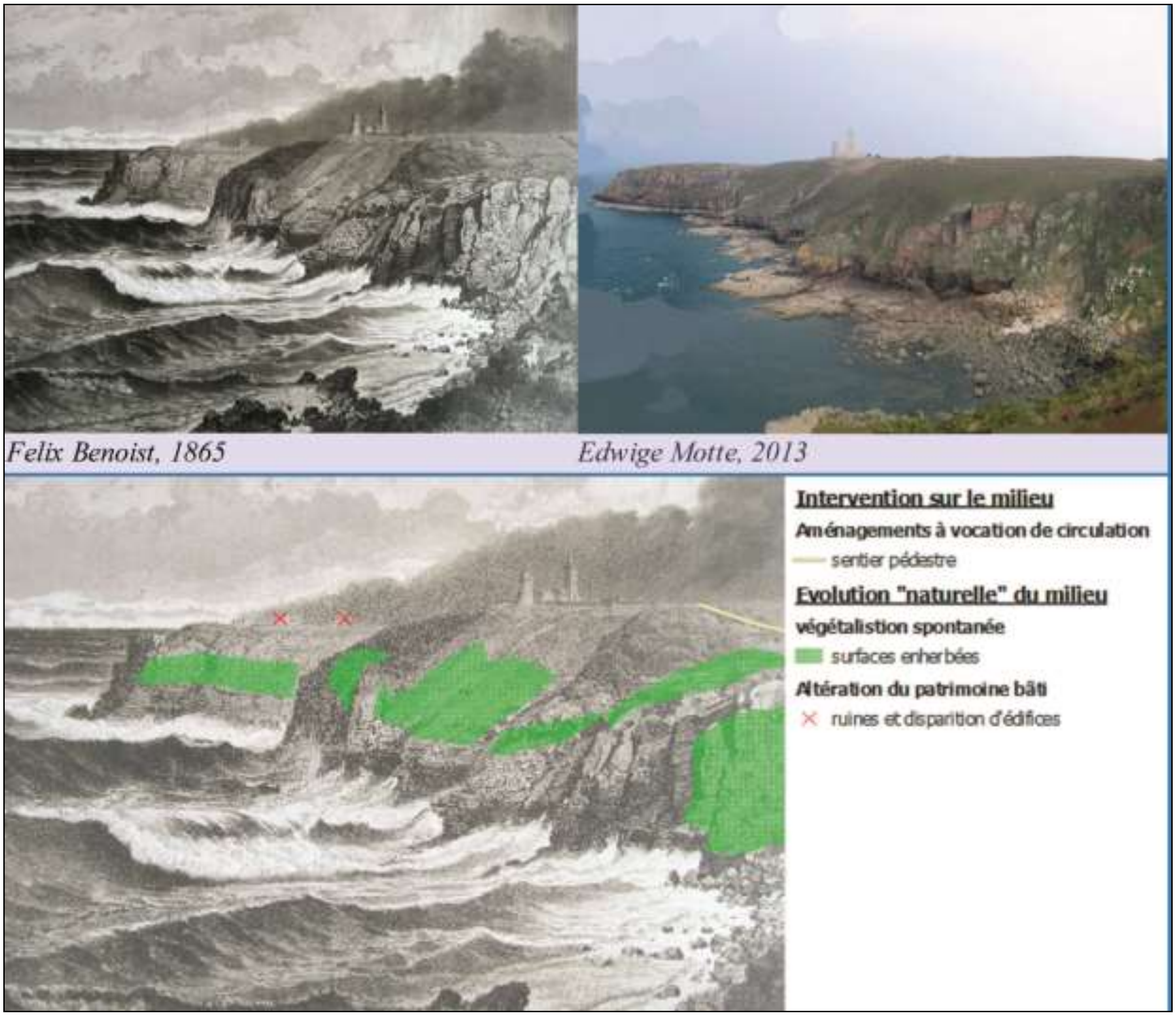

Figure 3H16. Cap Fréhel, yesterday and today (after Motte, 2013).

Geomorphological settings
The peninsula is surrounded mainly by cliffs which make it difficult to access via sea. The whole of the undulating terrain is covered in moorland and marshes which make it difficult to construct any structure on the site.

How the site can inform coastal risk management?
No towns or villages are situated on the peninsula, however, there are some located at the tip of it. As shown on E. Motte documents (Figure 3H16), some ancient buildings have been dismantled and only the two lighthouses, one from the 17th century and the other one from 1950, have been preserved as elements of the historic heritage.

Key coastal risk management issues for the location
This exceptional site is currently an ornithological reserve. Cap Fréhel is a good example of a remarkable site where it is possible to manage tourist activities with nature preservation.

Cap Fréhel painting - Ranking score achieved: 29

3H.5 Analysis
The Cote d'Emeraude study area provides evidences of the coastal changes occurring due to natural forces and human actions as revealed by historic paintings, photos, and maps, illustrating the rate and scale of this change over the last few hundred years. This section considers the most informative and reliable data gathered from this study area for contributing to understanding of the scale and pace of coastal change.

The Côte d'Emeraude area study has combined the use of paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve our understanding of coastal change. In this case study area there are several illustrations of long term effects of erosion, however, focus is particularly drown to short term transformations due to:

- Several sections of this area having been subject to intensive coastal occupation and tourist development since the 18th century, leading to dense coastal constructions (seaside resorts, private and public buildings, etc), some of them (e.g. the Saint-Malo dikes) completely transforming the coastline; and
- Many sites in this area are currently covered by protection measures (e.g. as natural or bird reserves) and we can then analyse the efficiency of the coastal management.

3H.5.1 Archaeology, Heritage and Palaeoenvironmental Features
Although archaeological fieldwork was not carried out within this study area, available data from sites was used to investigate changes. Some Palaeolithic layers and late prehistoric settlements give ideas of coastal changes, mainly the rise in sea level, but these often lack precise dating. The available data for the Saint-Servan Alet site, in the Sain-Malo area, is examined as it provides a good example of combining documentation for maximum analysis. Within the framework of the Arch-Manche project, it was possible to improve knowledge for the Mesolithic period, as it was less studied in this area.

Within a inventory of the ancient fish traps of Brittany (Daire and Langouët, 2008 and 2010), L. Langouët spotted a stone dam on several aerial views (IGN,Google Earth) with a length of 67 m between two rocky mounts called Petit Daviers and Frand Daviers (Figure 3H17). It was already visible in views of 1952. This site has been chosen due to the fact that this fish trap is no longer reachable on foot, which means it is probably a very old structure, used at times when the sea level was a bit lower. An underwater survey was conducted on this structure in order to gather more precise data.

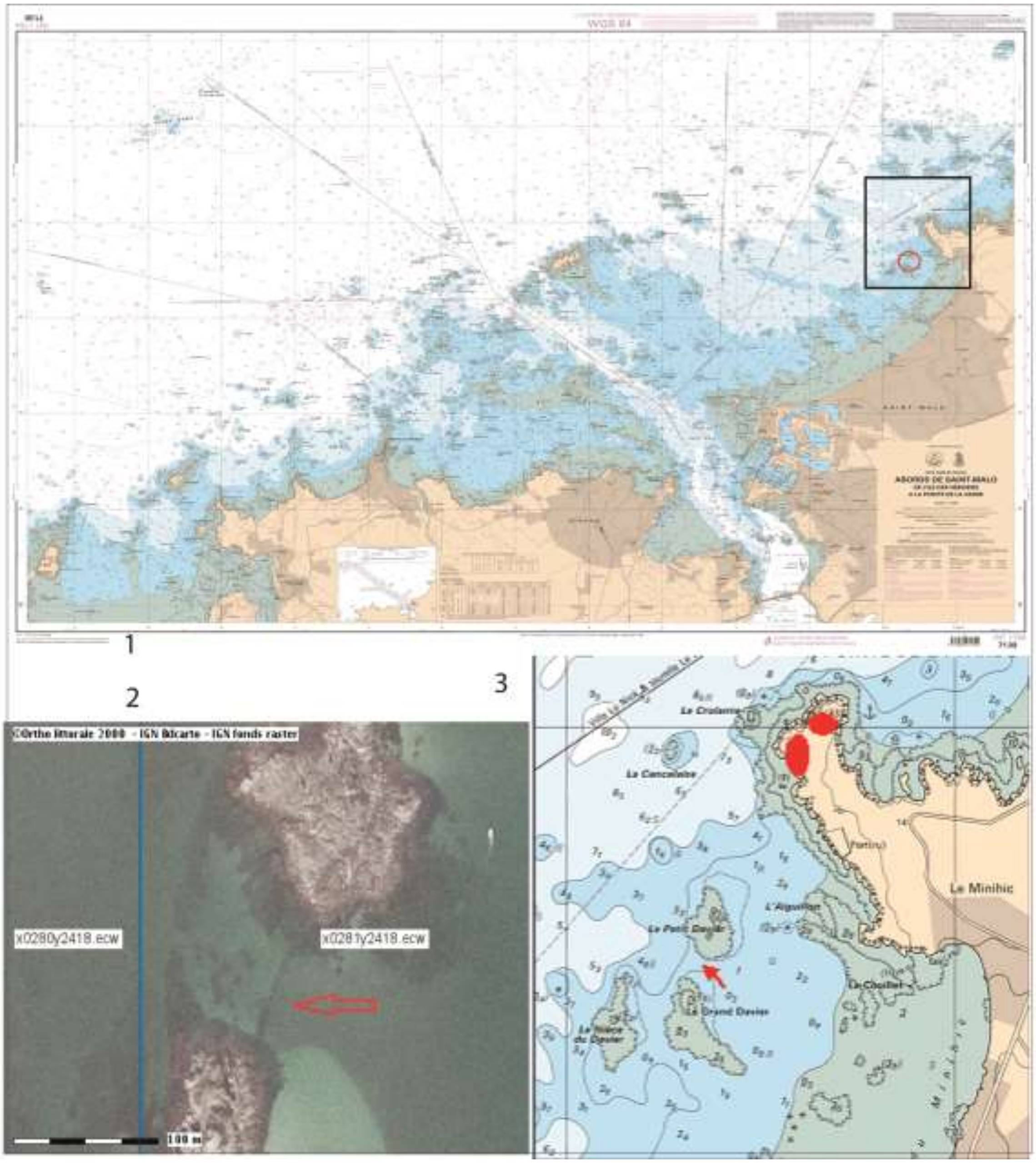

Figure 3H17. Saint-Malo, location of the Mesolithic site on the La Varde cape and of the underwater fishtrap on Marine map from SHOM (1 and 2) and dams of the fish trap visible on the aerial view (2) (source Geoportail, IGN) (doc. L. Langouët).

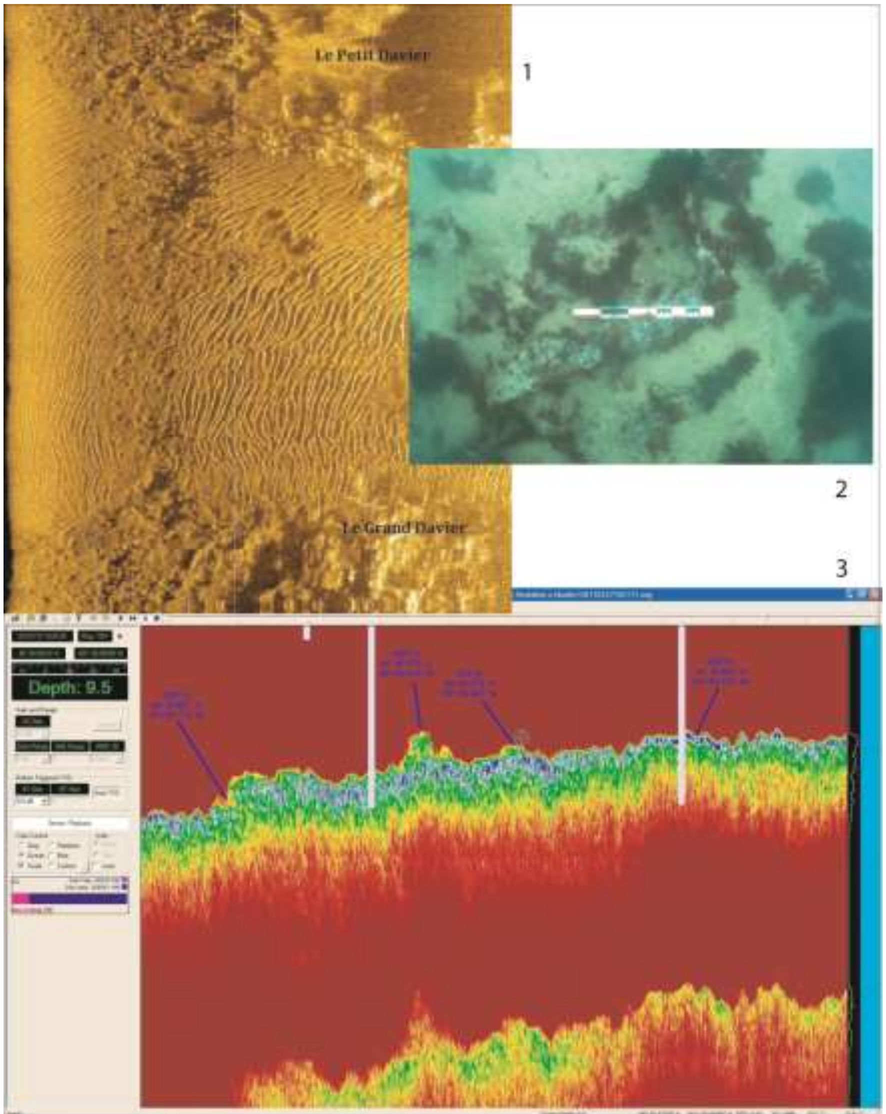

Figure 3H18. Saint-Malo, underwater survey views of the Daviers fihtrap. 1: Sidescan sonar mapping © Adramar. 2: Diving survey showing special arrangement of the stones, possibly the sluice © N. Job/Adramar. 3: Stratabox profile (27_SBP 10_21_11.seg) mapping the starting point of the southern wall of the fishtrap. © Adramar.

Following the Adramar work on this site (Le Ru 2013), a review of data obtained with a side-scan sonar and sediment penetrator (Figure 3H18) was undertaken. The stone structure, located between the Grand and Petit Daviers, is interpreted as an old dam. Seaweeds attached to stones, facilitated the overall detection of the weir on the aerial views of the IGN (Figure 3H17, n°2). It is well adapted to the concavity reflux stream between rocks, which represents a positive identification element. Side-scan sonar surveys have demonstrated the presence of an organised set of stones, and allowed the hypothesis that it could be a geological feature to be discounted. The dam, even if very damaged, is identifiable on the side-scan sonar documents (Figure 3H17, n°1).

Diver verification enabled visual observation of the northern part of the dam. When the stones were sufficiently high above the sandy bottom, the height of the dam remains ranged between 0.10 and 0.4 metres. The width of the dispersal of the stones is between 4.5 and 5 metres. As an access track was not observed by the divers, it is not possible to find the height of the dam when in use (Daire & Langouët, 2010: 28).

The sediment penetrator and dives could not inform on the nature of the geological substrate (sand mixed with stones or sand on shallow rocky bottom?). It is therefore difficult to assess the likely buried part of the dam. The sediment penetrator also showed that in its southern part (see SPB 15), the dam seems to have a relief and a significant vertical rock removal compared to the sandy bottom. The dives have confirmed the presence of granite blocks on the path of the dam. No organisation of architectural order was observed. In the explored areas, the height of stones compared to sandy bottom was 0.20 m maximum. A special arrangement was noticed, it could be the remains of a sluice, according to the provision of some stones (Figure 3H17, n°2).

The level of the sandy bottom near the dam was estimated on the maps (-1.90 m / 0 SHOM) but more precisely measured during the dives. The average values of the sandy bottom in contact with the dam indicate the value -2.15 M / 0 SHOM (plus or minus 10 cm). These measurements have been analysed regarding the regional curves and data related to sea level changes. According to the position of the fishtrap, it indicates a local rise of sea level (lower level of small tides = LLST) estimated to c. 7.70 metres. Such a change indicates that the Daviers fishtrap was built and used in the Mesolithic period.

In the cape of Varde in Saint-Malo, two deposits dating from the Middle Mesolithic (circa 8200-7600 BP) (Kayser 1991) have yielded abundant stone tools; the first study involved nearly 5,000 waste knapping fragments and over 190 tools made of various stones (Kayser 1991). The distance between both sites (the fishtrap and layers) is about 750 m; from the La Varde cape, there is a direct view to the Daviers fishtrap.

3H.5.2 Artistic Depictions

Following the research and location of a large number of artistic images of the coastline of the study area it was possible to rank their relative importance in terms of their value in informing on long-term coastal change. The art case study area was extensive. The ranking system directed research to the higher potential locations, usually where detailed artworks were available, often painted in watercolour or printed as aquatint or steel plate engravings.

We must emphasise that the paintings and prints available for the study area have been the subject of critical analysis (see the academic work by E. Motte, 2013). Indeed, painters and artists sometimes took liberties with reality when representing landscapes, this varied depending on the school of painting, and on the personality of the painters. A critical look at the results provides several lessons about the informative value of this media. In general, the comparison for each site between the realism of the representation and the current situation justifies the use of art as a source of geographic information. Identifying when the objectivity of representations had been influenced by the view or 'fantasy' of the artist aided analysis.

Observations show that only a quarter of iconographic representations used for this work (Motte, 2013) include examples where the artist has taken obvious liberties within the depiction. Most works appear to be relatively accurate depictions of a geogrphical area at a particular time. This result is significant in that it highlights in the predominance of an accurate rendering of reality in this type of media, legitimising its use as a source of scientific information.

In terms of the most helpful artworks for comparing coastal change, engravings, lithographs, and prints appear more objective because they are mostly political documentary productions or works with territorial and geographical meanings. Often their artistic meaning is less important than the record they provide in a legal-political and topographical sense (Motte, 2013).

The paintings often look more subjective, because they are essentially artistic works with sensitive and aesthetic meanings, considered as an artistic genre of landscape painting beyond mere rendering of reality. This difference is very well illustrated through the case study considered above: the engraving of the Cape Fréhel brings a very detailed view, allowing an accurate analysis of the local changes, whereas the paintings of Saint-Briac beach give a much more general idea of the coastal evolution.

3H.5.3 Combined Resources

As demonstrated above, the comparison between maps, drawings, and historic or archaeological data is the most relevant approach to illustrate coastal changes and understand the process and rhythms of this evolution. Each of the resources listed above can provide detailed information about past environments and the position of the coastline, through combining these resources it is possible to provide more accurate information not just from one time period but over a longer term, this can inform the rate, scale and pace of coastal change along the coastline. The data can not only provide quantitative information on coastline position, but can also provide qualitative information that can assist in illustrating coastal changes to a large audience. For example, it is possible to illustrate the 'long term' coastal changes and provide a 2D synthesis on the La Varde cape site (Saint-Malo); the Figure 3H19 shows the Mesolithic landscape (8000-6000 BC), with a lower sea level which uncovered a large foreshore; this allowed the exploitation of the Daviers fish weir, by the inhabitants of the La Varde cape, which was settled at this period.

The academic work carried out by E. Motte (2013) started to explore a novel approach to landscape evolution, taking as reference supports pictorial representations and ancient maps, compared with geography and geomorphologic features. The study established a methodology adapted for sites in Brittany and for the regional iconographic traditions, it has involved two complementary approaches: the construction of a 'rationalized' interpretive look of the iconography, and the invention of a system to extract and record graphically the information revealed by the diachronic study of comparative images. The application of this approach to illustrations of various types of coast has enabled the establishment of an inventory of many natural and anthropic changes. The comparison of these changes with knowledge from scientific literature is positive and validates the overall approach. However, the study of a larger collection is required to enable more localised and eventually more thematic analysis. Further targeted studies could be undertaken on images which include the same scale of area represented – either an opened-up or narrowed panorama - for maximum comparison.

The results of the combination of art and geomorphological approaches provides information on two levels. Firstly reviewing how art works can be used for scientific purposes rather than subjective reflections of a view. Secondly how the record of changes demonstrated through comparison with the modern situation can enrich knowledge of coastal evolution over centuries. The observations reflect the breadth and variety of changes on the coast for over a century. Considering all the studied sites, a summary of results is presented. Major landscape evolution features observed within artworks are coherent with the facts identified by the literature on the subject. This allows a conclustion that the collection of works of art provide an accurate description of landscape changes in Brittany, especially along the Côte d'Emeraude which is one of the best documented areas of the Breton region.

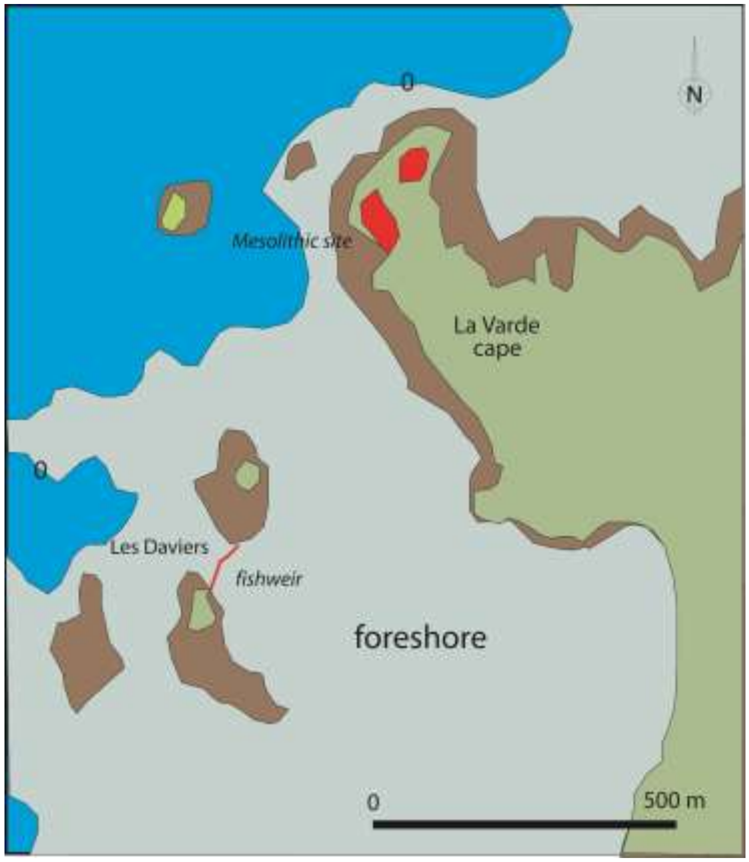

Figure 3H19. Map of the Daviers (Saint-Malo) area during the Mesolithic period (doc. L. Langouët).

As an illustration of the advantage provided by combining resources, the following images (Figures 3H20 and 3H21) show various views the Saint-Servan (Saint-Malo) peninsula, each of them providing elements for comparison as well as data related to coastal changes. The archaeological and palaeoenvironmental data (Figure 3H20), related to the pre-Roman and Roman environment of the Alet peninsula, illustrates the coastal change in this area of the Rance river estuary.

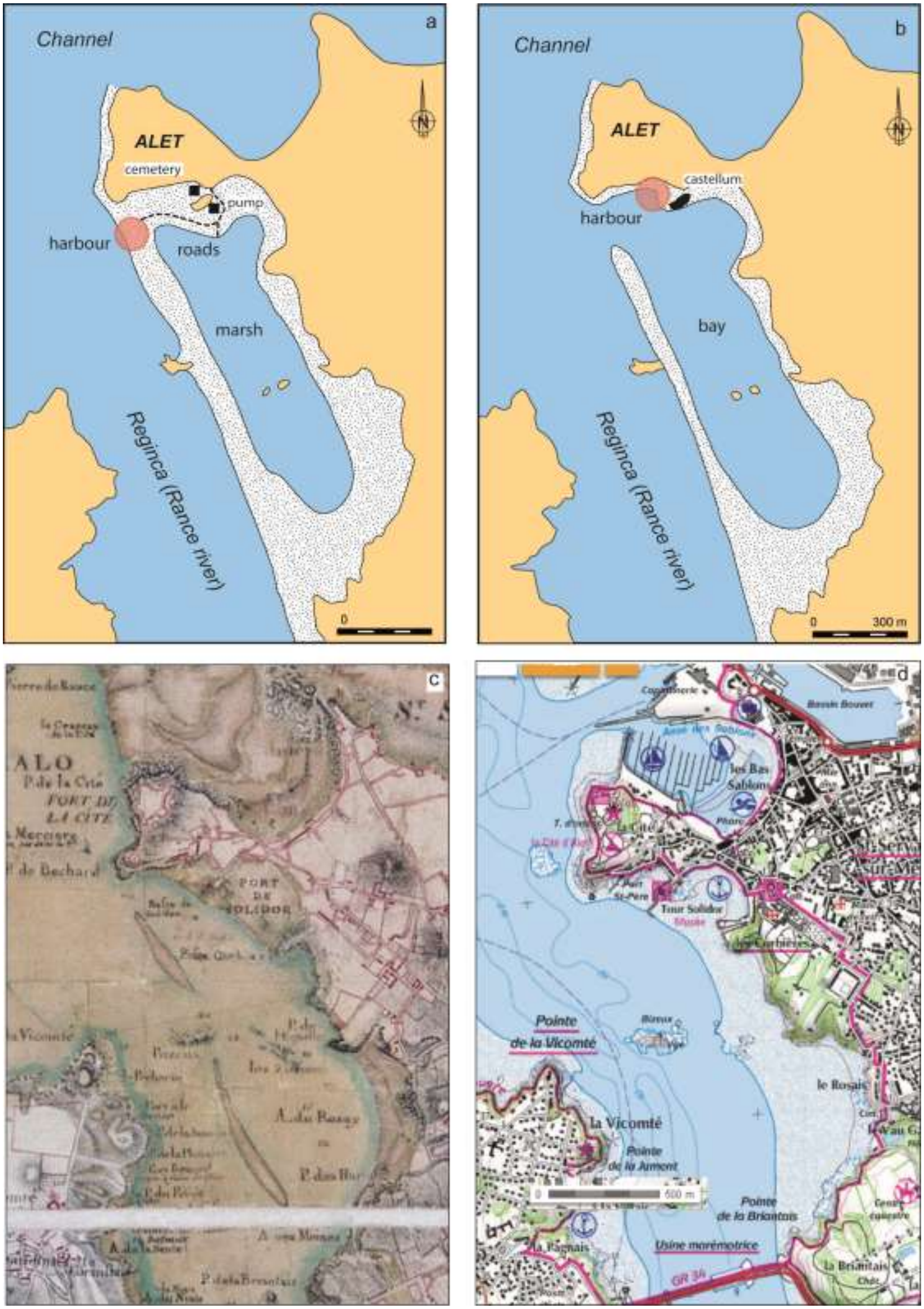

Figure 3H20. Saint-Servan (Alet) promontory and coastal evolution of the ancient harbour: evolution of the topography before (a) and after (b) the 4th century AD, the beak of the alluvial bar caused modification in the use and frequentation of the area. On the ancient map (18th century, Ministère de la Défense, Vincennes) (c) some remains of the alluvial bar still appear. d: 20th cent. view (IGN map).

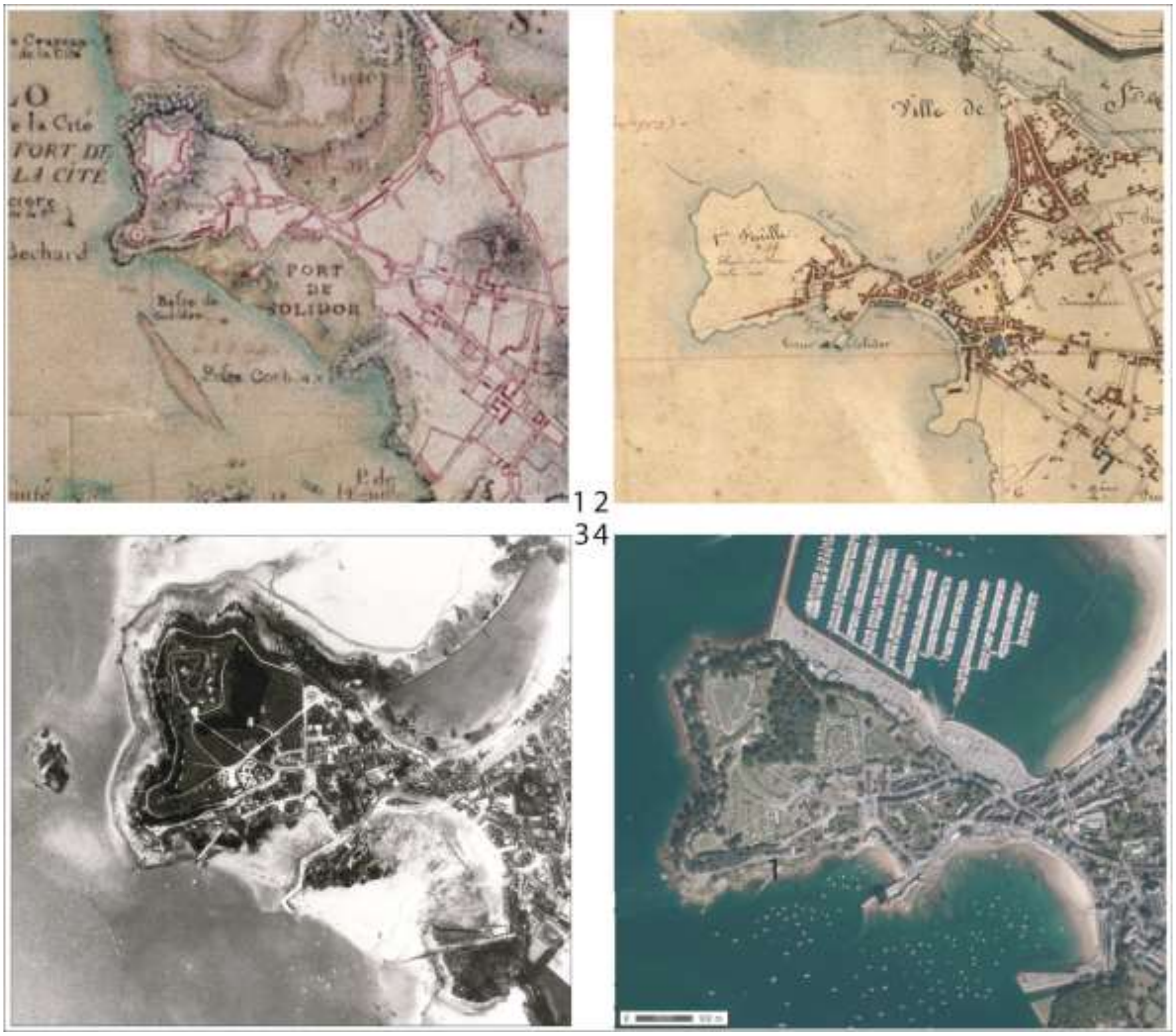

Figure 3H21. Saint-Servan (Alet) promontory and coastal evolution of the ancient harbour. 1. Carte des Ingénieurs Goégraphes du Roi (c. 1785) (Ministère de la Marine). 2. Napoleonian cadastre (1835) (Archives du département d'Ille-et-Vilaine). 3 and 4. Aerial views (1945 and c. 2012) (Geoportail, IGN source).

During the first millennium BC, the current Solidor Bay was protected from the sea by an alluvial bar. A fresh water pumping station has been found during archaeological excavations; it was installed in the cove in the 2nd or 3rd century AD, at a location 4 meters below the current highest water level. At the foot of the tower Solidor, a necropolis was installed during the Gallo-Roman period, probably during the 4th century, in a place that is today a beach. In the Middle Ages, the Alet landing port was installed in the same place. By combining all these paleoenvironmental and archaeological data from excavations conducted in 1960-70, it results in a pattern of evolution of the paleo geographical site. The main reason for these changes is the existence, originally, of an alluvial cordon, protecting land and installations located around a retro coastal marsh from the sea and river water floods.

The breakthrough of this bar could be due either to natural causes (storms and/ or an episode of marine transgression) or human action. Various elements indicate the rupture of the bar in the 4th century AD. The consequences of these changes were initially the invasion of the cove by sea water, then the abandonment of the Roman pumping station and necropolis, and the transfer of the landing harbour of Saint-Père Bay (Langouët, 1996).

During the following centuries, the major modifications of this area are linked to religious and historic events with the building of churches, fortifications (Figure 3H21, 1 and 2) and ramparts (Middle Ages to 17th-18th centuries); during the modern period, the density of habitations and the development of modern sailing harbour installations are visible while comparing the maps and aerial photos; more recently, the building of the Rance Tidal Power Station has had a great impact on the whole estuary and, more precisely, on the Saint-Servan/Alet area.

3H.6 Conclusions and Recommendations

The archaeological and palaeoenvironmental data demonstrate the constant transformation of some parts of the coastline of the Côte d'Emeraude, an area impacted by the highest tidal range in Europe, reaching 14 metres high in the heart of the Norman-Breton Gulf. The estuaries (Rance and Arguenon rivers) have always been intensively settled, as revealed by the density of archaeological sites and the importance of settlements such as Alet/Saint-Malo.

The art and map case studies demonstrate the dynamic nature of the coastal landscapes in the Côte d'Emeraude; together with the photos and paintings they illustrate the tourist and settlement development in this zone since 19th century, these have had a rapid and powerful impact on the coastal landscape.

The Côte d'Emeraude landscape is diverse and comprises various coastal features and situations, however, this area seems to be more threatened by pressures from human structures and developments than by natural erosion or sea level changes. Thanks to the legal tools currently available, some additional natural areas of ecological and tourist interest can be sustainably protected meanwhile some partially urban zones should be seriously monitored.

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3H.7 Case Study References

Bonnot-Courtois C., Augris C., Blanchard M., Houlgate E., 2002. Répartition des formations superficielles du domaine marin côtier entre le cap Fréhel et Saint-Malo (Côtes d'Armor – Ille-et-Vilaine). *Géologie de la France*, 2002, n° 3: 31-42.

Bréhier, L., Perez, D., Reghezza-Zitt, M. 2009-2010. Les conséquences environnementales du barrage de la Rance. Ecole Normale Supérieure, département de Géographie. Consulté le 14/01/2014. http://www.geographie.ens.fr/-Les-consequences-environnementales-.html

Cardin, J. 2003-2004. Cézembre, l'île meurtrie. Ecole Supérieure de Réalisation Audiovisuelle, 9'01. http://www.youtube.com/watch?v=mOJG5FH1z40

Cariou A., 2011. *De Turner à Monet, La découverte de la Bretagne par les paysagistes au XIXe siècle.* Musée des Beaux-arts de Quimper – Palantines, 191 p.

Clairay, P. et Vincent, J. 2008. Le développement balnéaire breton : une histoire originale. *Annales de Bretagne et des Pays de l'Ouest*, 115-4: 201-233

Cocaign J.Y. Bizien Jaglin C., Regnauld H., 1996 : Les sites protohistoriques de l'Anse du Verger en Cancale dans leur cadre archéologique et environnemental. *Les Dossiers du CeRAA*, 24 : 71-84 .

Cogné, J., Jeannette, D., Auvray, B., Morzadec-Kerfourn, M.-T., Larsonneur, C., 1980. *Notice explicative, Carte géologique France (1/50 000), Feuille Saint-Cast (206)*. BRGM ed.

Collectif 1992. *La mer et les jours, XVe siècle – 1940. 5 siècles d'Arts et Cultures Maritimes en Côte d'Armor*. Catalogue de l'exposition du Château de la Roche-Jagu, 20 juin – 1er novembre 1992. Conseil Général des Côtes d'Armor, 239 p.

Collectif, 2009**.** *La gestion du trait de côte*. MEEDM (Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer). Ed. QUAE, 352 p.

Collectif, 2013. *Guide méthodologique : Plan de prévention des risques littoraux.* Ministère de l'Ecologie, du Développement durable et de l'Energie. Direction Générale de la Prévention des Risques, Service des Risques Naturels et Hydrauliques, 168 p.

Daire M.Y., Langouët L. (dir.), 2008. *Les pêcheries de Bretagne Archéologie et Histoire des pêcheries d'estran*. AMARAI & Centre Régional d'Archéologie d'Alet éd., 144 p.

Daire M.-Y., Langouët L., 2010. *Les anciens pièges à poissons des côtes de Bretagne, un patrimoine au rythme des marées.* Rennes, Coédition Ce.R.A.A. – A.M.A.R.A.I., Les dossiers du Centre Régional d'Archéologie d'Alet, AG, 2010, p. 20.

Delignon, G. non daté a. *La station balnéaire*. 21p. Consulté le 04/12/2013. http://patrimoine.region-bretagne.fr/sdx/sribzh/annexes/la_plage_et_ses_infrastructures.pdf

Delignon, G. non daté b. *Le lotissement ou l'adaptation d'une pratique urbaine sur le littoral*. Consulté le 04/12/2013. http://patrimoine.region-bretagne.fr/annexes/le_lotissement.pdf

Delouche D., 1996. L'invention de la Bretagne dans la peinture du 19 e siècle, in « *Cent ans de tourisme en Bretagne* », Ed by Apogée, pp.19-30.

Delouche D., 2003. La peinture en Bretagne. Collection Patrimoine de la Région Bretagne, 84 p.

Feige N., 2005. *Les trésors engloutis de la baie de Saint-Malo*, Prestel ed.

Giot P.-R., Briard J., Pape L., 1995. *Protohistoire de la Bretagne,* Ouest France éd., Rennes, 423 p.
Giot P.R., Monnier J.L., L'Helgouac'h, 1998 - *Préhistoire de la Bretagne*. Ed. Ouest-France, Rennes, 588 p.
Goeldner-Gianella L., Feiss-Jehel C., Decroix G., 2011. Les oubliées du "désir du rivage" ? L'image des zones humides littorales dans la peinture et la société françaises depuis le XVIIIe siècle, *Cybergeo : European Journal of Geography* [Online], Environnement, Nature, Paysage, document 530, mis en ligne le 20 mai 2011, consulté le 09 février 2014. URL : http://cybergeo.revues.org/23637 ; DOI : 10.4000/cybergeo.23637

Graviou, P. 2012. *Géotourisme en Côtes d'Armor, petit guide géologique pour tous*. Biotope, Mèze (coll. Géotourisme), 96p.

Henaff, A., Michard, B., Le Visage C. 2007. Erosion côtière : c'est la nature qui commande. http://www.bretagne-environnement.org/Mer-littoral/Les-menaces/L-erosion-cotiere/Erosion-cotiere-c-est-la-nature-qui-commande

Jonin, M. 2008. *Géodiversité en Bretagne, un patrimoine remarquable*. Ed. Biotope, coll. Les Cahiers Naturalistes de Bretagne, SGMB, 160p.

Kayser, O., 1991. Les sites mésolithiques de la pointe d la Varde (35 – Sanit-Malo), *Les Dossiers du Centre Régional d'Archéologie d'Alet*, 19: 5-20.

Langouët, L. 1991. Un retranchement normand « insulaire : Gardaine à Saint-Suliac (35), *Bulletin de l'Association Manche Atlantique pour la Recherche Archéologique dans les Îles*, 4: 55-64.

Langouët, L. 1996. *La cité d'Alet, de l'agglomération gauloise à l'île de Saint-Malo*. Les Dossiers du Centre Régional d'Archéologie d'Alet, supp. S, 128p.

Langouët L., Daire M.Y., 2009. Ancient maritime fish-traps of Brittany (France): A reappraisal of the relationship between human and coastal environment during the Holocene. *Journal of Maritime Archaeology*, vol. 4, n°2, p.131-148.

Le Goff, E. (coord.), Guennoc, P., Hallegouët, B., Lebret, P., Thomas, E., avec la collaboration de Bourdillon, S., Courbouleix, S., Carn, A., Le Berre, P. Martelet, G. Langouët, L., Monnier, J.-L., Ehrhold, A., Pluquet, F., Bonnot-Courtois, C., Simeon, Y., Bitri, A., Egal, E., Augris, C. 2009. Notice explicative, Carte géologique France (1/50 000), Feuille Saint-Malo (243). Orléans, BRGM, 199p. Carte géologique par Le Goff E., Hallegouët B., Lebret P., Guennoc P., 2009.

Leribault C., 2012. *Eugène Isabey*. Cabinet de dessin, Louvre éd., 81 p.

Le Ru L., 2013 - Prospection géophysique et plongées d'expertises sur le barrage de pêcherie des roches du Davier (35). Rapport intermédiaire pour le projet Arch-Manche, ADRAMAR, 20 p. + annexe.

Monnier, J.-L. 1988. Le gisement paléolithique moyen des Gastines (Ille-et-Vilaine). Etude géologique et archéologique, *Revue Archéologique de l'Ouest*, 5: 11-33.

Motte, E. 2013. *Représentations et évolutions du littoral en Bretagne.* Mémoire de Master 2, Université Rennes 2, département de Géographie, 23 p.

Plaine, J., & Jegouzo, P.2012. *Géotourisme en Ille-et-Vilaine, petit guide géologique pour tous*. Biotope, Mèze (coll. Géotourisme), 96 p.

Regnauld,H., Jennings S., Delaney C., Lemasson L., 1996. Holocene sea level variations and geomorphological response: an exemple in Northern Brittany. *Quaternary Science Reviews*, 15 :781-787.

Regnauld H., Mahmoud H., Oswald J., Planchon O., Musereau J.. 2010. Tempêtes, rythme de fonctionnement d'une cellule sédimentaire et « accommodation sace » : exemple sur l'Anse du Verger, Bretagne Nord. *Norois* 215 : 133-146

Online resources:

Données météorologiques 1850-2014 : http://www.meteo-paris.com/chronique/annee/1905
Site sur l'urbanisme : http://www.urbaplu.fr/files_pdf_nat/133/141.pdf
- Atlas du patrimoine : http://atlas.patrimoines.culture.fr/atlas/trunk/
- Base Mérimée : http://www.culture.gouv.fr/culture/inventai/patrimoine/
- BRGM (Bureau de Recherches géologiques et minières), http://infoterre.brgm.fr/
- Glad, portail des patrimoines de Bretagne, http://patrimoine.region-bretagne.fr/sdx/sribzh/main.xsp?form=fulltext_query_form&menu=3
- INSEE (Institut National de ma Statistique et des Etudes Economiques) http://www.insee.fr/fr/regions/bretagne/default.asp?page=faitsetchiffres/presentation/videobretagne.htm
- Ministère de l'Ecologie : http://www.developpement-durable.gouv.fr
- Conservatoire du Littoral : http://www.conservatoire-du-littoral.fr/
- Inventaire National du Patrimoine Naturel : http://inpn.mnhn.fr/programme/inventaire-znieff/presentation
- Code du Patrimoine : http://www.legifrance.gouv.fr/affichCode.do;jsessionid=C6704148510F272CE7D5AE942E415F43.tpdjo08v_3?cidTexte=LEGITEXT000006074236&dateTexte=20140121
- Code de l'Urbanisme : http://www.legifrance.gouv.fr/affichCode.do?cidTexte=LEGITEXT000006074075&dateTexte=20140121
- Cœur Emeraude : http://www.coeur.asso.fr/
- Conseil Général des Côtes d'Armor : http://cotesdarmor.fr/lamenagement_du_territoire/lenvironnement/espaces_naturels.html
- Conseil Général d'Ille-et-Vilaine : http://www.ille-et-vilaine.fr/fr/article/les-espaces-naturels-chemin-faisant
- Cartographie de l'Inventaire National du Patrimoine Naturel : http://inpn.mnhn.fr/carto/metropole/znieff#

CASE STUDY 3I – TRÉGOR & NORTHERN FINISTÈRE

Case study area: Trégor and Northern Finistère, Brittany, France

Main geomorphological types: Soft cliffs, shingle and sandy beaches, shingle spits, creeks, estuaries and dunes.

Main coastal change processes: Coastal erosion, cliff instability, beach change.

Primary resources used: Archaeology, Palaeoenvironment, Art.

Summary: The study area comprises extensive cliff lines which are subject to erosion and instability. Extensive archaeological and palaeoenvironmental investigations have enabled us to retrace precisely the evolution of settlement in relation to coastal changes, especially in the bay of Lannion area, from early prehistory up to modern times. Artistic depictions, numerous photos and charts have provided further data concerning the rate and scale of erosion and coastal change over the last few hundred years.

Recommendations: The scientific observations should make coastal managers aware of the consequences of future sand and aggregate extraction, which is planed offshore in the bay of Lannion in the near future. These observations highlight the potential of analysing past changes (especially through geo-archaeological evidence), in order to evaluate the impact of current management decisions. This is especially important when considering the soft rocks or sedimentary features of the coastal areas, which are vulnerable and very sensitive to any change, either of climatic or anthropic origin.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

Trégor - North Finistère is one of four Brittany case study areas and represents the largest one in terms of geographical extent. This case study report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented along with the results of the art study. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. Further details of the project methodology are in Section 2.

Within the Trégor and North Finistère area, the archaeological and palaeoenvironmental resource and the available art resource have been researched, scored and analysed. The extents of the detailed study areas are shown in Figure 3I.1 and 3I.2 below. Within the case study area, a more limited zone is considered for archaeology and palaeoenvironment, i.e. western Trégor (bay of Lannion); it has been selected to provide a representative set of types of evidence across a range of periods spanning from the Palaeolithic through to more modern coastal heritage, which is further illustrated by recent field work results. The art, photograph and map case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time, including not only Trégor and the bay of Lannion (Côtes d'Armor) but also the whole northern part of the Finistère department.

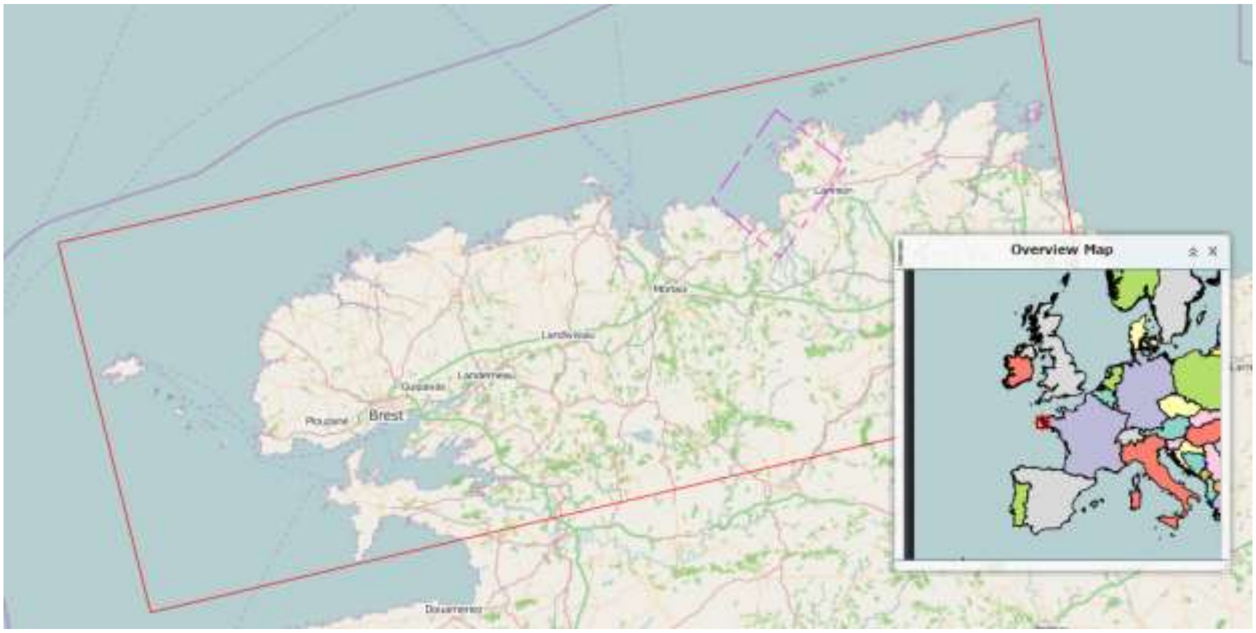

Figure 3I.1. Map of the Trégor- North Finistère study area, the dotted line represents the extent of the archaeological study area.

Figure 3I.2. Map of the Trégor- North Finistère study area, with present administrative limits and main zones mentioned in the text.

3I.1. Introduction to the Trégor and North Finistère Study Area

The Trégor and North Finistère areas are located in the north western part of the armorican massif, and peninsula of Brittany. The present administrative entities are departments of Côtes d'Armor and Finistère, the last one being the more western of Brittany, as indicated in the origins of its name. Some historical areas have been defined according to religious divisions, such as the ancient bishop's territories and cultural zones (Trégor, Léon). Then, for example, the Trégor area is located astride both departments (Finistère and Côtes d'Armor).

The area covered by the case study measures around 150km, within this the coastline has many indentations as rias and bays, numerous islands and islets, meaning the measured distance is closer to 300km. The coastline of Trégor and North Finistère has been developed progressively over the last millennium, as shown by the archaeological and palaeoenvironmental data (Bizien-Jaglin *et al*., 2002, Batt & Giot, 1980). The area has diverse landscapes, which alternate between sandy bays, small islands and rocky promontories. Some areas are densely populated such as seaside stations (e.g. St Michel-en-Grèves) and towns (Lannion, Morlaix), with other areas dominated by large sandy dunes (Léon area) or protected wild zones which are free of human coastal settlements (e.g. some islets of the Molène archipelago).

The case study demonstrates the role of natural phenomena and human pressures on the coastal evolution. Several coastal engineers have been carrying out recent work in the Trégor-Nord Finistère area (Cariolet, 2011; Hénaff *et al*. 2013), meaning coastal risk problems have been taken into account. At a local scale coastal managers have often asked scientists to help them in their decisions regarding land use planning and development proposals, even if the conclusions and advice were also often ignored. In recent centuries and decades the most usual response to protection of property and assets has been the construction of coastal sea walls and flood defences, for example in the Bay of St Michel-en-Grèves.

3I.1.1 Geomorphology of the Area

This section outlines the key geological and geomorphological features and processes of the study area. These factors have a significant impact on the on-going changes to the coastline and associated sites, deposits and features preserved related to the archaeological and heritage resource, in addition to being depicted through a range of art sources.

This case study area comprises two main areas, with the bay of Lannion (belonging to the Northern armorican domain) of Cadomian origin (structured between 2000 and 540 My) and the Léon area, of Hercynian origins (Augris and Simplet 2011).

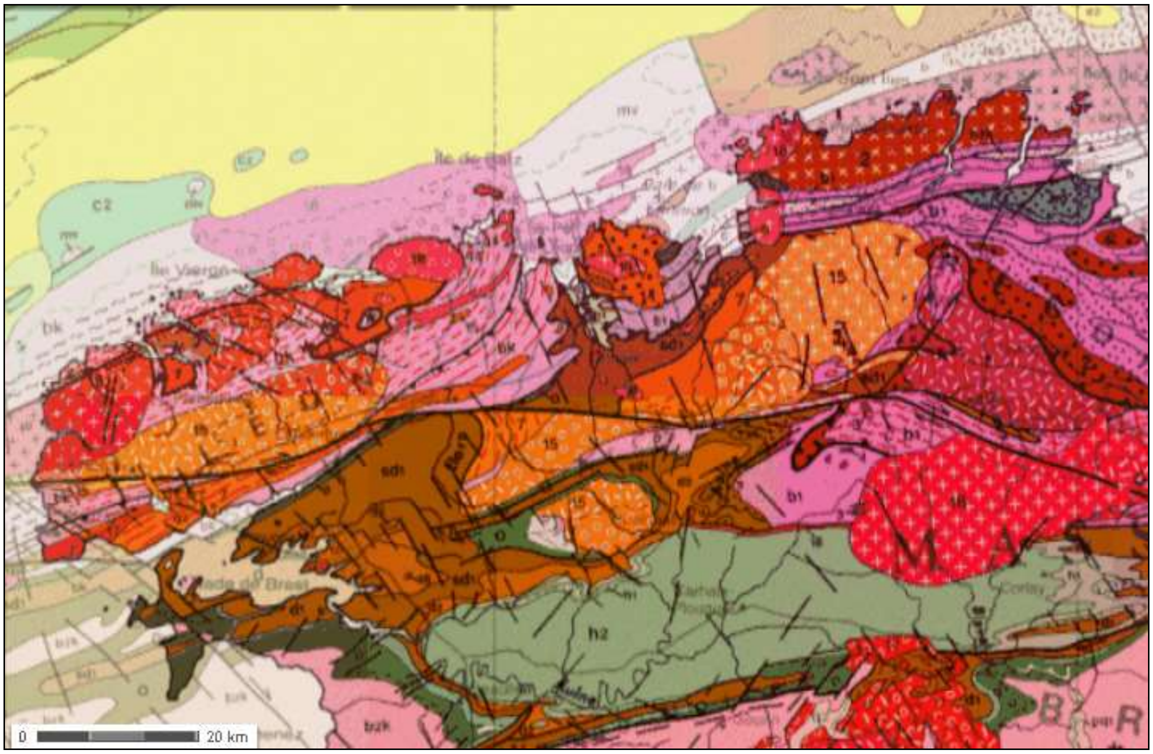

Figure 3I.3. Geological map of the Trégor-North Finistère study area (after BRGM, source Geoportail, IGN).

Geological History

In the Trégor (Port Blessed Trébeurden and Moulin de la Rive), you can see the relics of the oldest rocks of France (Figure. 3I.3). They are exposed in a limited and fragmented way, so that it is difficult to trace their history. At nearly 2 billion years old, they are hardly more than memories in the rock record.

For 650 million years, major tectonic phenomena have twice agitated Brittany, conjuring mountain ranges equivalent to the Himalayas. In the Trégor and North Finistère area, it is the Cadomian chain that is situated in the north of the region (Guingamp, Bay of Saint- Brieuc) and the Hercynian chain.

Over the past 65 million years, the Armorican massif was regularly transformed by the neighboring tectonic episodes and, depending on sea level changes; the seas covered intermittently entire parts of the Armorican massif. Periods of intense erosion in hot and humid climates have followed as well as phases of sedimentary deposits more or less marine.

Finally, it is the Quaternary era (starting overall 2 million years ago) which gives the final shaping to the current landscape of the region. It is punctuated by large glacial and interglacial periods, when most terraces and associated alluvial deposits were developed (Augris and Simplet, 2011) (Figure 3I.4).

Geomorphologic Processes and Human Intervention

The coastal morphology of the Bay of Lannion shows a succession of cliffs and sandy beaches. In its western part, between the Primel cape and Beg an Fry, the coastline of the bay looks like a massive step forward, slightly indented at the mouth by small streams bordered by the highest cliffs of North Finistère which overlook a foreshore that is sometimes very narrow.

To the east of Locquirec, cliffs lower while the foreshore widens (Douron estuary, Saint-Michel foreshore). From St-Michel-en-Grève, the shoreline, previously oriented in an east-west direction forks and turns to a more southern direction. It comprises cliffs one hundred meters in height, between the tip and Locquémeau Beg ar Forn, deeply cut by rivers, including the Léguer also called Lannion river. All rivers discharging into the bay take a course perpendicular to the coastline and could limit small lithological units of the base.

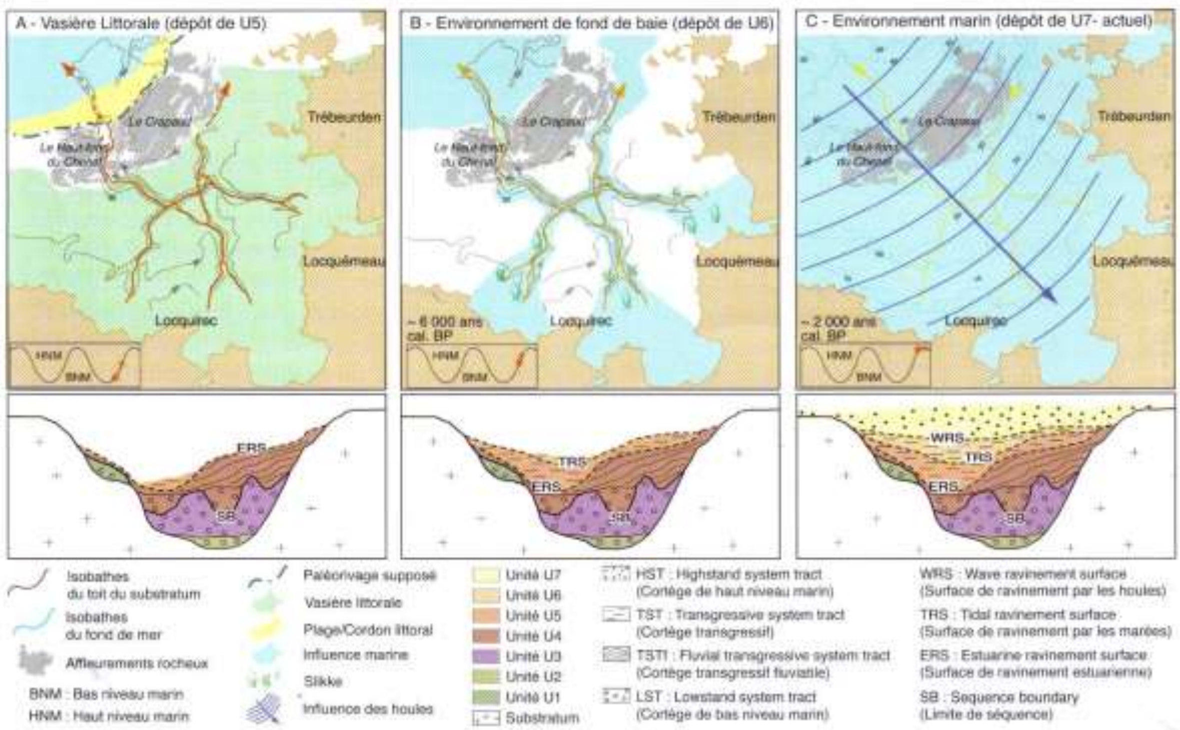

Figure 3I.4. Mapping of the Bay de Lannion channels, fill deposits laid down during the last sea level rise (transgression flandrienne) (after Augris and Simplet 2011).

Located in the heart of the Bay of Lannion, the Léguer estuary cuts the granite massif of Trédrez, consisting of coarse-grained porphyritic granite, which has areas of greater or less fine texture (Auvray and Lefort 1971). This granite is characterised by very numerous rifts, grouped into two sets arranged more or less at right angles and with vertical dips, and a third set of a much less steeply dipping from 10° to 20° only west/northwest. Along the upper foreshore, these rifts facilitate a natural breakdown in rectangular large blocks which, under the prolonged effect of the swell, were processed into pebbles of various sizes. These geological details are important later for architectural observations of the fish traps on both sides of Léguer. The river follows in a east-west trajectory, perpendicular to the coast line which is north-south oriented in this part of the Bay of Lannion.

This coast forms steep cliffs, the height of which reaches 100 meters, between Locquémeau and Ber ar Forn, these are deeply cut by rivers and in particular the Léguer. This topographic configuration is a constraint in terms of the population's access to the resources of the sea, but also provides downwind slopes for the development of wooded areas, the importance of which will be analyzed further.

The current mean sea level in the Bay of Lannion is 5 m above the hydrographic zero, which corresponds to the largest astronomical half tidal range (Augris and Simplet 2011). Even though the tidal range may not be as large as on the Channel coast, the range is sufficiently powerful in the bay of Lannion to justify the development of numerous fish weirs which take advantage of the hydrodynamic flow of the tides.

The economy of the Breton coast has come to rely heavily upon tourism, and this is illustrated in several parts of this study area. This in turn brings about the construction of specific infrastructure, especially yachting harbours (e.g. Trébeurden) and hydrotherapy centres (Trégastel) (Le Dû 1993). For the past few decades, the increase in projects has lead to an inbalance between supply and demand, noticeably the change of the landscape, and considerable spacial conflicts (see Trébeurden harbour). The strict application of the littoral law (1986) is in opposition to financial interest pressures and elected representative ambitions, supported by decentralization. Human intervention is especially noticeable in the tourist destinations of the Trégor area (Perros-Guirec, Trégastel, Trébeurden) as well as in some towns of Northern Finistère (Locquirec, Roscoff, etc). The main transformations are linked to the building of structures (basins, quays), protection dikes, fishing and sailing ports. In some areas (Pleumeur-Bodou and Guissény), new constructions are dedicated to the protection of the coastline against the natural erosion: embankments, breakwaters, moles (Figure 3I.5) which generally have a great impact on the coastal geomorphology.

Figure 3I.5. The Trébeurden new sailing harbour, built in the 1990' (source: http://portdeprimel.fr/).

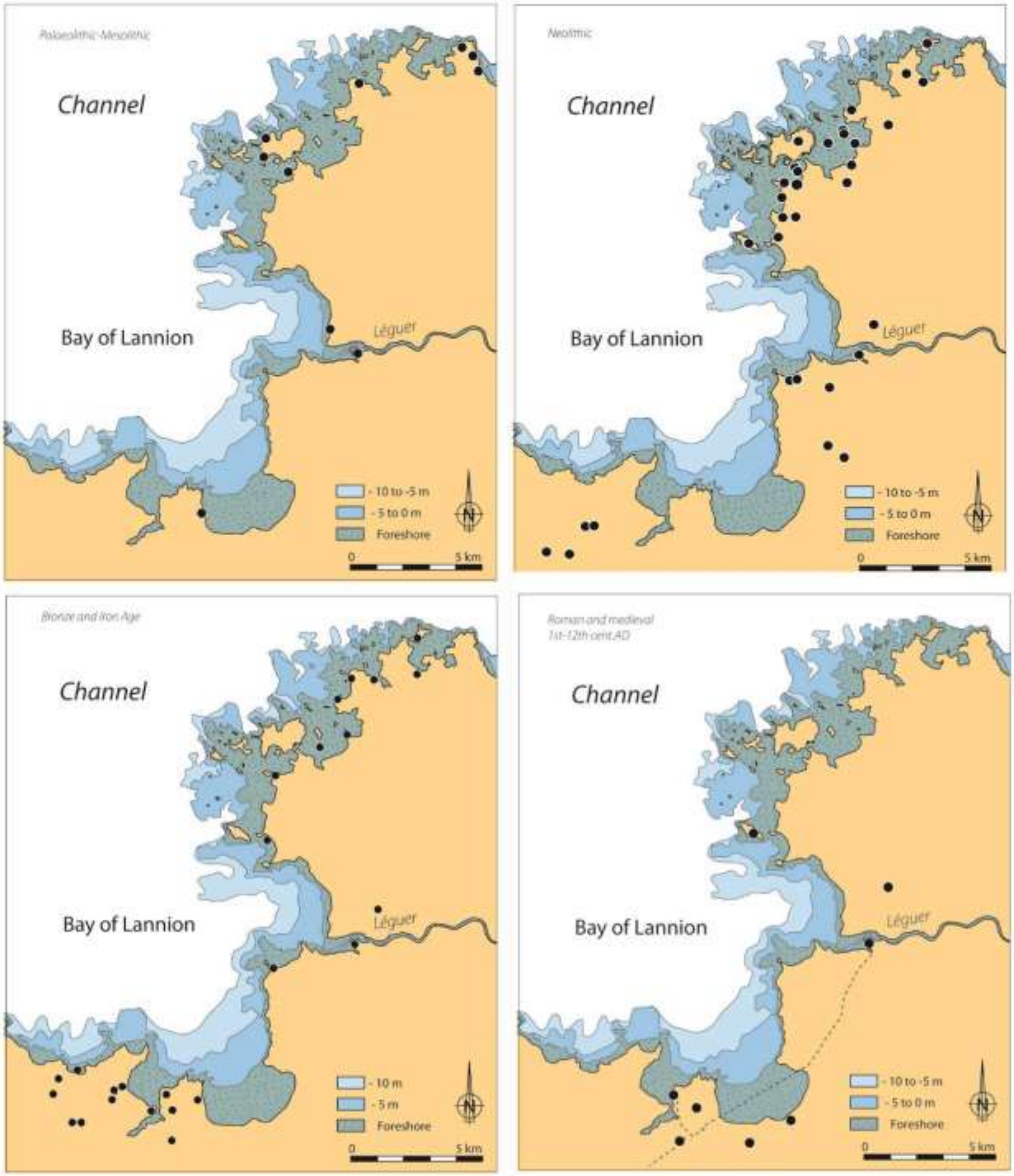

Figure 3I.6. Mapping of the archaeological sites of the area (from Palaeolithic up to Middle Ages) (doc. L. Quesnel and L. Langouët).

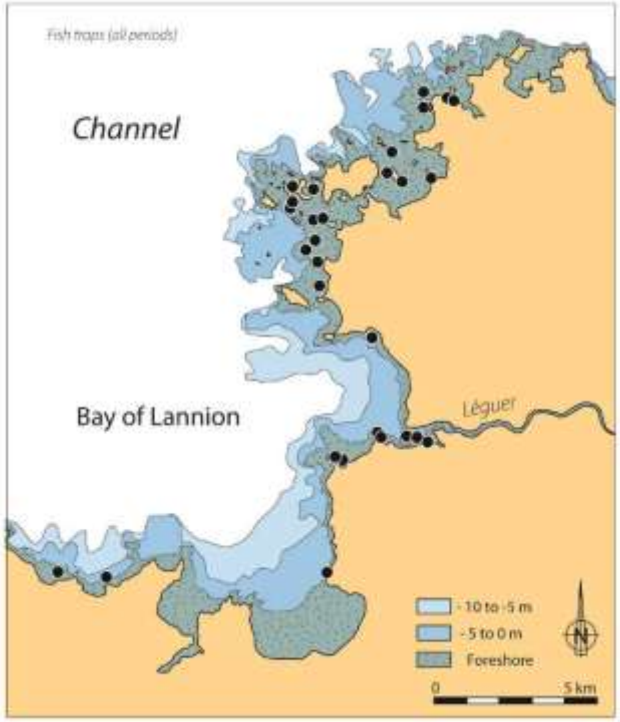

Figure 3I.7. Mapping of the archaeological remains of fish traps (all periods) in the case study area (doc. L. Quesnel and L. Langouët).

3I.1.2 Summary of the Archaeology and History of the Northern Finistère and Trégor Case Study Area

The western part of the study area is very rich in archaeology, (Giot 1987, Giot *et al.* 1998, Sparfel & Pailler 2009) detail of this is developed further through the photographic analysis outlined below. The archaeological and palaeoenvironmental study area focuses on the Léguer estuary area, extending from Pleumeur-Bodou in the north to Locquirec in the south (Figures 3I.6. and 3I.7). The coastline of the case study area consists of the estuary of the River Léguer, where the largest concentration of fish traps are found, including the Petit Taureau fish trap. Their position which is dependant on sea level is the best example in this area demonstrating sea level rise and is the reason why the study area was chosen.

The Léguer estuary is immediately surrounded by cliffs up to 60 m above sea level. The erosion of the cliff is not a major issue, as it consists of granite rocks. On the other hand, the changes in the coastline are important in the bay of Saint-Michel-en-Grève and have rapidly changed in the last three centuries, as can be seen from historical maps. The study area also encompasses the Ile Grande zone in the north which is surrounded by marshes, where is possible to find archaeological sites. In this zone, changes of the coastline were provoked by human activity in the last two centuries, especially with the exploitation of granite quarries. In the entire area, the island archaeology has been particularly dynamic during the past few decades (Le Bihan and Villard, 2007 & 2010; Daire, 2009).

Early Prehistory (Palaeolithic and Mesolithic)

Evidence for the Pleistocene period in the Léguer estuary area includes mainly worked flints dated from the Upper Palaeolithic, when the sea level is considered to be 10m lower than the current level. This material has been found in the intertidal zone around the Ile Grande, several quartz tools were also found in this area, as the quartz veins are common around the Bay of

Saint-Michel-en-Grève, and all along the cliffs of Beg Léguer. As flint is not naturally present in this area, the flint artefacts were made from flint pebble tools carried to the area by the sea.

Many sites dated from the Middle and Upper Palaeolithic have been identified in this area associated with Pleistocene loams (Giot *et al.,* 1998) but no archaeological excavation has taken place. The Palaeolithic evidence in the Léguer estuary area consists of sporadic finds of hand axes and worked flints picked up from the beach. The most important concentration of worked flints was recovered from the beach of Runigou in Trébeurden (Giot *et al.,* 1998).

Later Prehistory (Neolithic, Bronze Age and Iron Age)

The evidence of Neolithic peoples around the Léguer estuary is notable. The main feature of this period is an intense concentration of burial graves and standing stones in the Ile Grande area at the summit of the islands, especially in places with an important visual connection, such as Ile d'Aval, Ile Grande and Enez Vihan (Marchat & Le Brozec, 1991: 42). During this period, the sea level is considered to be 5-7m lower than the current level, and the foreshore archaeological remains of this period are the best evidence of sea level rise all along the coast of Brittany. The Neolithic habitat would be placed in lower areas, nowadays flooded and only accessible at low tide as some the flint tools found in the intertidal zone of Kervegan could be dated from this period. The abundance of standing stones, nowadays located on the shore, such as Prajou, Run ar Gam and Toenno in Trébeurden are a good example of the sea level rise (Figure 3I.8).

Figure 3I.8. A Neolithic of Bronze Age standing stone nowadays located in the tidal area, at Toenno (Trébeurden) (cl. L. Langouet).

Within the area, Neolithic flints have been found in the estuary area of Léguer. Five polished stone axes made from dolerite axes were recovered in the site of Yaudet during excavations (Cunliffe & Galliou, 2005: 31) and another polished axe was found dredged from the estuary of Léguer (Giot,1958).

The main evidence for the Bronze Age and Iron Age in this area is the site of Yaudet. The excavations were carried out by Barry Cunliffe and Patrick Galliou from the Institute of Archaeology, University of Oxford and the ‘Centre de recherche bretonne et celtique, Université de Bretagne Occidentale’, they began in 1991 and continued until 2002 (Cunliffe & Galliou, 2004, 2005, 2007). The site may have been defended in the Late Bronze Age, but the massive rampart was built in the Late Iron Age. Dredging in the estuary of the Léguer close to Le Yaudet has also recovered three bronze swords (Briard, 1971). The swords dated from Early Bronze Age or beginning of the Middle Bronze Age (c.1500 BC) to the end of the Late Bronze Age (c.800 BC) were ritually deposited in marshland fringing the river over a period of time when the mean sea level was several metres lower than it is at present. A lack of Bronze Age structures is an issue in the whole region and this period is mainly documented by funeral monuments, such as those discovered within the shore near the pointe of Sehar (Locquémeau-Trédrez) (Daire, 2011: 143) or by objects, especially weapons, frequently found in rivers bed or estuaries (see below). In the Léguer estuary area, the main evidence of Iron Age settlements is the Yaudet promontory and the Moulin de la Rive habitat, the last one being buried under a thick dune level, where a huge number of pottery sherds were recovered after the erosion of the cliff (Giot *et al*., 1986).

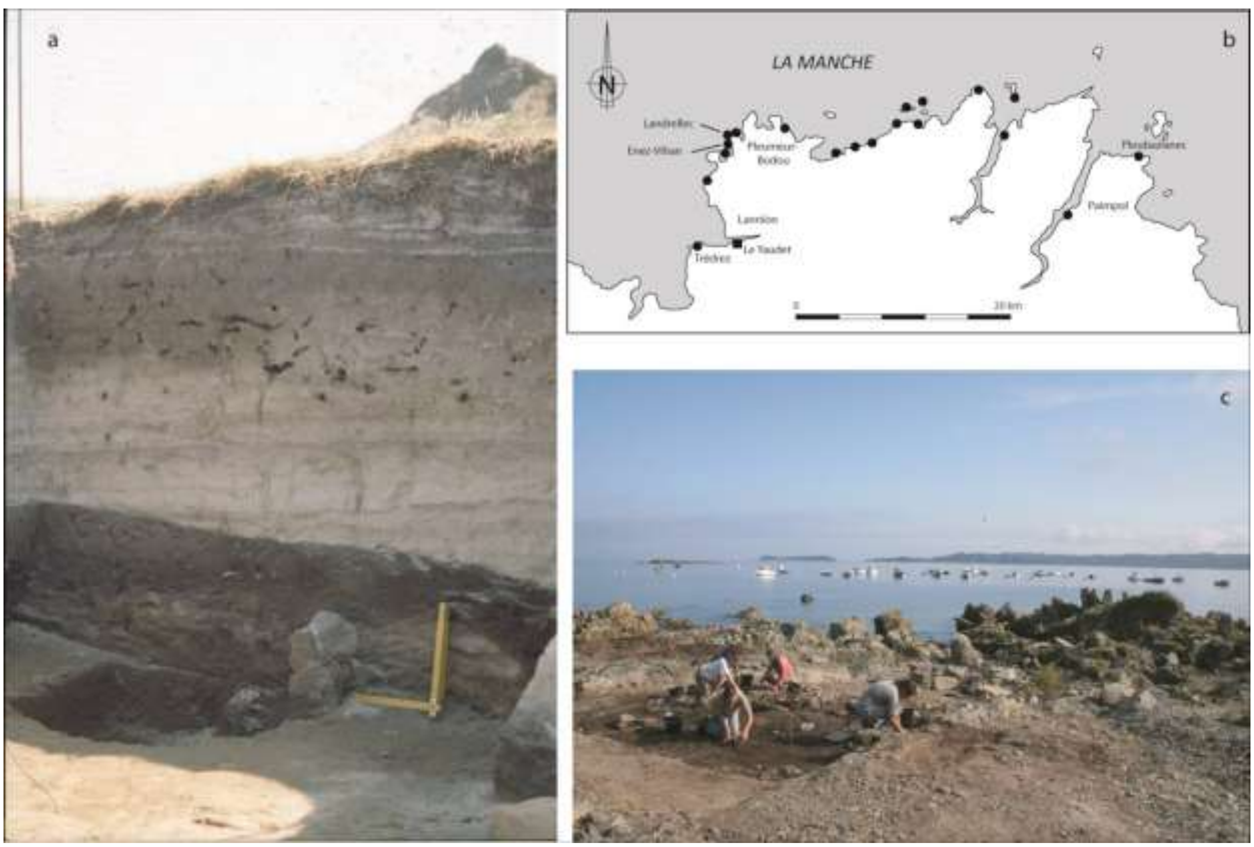

Figure 3I.9. Iron Age salt production in the Trégor area. a: Sandy dunes formed above the Iron Age archaeological level, Landrellec. b: Distribution of the Late Iron Age salt workshops in the area. c: Excavation in progress on the Dossen Rouz site, in 2009 (doc. M.Y. Daire).

The archaeological evidence in the Late Iron Age, when the sea-level was about 2 meters lower, shows an important coastal occupation with considerable salt working and fishing activity within the Léguer estuary area. The whole Trégor area shows a dense network of salt workshops sharing the same technology and producing salt in large quantities for an export market (Figure 3I.9). The excavation of the salt working site of Dossen Rouz took place in 2009

(Daire, 2011), after the Xynthia storm in 2008 eroded the Sehar peninsula, forcing a rescue archaeological project to protect the site (Figure 3I.9.c). At this point, during one night, the coastline retreated 9 meters! Another salt working site was identified within the cliff of Landrellec due to the erosion of the cliff after a storm in 1990, an excavation took place and some well preserved structures were identified, a big excavated kiln and a series of five pits (Daire & Le Brozec, 1990). Another contemporary salt workshop (2nd-1st cent. BC), featuring the same architecture and inner organisation, has been excavated on Enez Vihan island (Daire *et al.,* 2001). The excavation of the Iron Age site of Yaudet promontory, which is one of the major sites of this area (Figure 3I.10), has shown intense occupation in this period with the construction three ramparts within the first century BC (Cunliffe & Galliou, 2005). Another fortification, possibly going back to the Iron Age has been identified in the Dourven cape, only 1 km downstream from Yaudet; no excavation has taken place but is possible to see several ramparts made with stones (Daire, 2011: 129). The Yaudet settlement was placed within an important network of exchange between the Atlantic coast of Gaul to the Gironde and beyond, and northwards across the Channel to the south coast of Britain stretching from Devon to Hampshire, from the second century BC until the first century AD.

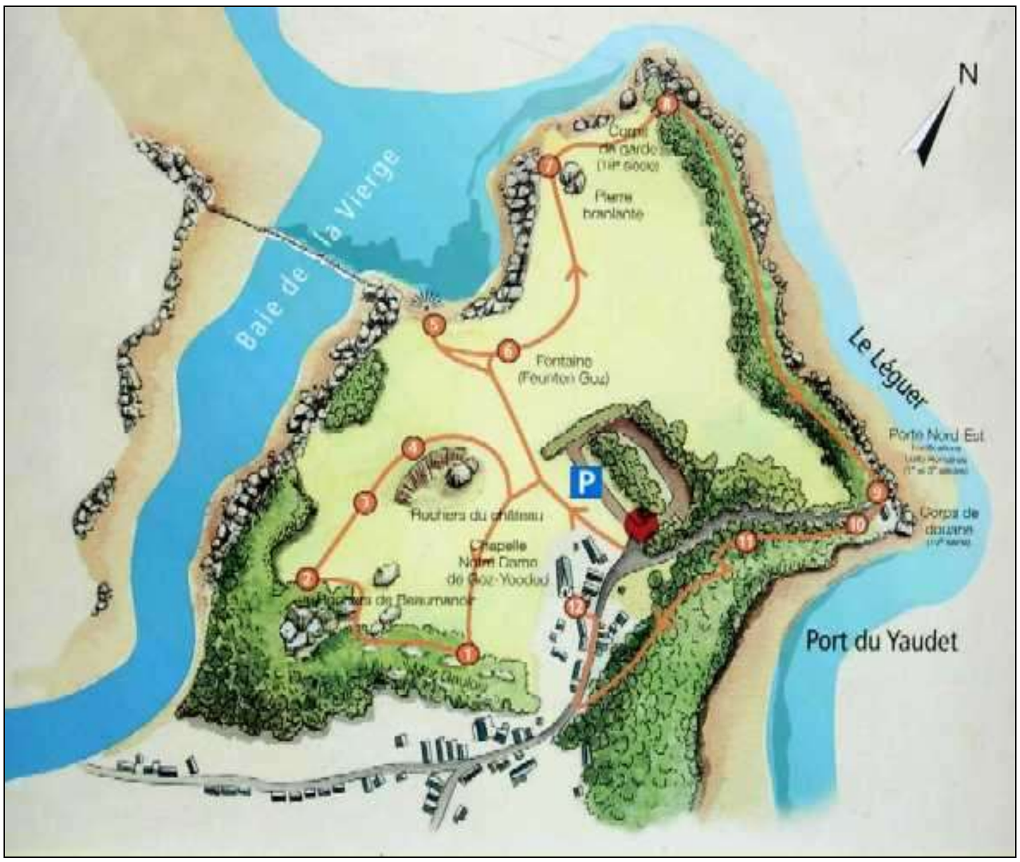

Figure 3I.10. The Yaudet fortified promontory and surrounding maritime installations (source: http://bro-plistin.pagesperso-orange.fr/)

Roman Period

After the Caesarian campaign against the Armorican tribes in 56 BC, a period of constant revolts of the tribes occurred, and the later rampart of the site of Yaudet would represent either a response to the subsequent events of the conquest period or a resurgence of native resistance. After the defeat, the occupation continued uninterrupted well into the first century AD, when new towns were established under the Augustan settlement (Corseul and Carhaix), these changed the economic dynamics and the maritime oppida became marginal. The site of Yaudet was then only occupied in the Upper Plateau by a small community and during the third century would be a military installation.

In the late Roman period several Roman towns of Armorica were defended by walls, and the fortification of Yaudet shows its important location on a maritime promontory protecting the estuary (Figure 3I.10), as it was also the case of Alet (Saint-Malo) and Brest. There is little evidence of activity in the first half of the fourth century but by around AD 400 the site was again in active use and has been occupied ever since.

Roman villas are not uncommon in the study area and an important coastal settlement was identified around the Bay of St-Michel-en-Grève (Figure 3I.11). The most important was the construction of a roman villa near the Douron estuary; some remains of the villa were discovered, but the bathhouse was well preserved covered by dunes. The bathhouse was built in the 1st century AD and later converted into a house and partially demolished. The site was abandoned during the 3rd century AD and covered then by dunes. An excavation took place in 1981 and 1982 after a first dig by Colonel Pérès until 1938 (Bardel, 1984). Another roman villa was identified under the cemetery of St-Michel-en-Grève parish where after a big tempest, some roman structures were discovered. A protective wall was built then in 1869 in order to defend it against the tidal bore.

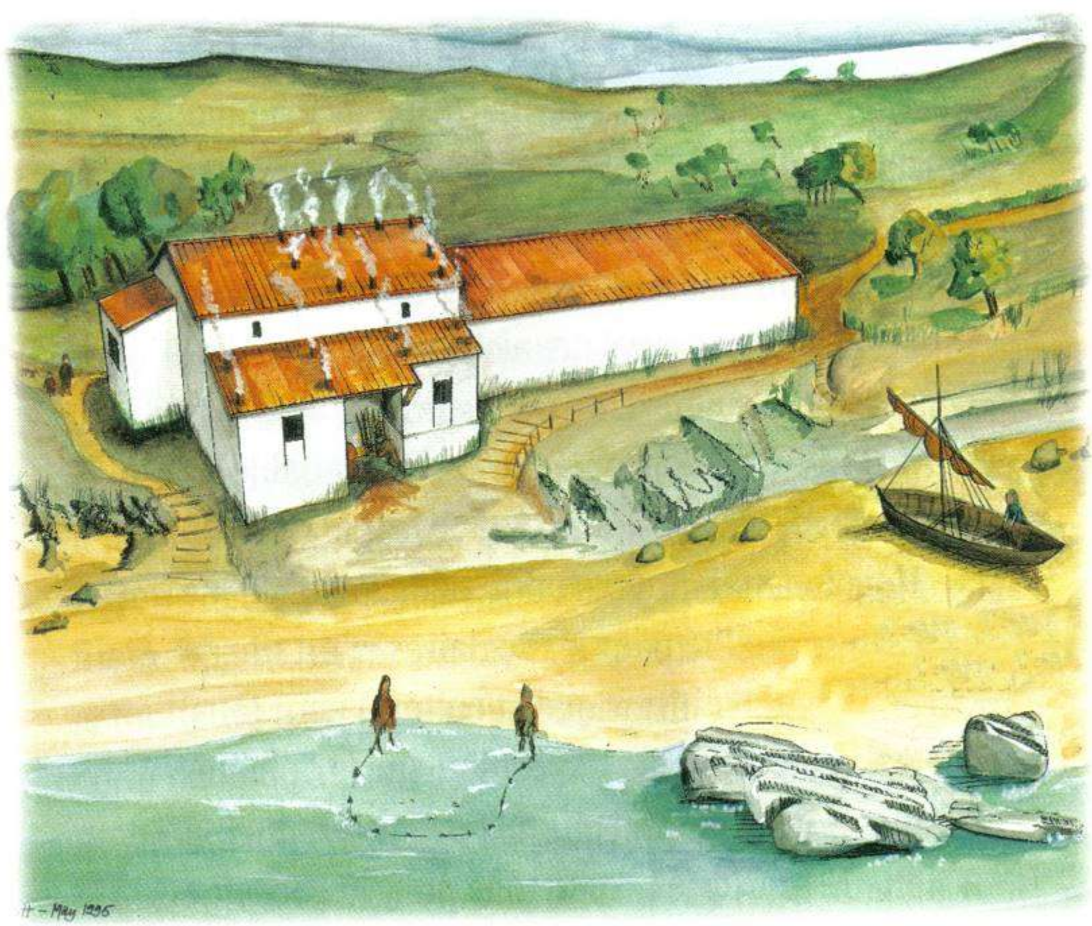

Figure 3I.11. Reconstitution of the roman bathhouse of Plestin-les-Grèves, Hogolo (drawing by M. Batt, after Bardel 1984).

A road was built in the Roman period between the oppidum of Yaudet and the town of Saint Michel en Grève. The name of "voie romaine" (roman road) is still preserved in the city of St Michel en Grève, as a 'fossil' of the roman road (see below in both Art and Maps and Charts analysis). After the town, the road crosses the beach of St-Michel-en-Grève towards the Saint-Efflam area. At the time of construction, the sea level was lower and the path was never flooded by the tide, it was also protected from the sea by a shingle barrier. This road has traditionally been an important route of communication between the towns of Lannion and Morlaix and it was in use until at least the 18th century.

Medieval Period (500AD – 1485AD)

For the early Medieval period there is a lack of significant activity in the late 4th or early 5th century in this area. The known archaeological record from 380-550AD is almost non-existent, except from the site of Yaudet, the headland which was occupied throughout the 5th and into the 6th century. The archaeological remains of Yaudet between c.AD 380 and 550 are of potential relevance to the lively debate surrounding the supposed large-scale emigration of communities from Britain in the 5th century and their settlement in Armorica.

The main coastal activity for this period would be fishing (see below) and the estuary exploitation around a monastic establishment founded during the 6th century on the Yaudet promontory. This monastic community was also responsible for the construction a dam built of massive blocks, the Baie de la Vierge fish trap. The construction of the Petit Taureau fish trap in the Léguer estuary is probably related to the community of Yaudet, with an early medieval construction phase around 615AD (see below for the detailed study).

Between the 9th and the 10th centuries, the whole area suffered sporadic raids, mainly from Viking enclaves settled along the Seine, which continued until the middle of the tenth century. The Yaudet monastery was probably attacked but there is no archaeological evidence of destruction. Anyway, the constant raids and the Viking invasions provoked a progressive abandonment of coastal habitat. In the bay of Saint-Michel the sea level rose and a cross, the Croix de Mi-Lieu, was placed as a landmark for pilgrims and travellers.

In the high medieval period, the Léguer estuary area is dominated by the town of Lannion, 6 km upriver, which became the port-of-entry and had a better location than the Yaudet promontory. It was also protected by attacks from the sea, and it has a privileged location on an important route node that made Lannion an important commercial point. On the other hand, the Yaudet site became more and more isolated, located off of the commercial routes.

Post-Medieval Period (1485 AD – 1900 AD)

A significant element of archaeological record within the Post-Medieval period includes the construction of coastal military defences in order to protect the population and the ports from attack. A key feature is the construction of a path along the coastline of Brittany which was created for watching of the ships for customs purposes. This is now a coastal path used for pedestrians and visiting tourists. The position of batteries and guardhouses along the coast in strategic positions is mainly reflected in historic maps dated from the 18th century.

Between the 19th and the 20th century the coast has suffered intense granite quarry exploitation, especially the Granite Rose area between Trébeurden and Perros-Guirec (Figure 3I.12). The quality of this granite and the particular colour was the main reason for the intense exploitation that provoked important changes in the coastline and the destruction of archaeological sites. The fishing industry and the building of the harbour of Trébeurden, Plestin or Trégastel was also an important issue for the local economy.

Modern
During WWI and the inter-war period, the main coastal activity was tourist related. The beaches of Trébeurden and St-Michel-en-Grève became a major tourist destination in France. The main impact of sea level change was the construction of the railway between Lannion and Morlaix along the coastline of Saint-Michel (Figure 3I.13).

The majority of sites from the 20th Century comprise WWII defence systems with the construction of the Atlantic Wall by the German army. A defensive system was placed within the shore of Plestin-les-Grèves, in front of Villa les Dunes, as a part of the Atlantic Wall. It consists of one casemate and four blockhouses partly buried in the sand; it was partly destroyed after the war. The main area controled by the German army was Saint-Michel bay, as it was a probable disembarkation zone, during this period the Cross of Mi-Lieu was destroyed by target practice.

Figure 3I.12. Remains of the granite quarry activity in the Trégor area (Enez Vihan, Pleumeur-Bodou) (ph. M.Y.Daire).

Figure 3I.13. Early 20th century promotion of Plestin-les-Grèves seaside station (source: the passion-metrique.net).

3I.1.3 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for Project

The archaeological and palaeoenvironmental data has been obtained from the *AMARAI* Database, the *Atlas des Patrimoines*, the *Splashcos* Database and the *Inventaire du Patrimoine des Côtes d'Armor,* further information about the data collected for the project is available below. Several books were also used, either general (Giot *et al.,* 1995; Collective, 1992), or thematic (Monnier 1981), or local (Boutouiller, 2002; Apegit annual bulletins 1986-1996).

Several archaeological projects have been carried out in this area over the last twenty years. The longest research project was the Yaudet excavations undertaken annually between 1991 and 2002, the main interest was the Iron Age period but the excavations showed that the promontory had been in use almost continually since the Neolithic period. The scientific report was published in three volumes (Cunliffe & Galliou, 2004, 2005, 2007), the first one presents a background study of previous research and volumes 2 and 3 form the detailed report of the excavations from the Neolithic to the present day, and include a useful general overview of the archaeology around the Yaudet site for every chronological period.

Another archaeological project was the study of fish traps from the Mesolithic to modern period along the Brittany coast coordinated by Loïc Langouët and Marie-Yvane Daire, since 2006 (Daire & Langouët 2008, 2010). Over 750 fish traps were identified in Brittany, but Servel-Lannion was chosen for the Arch-Manche project because of its richness and diversity of heritage from various periods. The description of the works carried out in 2012 and 2013 are detailed below. The last archaeological research project in this area to be considered is the study of Iron Age salt working sites conducted by M.Y. Daire, as several sites were identified and three of them were excavated (Landrellec, Enez Vihan and Dossen Rouz) generally after a big storm event. The salt working sites, once located within the Iron Age coastal belt, are nowadays strongly affected by erosion and are particularly illustrative of coastal changes.

Alongside this, another research project was the *Inventaire de Patrimoine des Côtes- d'Armor* funded by the department of Côtes-d'Armor, the region of Brittany and the Ministry of Culture of France between 2002 and 2011. The main objective was to create an inventory of coastal heritage for use in coastal management and supporting tourist information (http://archives.cotesdarmor.fr/). The programme includes a compilation of archaeological evidence, historical maps, ancient photographs and architectural heritage in 49 coastal towns.

A database on submerged prehistoric sites has recently been constituted, as the French contribution to the international Splascos Atlas (in progress); it was a main resource for prehistoric sites in addition to the archaeological inventories of the Atlas des Patrimoines (http://atlas.patrimoines.culture.fr/atlas/trunk/) and especially the AMARAI Database, which provided the most detailed and updated information about archaeological sites in Brittany, especially island and coastal sites.

3I.1.4 Art History of the Area

This section presents the background to artistic representations within the area including key schools of artists and individual artists. This provides the background to the broader consideration of individual artworks within the study area. The coastal region of Northern Finistère and Trégor was not very frequently depicted in comparison to the tourist region of Cote d'Emeraude or Cornouailles which were a major source of inspiration for artists from all over the world and where the Pont-Aven School of painters was created in the nineteenth century. Fortunately, some pioneers of photographic techniques represented numerous parts of this case study area. Photographers produced photographic images for postcards which provide visual records of areas where tourism developed on the coast.

The art study area extends for a distance of 260 km along the coast from Paimpol in Côtes-d'Armor, eastwards and then westwards to Crozon in Finistère. The area formerly selected for the analysis of archaeological records has been enlarged to a wider territory for the art study, especially in a western direction, in order to gather a sufficient set of illustrations, and include some important study sites, such a those of the Léon coastal area.

As in the other case study areas, the approach for the coastal study sites aimed to:

- Demonstrate the role that historical works of art (oil paintings, watercolours and prints) and especially photos, can play in terms of supporting understanding of long-term coastal change;
- Assist understanding of the chronology of coastal change in Northern Finistère and Trégor; and
- Provide examples of those artists' works which form reliable records of coastal conditions at the time they were painted.

Art Resource

The main resources used for the paintings of the area included some illustrated books which provided a wealth of paintings and watercolour drawings (Delouche 2003), but the main resource was the Joconde online database. The Culture ministry database 'Joconde' is the gateway to the collections held by museums and public galleries in France. The cataloge contains nearly 500,000 records of objects of any kind (archeology, fine arts, ethnology, history, science and technology etc) enhanced by thematic sections, zooms and virtual exhibitions.

Joconde is the result of an ongoing partnership between the office of the digital broadcasting service, collections of museums in France and the participating museums.

The most prominent figure for art in this area is Henri Rivière. Henri Rivière (1864–1951) was a French artist and designer best known for his creation of a form of shadow play at the Chat Noir cabaret, and for his post-Impressionist illustrations of Breton landscapes. Rivière first visited Brittany in 1884, spending most of his summers there until 1916. Together with bustling Parisian life, rural Brittany constituted the majority of the subjects of his landscape works, between 1890 and 1894. He also made colour woodcuts (studies of waves), strongly influenced by the vogue for Japonism at the time (Collective, 2008).

Another important artist is Emmanuel Lansyer (1835-1893), considered as one of the best landscape artists of his time, with Corot; his work includes more than 1,500 paintings, including many Breton landscapes (Delouche, 2003).

3I.1.5 Art Resources Consulted for the Project

For the Northern Finistère and Trégor area, the art approach benefited from the academic work (Master2) led in the Rennes 2 University by E. Motte (Motte 2013). The theme of the dissertation was: '*Representation and Evolution of the Shoreline: What do regional paintings teach us about the breton coastal environment*?'. In order to establish the art resource available for this study, it was necessary to review the topographical paintings, drawings and prints held by the principal national, region and local collections covering the case study area.

The main source for photographs was the collection available in the Archéosciences Laboratory (University of Rennes) (ICARE, http://ntarcheo2.univ-rennes1.fr/icare/). Several books have recently highlighted the importance of pioneer photographers in the region, these provided important contextual information for our research (Croix *et al*., 2011; Prod'homme, 2012; Biet and Bouze, 2010).

One of the most informative maps and charts used within this case study area was the '*Carte des Ingénieurs géographes du Roy*' (18th century), which provides very accurate details especially along the coasts. At a local scale, a very detailed example is the 'Cadastre Napoléonien' (19th century) which provides a view of the limits of private and public properties, buildings and fields, sometimes with additional information.

3I.2 Current Environmental Impacts, Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the coastline and reviews the current coastal management issues and approaches (Collective, 2009).

3I.2.1 Review of Key Contributors to Coastal Change

The question of coastal changes due to the effects of sea level rise has recently been revised by P. Stéphan for north western Brittany (Stéphan, 2011) (Figure 3I.14). The lithostratigraphy and biostratigraphy of three back-barrier sediment sequences in the Bay of Brest are examined to reconstruct the Holocene sea level history in the western part of Brittany. A saltmarsh foraminifera-based transfer function is used to assess palaeo-sea level positions with a precision of ± 0,51 m. The transfer function is applied to foraminiferal assemblages from four cores, providing 16 new sea level index points from western Brittany. Our data suggests a relative stability of relative sea level between 6250 and 5500 cal. yr BP, followed by a period of sea-level rise (about 2 mm/yr) between 5500 and 3200 cal.yr BP. A decrease of relative sea level with a magnitude of 2 m is suspected between 3200 and 2800 cal.yr BP. After 2800 cal.yr

BP, a new period of sea level rise is recorded, slowing until today. These results are in agreement with the curve of Morzadec- Kerfourn (1974) from the northwestern part of Brittany. However, the period of relative sea level fall around 3000 cal.yr BP is questioned. Although this regression phase is recorded in the North Sea and in parts of the English Channel, this event is recognised neither along the other French coasts, nor along the south western coast of England.

In addition to natural causes of coastal change, several recent publications have underlined the impact of human interventions on coastal areas. An illustration is provided here with Vougot beach (Guissény, north coast of Finistère) which has been subject to a recent geomorphologic study (Suanez *et al.,* 2010). It is a massive drifting sand body approximately 250 to 400 m wide and 2 km long. This dune, with a southwest to northeast position, protects a vast polder area which was disconnected from the sea by a dike construction in 1834. For several decades the eastern part of this dune experienced erosion mainly due to the construction of an artificial jetty in 1974 (Curnic jetty), which entirely modified the hydrodynamics and sedimentation processes. In order to determine the actual trend of evolution, the advance rate, and the resultant sand drift that is occurring, a survey of the dune was achieved between 2004 and 2009 (Figure 3I.15). The results show that the speed of dune retreat has increased in the last decades, and confirm the fact that the Curnic jetty is constantly interrupting the sand drift inducing an increase in sediment loss from the Vougot beach/dune system.

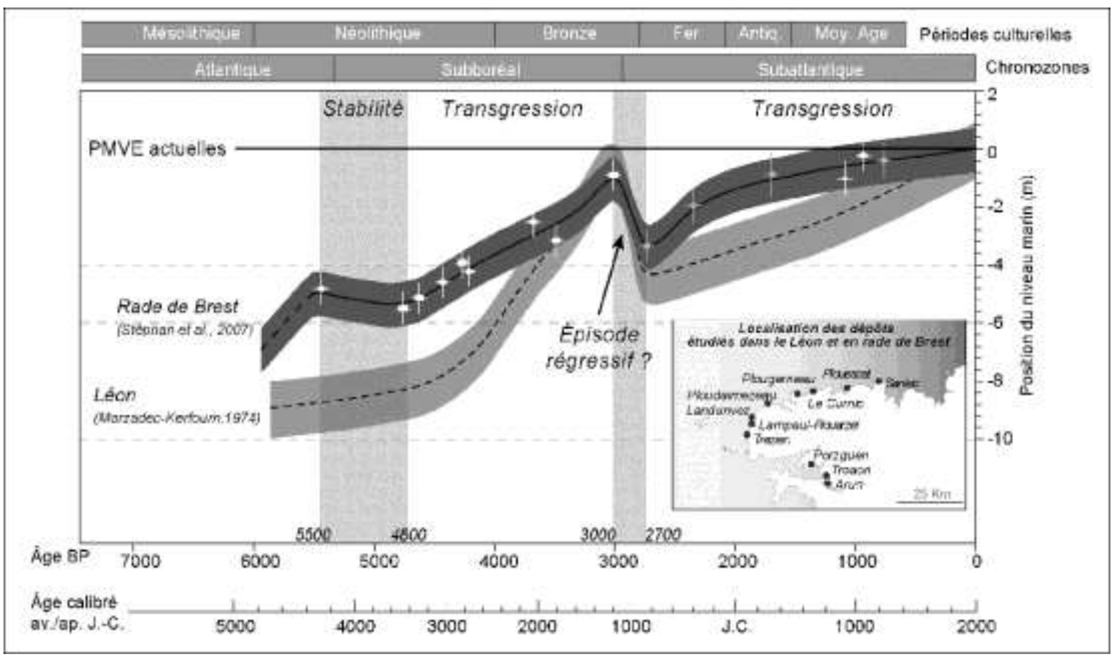

Figure 3I.14. Curves for the Holocene sea level variations (highest sping tides (PMVE)) in the North Finistère Léon area, calculated (after Stéphan in Sparfel & Pailler, 2009: 10).

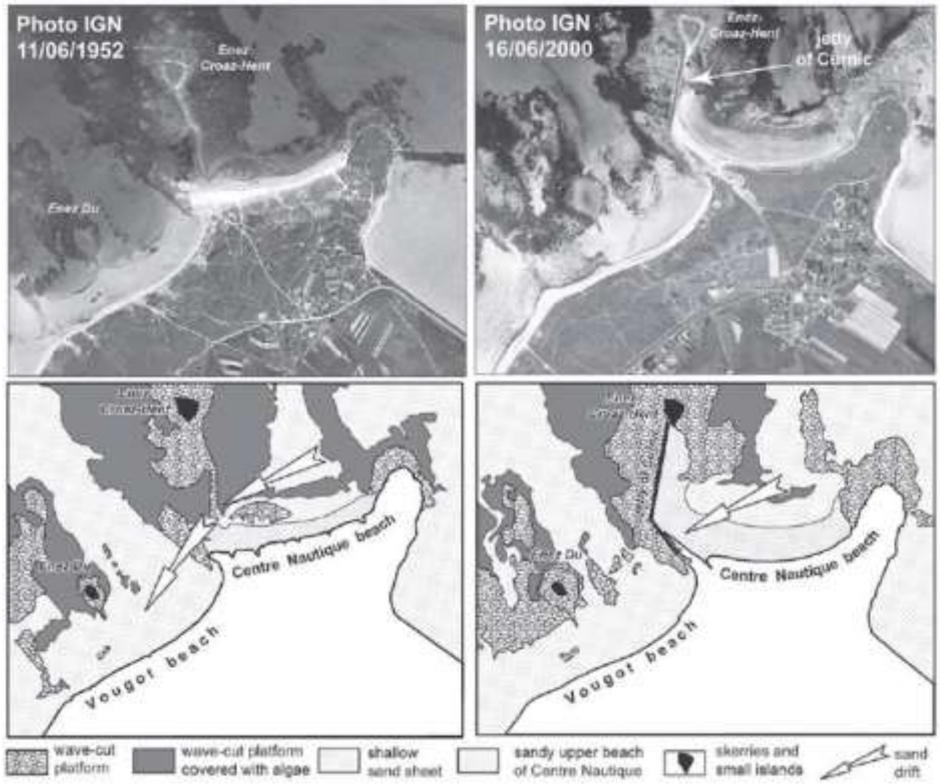

Figure 3I.15.Comparison of 1952 and 2000 aerial photographs illustrating the accretion of the Guissény (Northern Finistère) beach due to the building of the Curnic jetty in 1974. The east-to-west sand drift is generated by wave diffraction around Enez Croaz-Hent island (after Suanez et al., 2010).

3I.2.2 Summary of Current Coastal Management Approach

Coastal risk management is a responsibility of coastal local authorities (i.e towns, departments) in partnership with regional and national institutions (Conservatoire du Littoral, Maritime Affairs, Culture Ministry) (Merckelbagh, 2009). Scientific assessments of coast change and management have been carried out within the framework of several geomorphological studies, generally in response to requests by local managers. These studies showed that uncombined planning policies could produce particularly detrimental effects impacting geosystem functioning 'irreversibly'. Elected representatives and coastal populations settled in coastal areas are concerned with the acceleration of the retreat of dunes and coastal ridges. The scientists raise issues of coastal protection against marine damage and, to this effect proposals were made by researchers to the elected representatives (Figure 3I.16).

According to our current knowledge of the natural environment, several sites of interest are inventoried in the Country TRÉGOR - GOELO:

- 60 Natural Areas of Ecological Interest, Flora and Fauna (SSSI) type 1, a total area of 5,170 ha comprising marine environments, coasts, land (islands, dunes, estuaries, mudflats, rocky coasts, forests, ponds, marshes, moors)
- Protected sites of the country include one Nature Reserve (the Sept-Îles archipelago) and three Special Protection Areas (SPAs); 32 sites are classified under the 1930 Act.
- Management systems in place consist of 6 Sites of Community Interest in the Natura 2000 network.

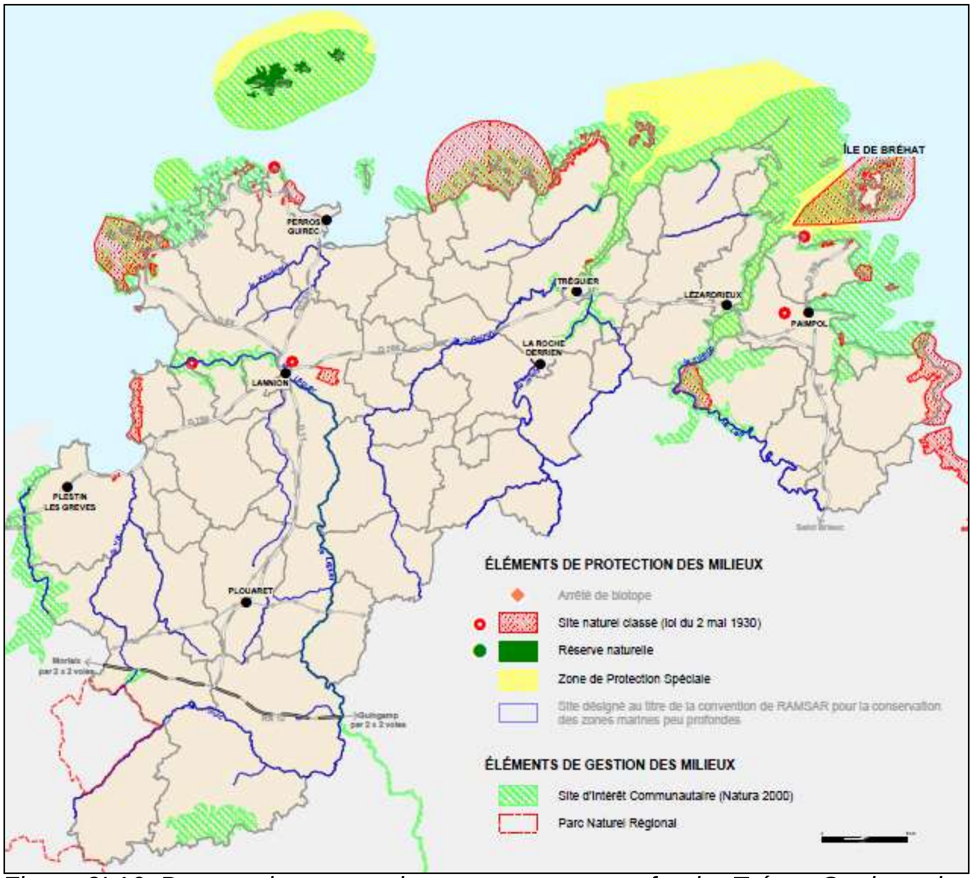

Figure 3I.16. Protected zones and management areas for the Trégor-Goelo region (source: www.bretagne.developpement-durable.gouv.fr/).

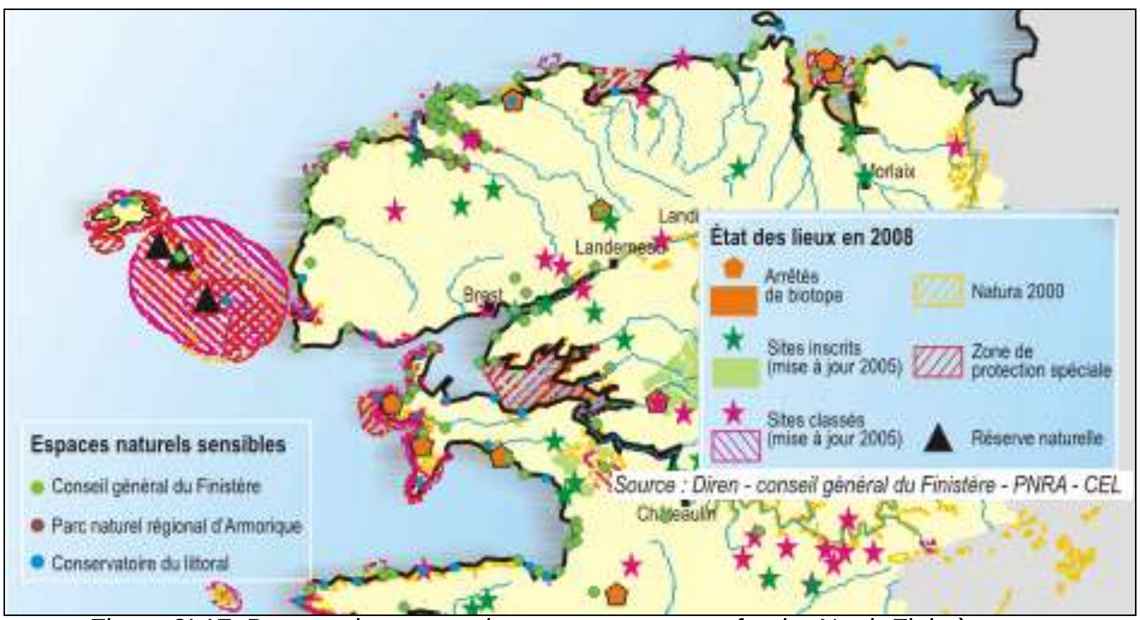

Figure 3I.17. Protected zones and management areas for the North Finistère area (source: www.bretagne.developpement-durable.gouv.fr/).

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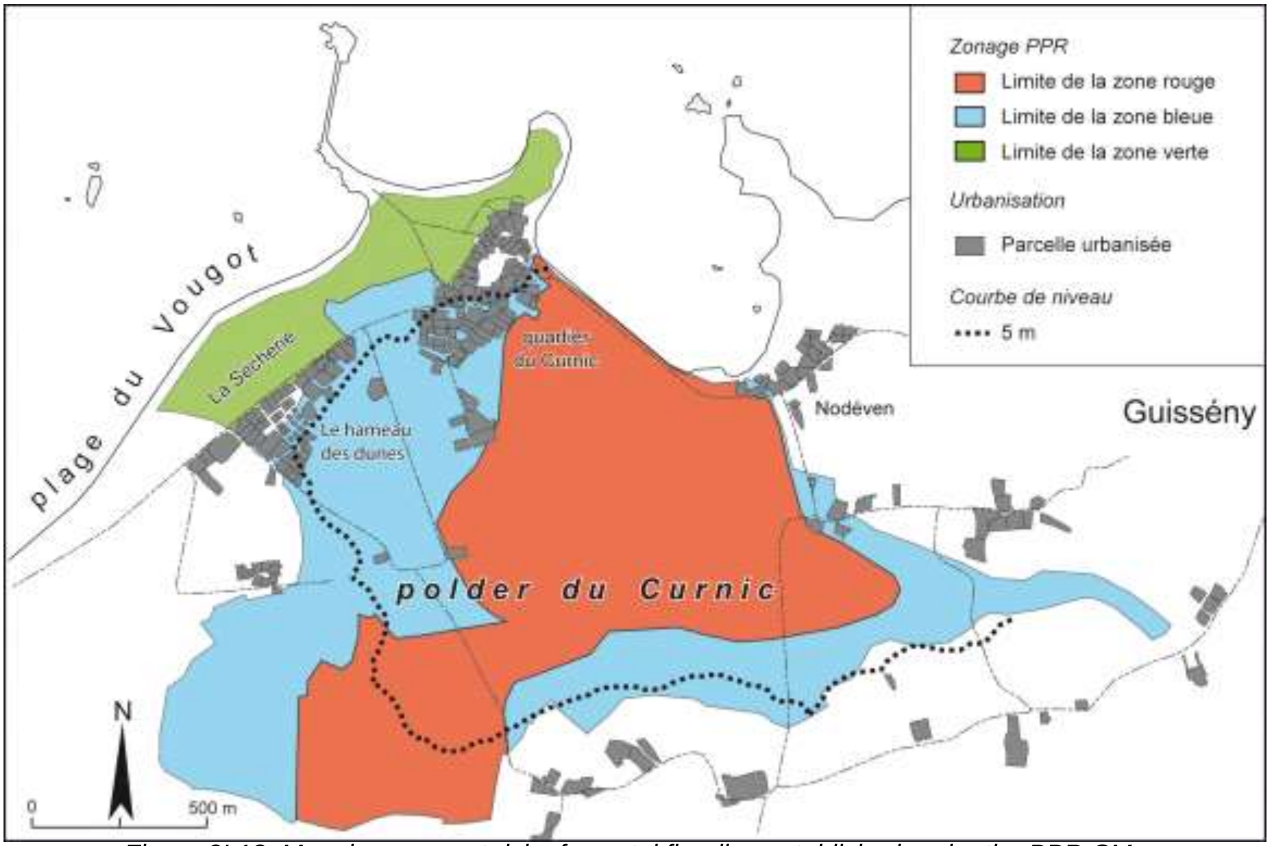

Figure 3I.18. Mapping areas at risk of coastal flooding established under the PPR-SM for the municipality of Guissény (after Cariolet et al., 2012).

In Northern Finistère there are numerous protected areas, as shown on the Figure 3I.17 (www.bretagne.developpement-durable.gouv.fr/). Risks threatening coastal areas within this case study, are of different natures: coastal erosion, flooding and, in some areas, anthropic pressure (tourism, pollution), as shown for example in the Curnic area (Figure 3I.18).

3I.3. Archaeological and Palaeoenvironmental Ranking

This section outlines the results of the archaeological and palaeoenvironmental ranking from the Trégor and north eastern Finistère study area, followed by a discussion of the results. The ranking methodology applied is detailed in Section 2.

The ranking results have benefited from detailed research carried out in the area, especially linked with the excavations and environmental study of the Servel-Lannion fish traps and their surroundings, i.e. the Léguer estuary (Langouët *et al.* 2012, Langouët and Bernard, 2012). Another area of interest was located around the St-Michel-en-Grèves bay, were an important settlement dating back to the Roman period has been recently studied and restored.

3I.3.1. Results of the Archaeological and Palaeoenvironmental Ranking

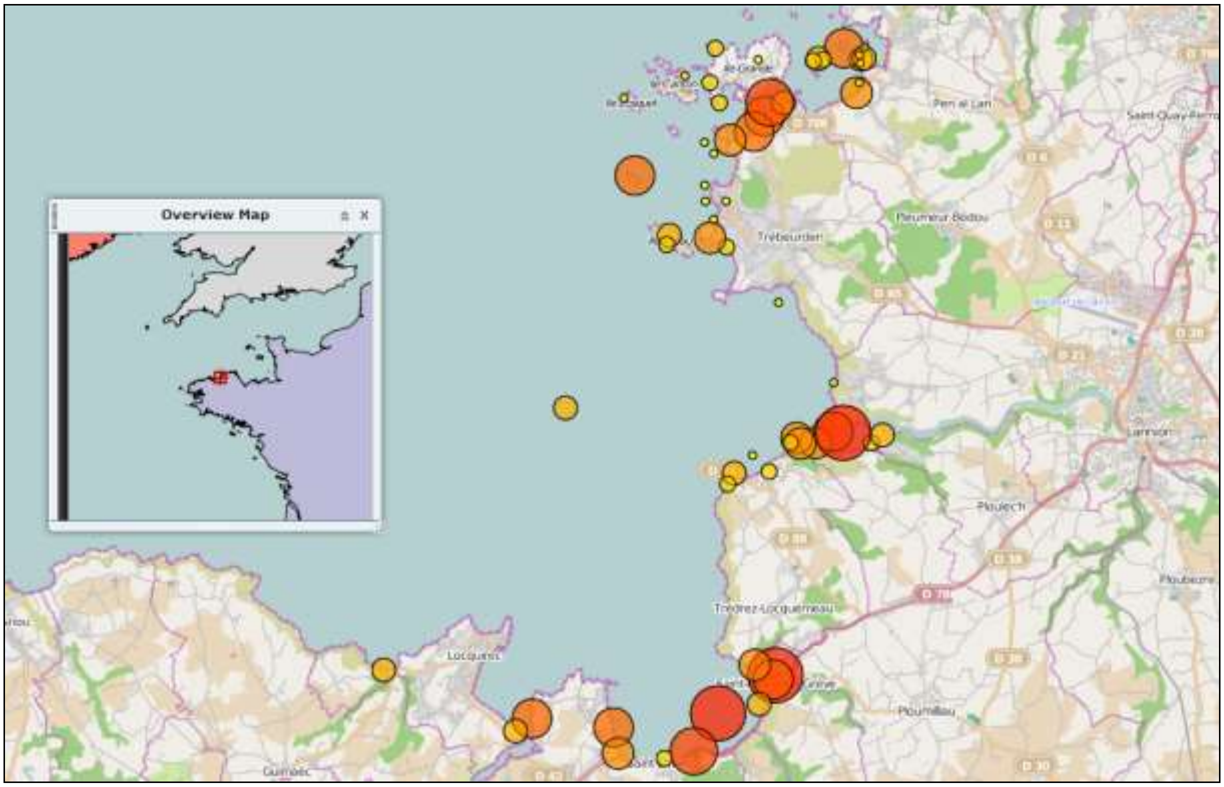

Figure 3I.19. Map showing the distribution of ranked archaeological sites within the Trégor and North-Eastern Finistère study area.

Within the Léguer estuary study area data was obtained from the AMARAI Database, the *Atlas des Patrimoine* of the Ministery of Culture, the SPLASHCOS Database and the Inventaire du Patrimoine des Côtes d'Armor of the Region of Brittany. Where sites ranked highly further research was then required in order to understand the full nature and extent of the site. Each data set went through a process of cleaning, in order to prevent the duplication of sites; this process is detailed further in the Methodology Section 2. A total of 62 sites and records were assessed.

The highest ranking sites (Figure 3I.19) are listed in the table below (Table 3I.1), the total score has been normalised to give each site a score out of 100.

APE uid	Site Name	Site Type	Period	Score – Sea Level	Score – Environ mental	Score – Temporal Continuity	Total Score	Coastal Context
361	SAINT-MICHEL-EN-GREVE – Croix de Mi-Lieu	Monument	Medieval	High	High	High	100	Inter tidal
700	SAINT-MICHEL-EN-GREVE - Roman road	Other find spot	Roman	High	High	High	100	Inter tidal
457	LANNION - Petit Taureau	Marine Installation	Medieval	High	High	High	100	Inter tidal
687	PLESTIN-LES-GREVES - Railway	Monument	Inter-war	High	High	Medium	88	Above HW
686	TREBEURDEN - Enclosure	Other find spot	Medieval	High	Medium	High	88	Coastal
360	PLESTIN-LES-GREVES - Hogolo	Monument	Roman	Medium	High	Medium	77	Above HW

363	PLESTIN-LES-GREVES - Palaeolithic soil	Monument	Palaeolithic	High	Medium	Medium	77	Above HW
467	SAINT-MICHEL-EN-GREVE - Eglise	Monument	Medieval	Medium	Medium	High	77	Above HW
520	LANNION - Corps de garde	Marine Installation	Medieval	Medium	Medium	High	77	Inter tidal
439	TREBEURDEN - Ile Molene	Other find spot	Iron Age	Medium	High	Medium	77	Inter tidal
371	TREBEURDEN – Runigou	Other find spot	Palaeolithic	Medium	High	Medium	77	Inter tidal
373	TREBEURDEN - Menhir Run-ar-Gam	Monument	Neolithic	Medium	Medium	High	77	Coastal
403	PLEUMEUR-BODOU - Enez An Erc'h	Other find spot	Palaeolithic	Medium	High	Medium	77	Coastal
695	PLEUMEUR-BODOU - Beg Crec'h ar Men	Other find spot	Iron Age	Medium	Medium	Medium	66	Coastal
689	PLEUMEUR-BODOU - Landrellec	Other find spot	Iron Age	Medium	Medium	Medium	66	Inter tidal
417	PLEMEUR-BODOU - Keryvon dolmen	Monument	Neolithic	Medium	Medium	Medium	66	Coastal HW
369	TREBEURDEN - Menhir Toenno	Monument	Neolithic	High	Medium	Low	66	Inter tidal
696	TREBEURDEN – Trozoul	Monument	Iron Age	Medium	Medium	Medium	66	Above HW
449	PLOULEC'H - Poull Mad Dogan	Marine Installation	Medieval	Medium	Medium	Medium	66	Inter tidal
516	TREDREZ-LOCQUEMEAU - Plage de Kirio B	Marine Installation	Medieval	Medium	Medium	Medium	66	Inter tidal
515	TREDREZ-LOCQUEMEAU - Plage de Kirio A	Marine Installation	Medieval	Medium	Medium	Medium	66	Inter tidal
739	SAINT-MICHEL-EN-GREVE - Toull ar Vilin	Buried Landsurface	Modern	Medium	Medium	Medium	66	Above HW
514	PLESTIN-LES-GREVES - Saint Efflam	Monument	Medieval	Medium	Medium	Medium	66	Coastal

Table 3I.1. Top archaeology and palaeoenvironement ranking results within the Trégor – North Finistère case study area.

Ranks for sea level change

	High	Medium	Low
Number of sites	8	30	24

Ranks for environmental change

	High	Medium	Low
Number of sites	6	28	28

Ranks for temporal continuity

	High	Medium	Low
Number of sites	10	18	34

Table 3I.2. Detail of archaeology and palaeoenvironemental site ranking results for each category.

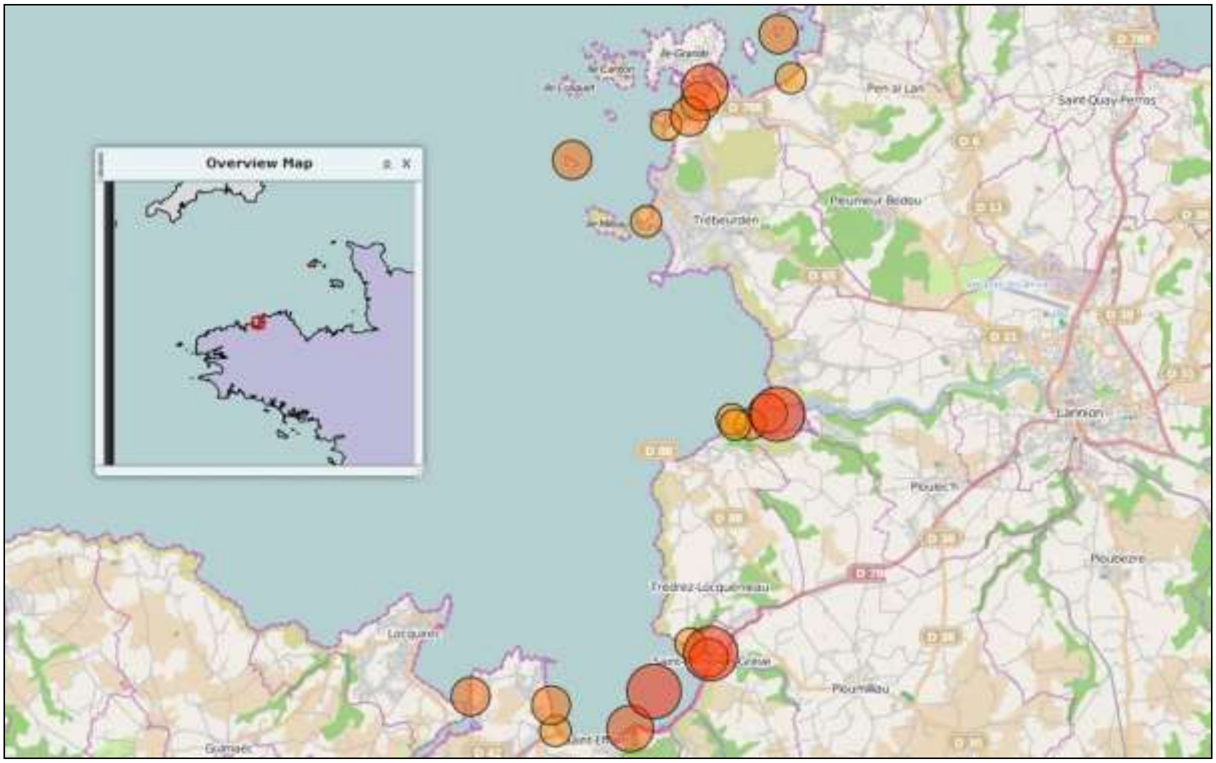

Figure 3I.20. Map showing the distribution of the highest scores sites within the Trégor and North-Eastern Finistère study area.

3I.3.2 Discussion of the Ranking Results

The table of highest ranking archaeological and palaeoenvironmental sites is dominated by medieval and prehistoric monuments. The estuary of the River Léguer is dominated by the fish traps within the intertidal zone, and it represents one of the biggest concentrations of fish traps on the coast of Brittany. The chronology of the fish traps depend on their position within the estuary, which is why they are important for demonstrating landscape evolution. The level and dates of the Servel-Lannion fish traps and others in the area provide valuable evidence of coastal and sea level change. In addition to the archaeological works carried out on the Petit Taureau fish trap, (which included and dating of several different phases), the analytical studies done in the intertidal zone help to reconstruct the environment of the estuary and its geomorphological changes from prehistoric times.

Alongside the fish traps, prehistoric monuments are also represented with in the high ranking sites. Examples include Neolithic monuments, burial graves and standing stones in the area around the Ile Grande, in the north of the Léguer estuary. Their current coastal position is one of the best sources of evidence of sea level rise in Brittany, as they were originally located several kilometres inland in an elevated position above the coast, with an important visual connection. The menhirs of Toenno (Figure 3I.8), are the best sample of sea level rise in this area. Unfortunately, no recent archaeological excavations have taken place on this site, the burial graves were mainly excavated at the beginning of the 20th century, and no further analytical studies of the monuments have been completed. At the same time, prehistoric finds of worked flints have not been subject to a research project and are mainly isolated finds.

The bay of St-Michel-en-Grève is the last area where we can find highest ranking sites. The long term and continued occupation of the bay, from Palaeolithic to modern times, enables the development of modelling of coastal change. Rises of sea level within the bay were visible in the

18th century when the road that used to cross the beach from at least roman times was abandoned due to the danger of the tides flooding the path. Dredging and herding activities were responsible for coastal changes in modern times, as the dunes visible at least during the 17th century suddenly disappeared due to human impact. Over the last two centuries, several embankments were necessary to protect the coastline, the road and the railway. They also had a purpose for tourists, as the bay became a major draw for visitors to the coast of Brittany, who needed transport to the area in addition to protection from the waves.

The intense quarry exploitation of granite sources provides information on coastal change over the last two centuries. This activity provoked not only the disappearance of archaeological sites but also a direct impact on the coastline, especially the islands around the Ile Grande. Other sites which scored lower, because they do not have temporal continuity, but still have the potential to provide information on coastal change were the salt working sites. The sites of Dossen Rouz, Landrellec, Trozoul, Beg Crec'h ar Men or Enez Vihan provide information of coastline change and due to their fragility they are very sensitive to the coastal erosion.

Several megalithic remains from the Neolithic period are considered further through the photo ranking analysis. These sites are now within the tidal area and illustrate sea level rise and coastal change more generally since the Neolithic period.

3I.4 Art, Historic Photos, Maps and Charts Ranking

The ranking systems developed for artworks, historic photographs, maps and sea charts are outlined within Section 2. The ranking systems were applied to a range of selected artworks, some of them being described in more detail below.

3I.4.1 Ranking Artistic Depictions

Research identified eight exhibiting artists who painted on the coastline of Northern Finistère and Trégor between 1770 and 1920 and fifteen paintings were considered (Table 3I.3). By entering data on artwork type, medium, subject matter, time period and other parameters into the the project database it was then possible to calculate the ranking scores for fourteen works of art from the Northern Finistère and Trégor art case study site. The highest ranking artworks, usually gaining 60 points are detailed oil paintings and watercolour drawings, lithographs and steel engravings from the second half of the nineteenth century. These are followed by watercolour drawings from the mid-nineteenth century that were painted by impressionist and postimpressionist artists, the main artist in this period was Henri Rivière who had a house in Ploubazlanec in the Trieux estuary and was fascinated with the coasts of Brittany.

Artists tended to paint attractive or dramatic coastal locations as well as shipping subjects. Marine representations have always been an important subject, especially between the 18th and the 19th century. From the mid 19th century the coast of this region and of Brittany was painted by impressionist or postimpressionist artists. Their aim was not a detailed representation of marine erosion or geomorphological aspects, but a personal point of view. The interest in painting the coast at different periods provides evidence of change over time.

Figure 3I.21. The Loguivy harbour while low tide by Henri Rivière, 1905 (Musée d'Art et d'Histoire de Saint-Brieuc)

The result is that many of the sites of key geomorphological and coastal risk management interest have been painted by artists particularly during the nineteenth century. Even if located at the eastern limit of our study area, the River Trieux estuary painted by Henri Rivière (Figure 3I.21) and also by Paul Sébillot illustrates how art can inform us of long-term coastal change.

These differing coastal landforms and processes and their impacts on coastal residents, assets and infrastructure could not have been easily matched to the most informative works of art without the provision of the ranking system. The ranking system has identified ten study locations, at each at least one artwork has been examined in more detail (see Table 3I.3).

A more detailed explanation of some selected sites and the interpretation of the individual artworks are provided below. The assigning of scores to each artwork suggested names of those artists who had depicted different aspects of the Northern Finistère and Trégor coast across the timeline 1770-1920. These artists include Paul Sébillot (1843-1918), Emmanuel Lansyer (1835-1893), Nicolas Ozanne (1728-1811), Louis Nicolas van Blarenberg (1716-1794), Théodore Gudin (1802-1880), Henri Rivière (1864-1951), Théophile Busnel (1882-1908) and Jules Coignet (1798-1860). These artists can be relied upon in terms of the accuracy of their depictions of the Northern Finistère and Trégor coastline.

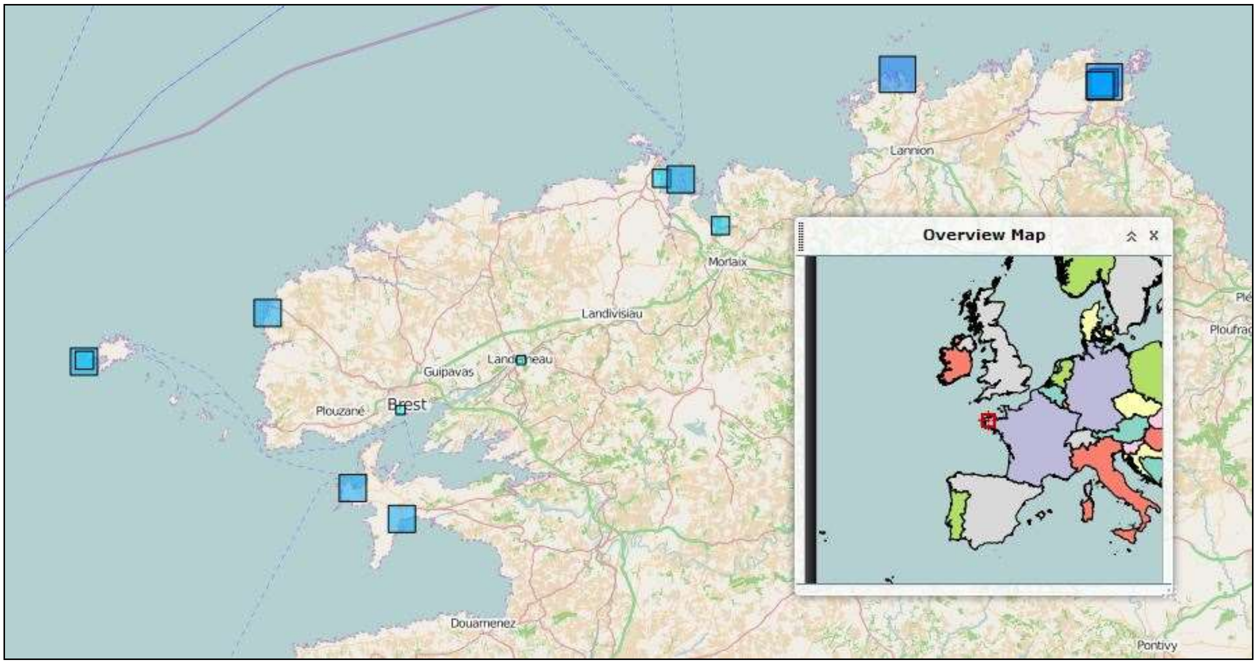

Figure 3I.22. Location of art images within the Trégor – North Finistère case study.

Study No.	Location	Artist	Date	Score type	Sco-re pe-riod	Sco-re style	Sco re heri - tage	Score envi-ron.	Total Score
1	Embouchure du Trieux, Loguivy	Paul Sébillot	1879	Oil	Mid	Topog.		Det. View	62
2	Bréhat, Loguivy	Henri Rivière	1905	Water-colour	Late	Topog.		Gen.l View	55
3	Embouchure du Trieux, Loguivy	Henri Rivière	1905	Water-colour	Late	Topog.		Gen.View	55
4	Embouchure du Trieux, Loguivy	Henri Rivière	1908	Water-colour	Late	Topog.		Gen. View	55
5	Saint Guirec, Trégastel	Théophile Busnel	1890	Water-colour	Late	Pictu.		Gen.View	62
6	Ile Callot, Carantec	Emmanuel Lansyer	1893	Oil	Late	Topog.		Gen.View	51
7	Porspoder	Théophile Busnel	1893	Water-colour	Late	Pictu.		Gen.View	55
8	Le Teucer, Ouessant	Emmanuel Lansyer	1885	Oil	Late	Marine		Det. View	55
9	Port de Camaret	Théodore Gudin	1830	Oil	Early	Topog.		Det. View	55
10	Morgat	Henri Rivière	1907	Water-colour	Late	Topog.		Gen. View	55
11	Rivière près du Dourduff	Emmanuel Lansyer	1874	Oil	Late	Topog.		Gen. View	40
12	Batteries du port de Brest	Louis Nicolas Van Blarenberghe		Watercolour	Early	Pictu.		Gen. View	37

Table 3I.3. Top art ranking results within the Trégor – North Finistère case study.

3.4.2 Ranking Historic Photographs

A total of 443 historic photos (and photographic postcards) were assessed as part of the project, images were primarily chosen from locations along the coastline where historic paintings and archaeological sites were also known. The photographs were collected and then scored using the methodology outlined in Section 2 (Figure 3I.23).

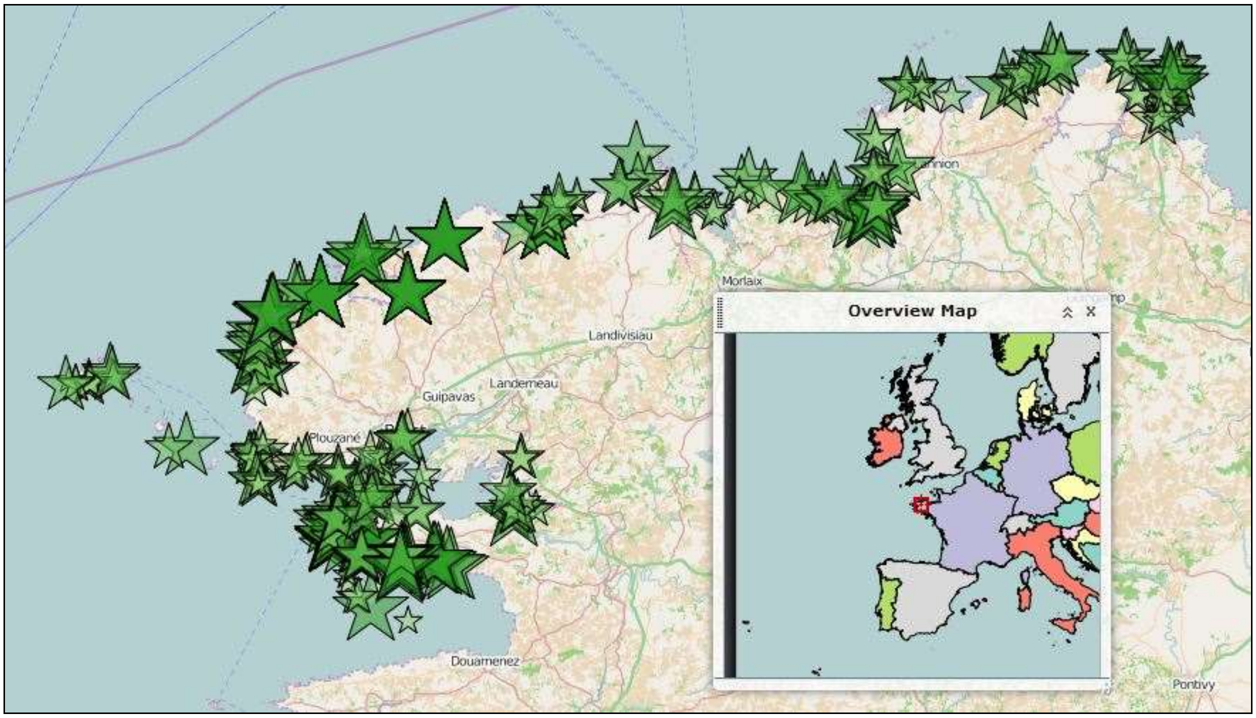

Figure 3I.23 Location of historic photos in the Trégor – North Finistère case study area.

Hundreds of historic images exist for this stretch of coastline, it should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic photos to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums and galleries, as well as private collections has the potential to provide many more.

The table below (Table 3I.4) outlines the results of the ranking, note that photographs were scored as either a heritage view or a non heritage view. The majority of photos assessed were of heritage views, containing features which can be identified today, the oldest photo assessed was taken around 1900; amongst the 443 selected photos for this area, most of them date from the first quarter of 20th century. Unfortunately, the name of the photographers is seldom known and most of them remain anonymous. Photos scoring c.100 and those showing archaeological sites or megatlithic monuments located on the foreshore on in dunes were selected as they have the most potential to illustrate coastal changes and especially sea level rise.

Figure 3I.24. View of the pointe du Toulinguet (Finistère) geology, around 1910 (© Labo Archéosciences UMR 6566 CReAAH).

The distribution of photographs is quite unequal as many depict areas of tourist interest or coastal towns. For example where are few tourist views of the Molène archipelago, this is fortunately counterbalanced by the fact that some pioneer prehistorians had a great interest in the study of the megalithic monuments in this archipelago.

Some places are very well represented, e.g. the Crozon peninsula (Finistère) or the Bréhat archipelago, for tourist or scientific purposes. For example, serveral geologists such as L. Collin were early interested in the Crozon peninsula and its remarkable sites (Pen Hir, Tas de Pois, Dinan bay, Toulinguet cape, Morgat grottos) (Figure 3I.24).

For this area, a lot of archaeological and geological ancient views are available; these views generally illustrate not only the coastal changes but also cultural heritage elements, some of them having disappeared since that time. For example, on Melon island (Porspoder) the great standing stones represented on the A. Devoir photos have been totally destroyed in 1942 (Figure 3I.25) (Daire & Lefeuvre, 2001). Another example is the 'Pont Crac'h' in Plouguerneau, corresponding to a very old (Roman or Iron Age) ford built to facilitate the crossing of the Aber Wrac'h river; this site, reached and regularly damaged by the sea at high tides, was rebuilt in 2008 (Figure 3I.26).

Id	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
58	Yaudet-Chapel & Leguer estuary	1910-1920	Medium		Good	100
60	La croix de Mi-Lieue	1900-1945	High		Good	100
65	Pare-lames (Plestin)	1918	High		Good	100
146	Menosach (Plouguerneau)	1900-1910	High		Good	100
154	Allée couverte de Kernic (Plouescat)	1900-1910	High		Good	100
164	Menhir de Men Ozach (Plouguerneau)	1900-1930	High		Good	77
165	Allée couverte de Lerret (Kerlouan)	1900-1930	High		Good	100
198	Pont du Crac'h (Plouguerneau)	1900-1930	High		Good	100
229	Grand Menhir (Porspoder)	1900-1923	High		Good	100
231	Grand Menhir (Porspoder)	1900-1923	High		Good	100
268	Allée couverte du Ribl (Lampaul-Ploudalmézeau)	1900-1930	High		Good	100
342	Falaise Est de Portz Naye (Camaret-sur-Mer)	1900-1930		High	Good	100
357	Pointe du Toulinguet (Camaret-sur-Mer)	1900-1930		High	Good	100
381	Anse de Kervenny (Plouguerneau)	1900-1930	High		Good	100
385	Le château de Dinan (Crozon)	1900-1930		High	Good	100
408	Tombe de Roch Glas (Penvenan)	1958	High		Good	100
421	Pointe du Grand Grouin (Camaret-sur-Mer)	1900-1930		High	Good	100
498	La jetée de Pempoul (Saint-Pol-de-Léon)	1900-1925	High		Good	100
521	Oratoire Saint-Guirec (Perros-Guirec)	1900-1925	Medium		Good	77
633	Moulin du Birlot (Bréhat)	1900-1925	High		Good	100

Table 3I.4. Top photo ranking results within the Trégor – North Finistère case study.

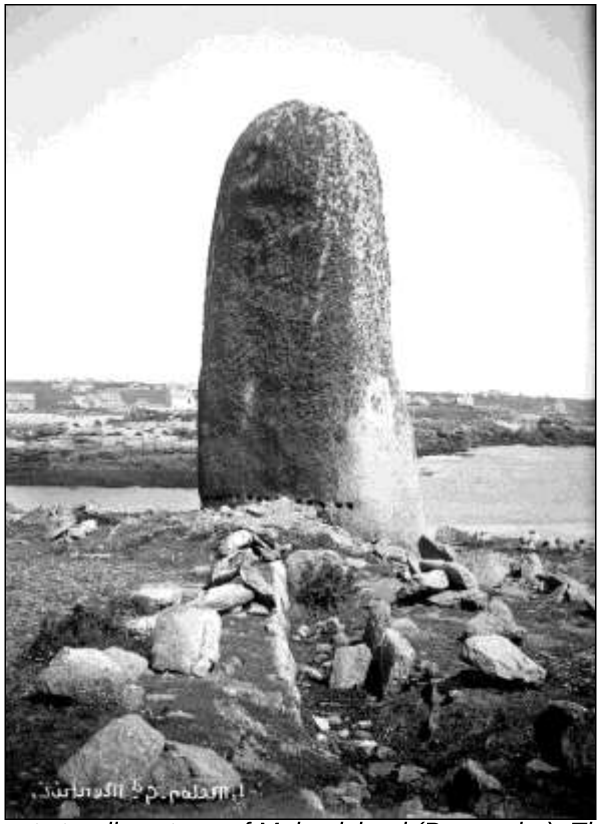

Figure 3I.25. View of the great standing stone of Melon island (Porspoder). This menhir was bombed and destroyed in 1942 (© Labo Archéosciences UMR 6566 CReAAH).

Figure 3I.26. View of the pre-Roman ford of Pont Crac'h (Aber Wrac'h) which was totally rebuilt in 2008. (© Labo Archéosciences UMR 6566 CReAAH).

Most of the pioneer 'antiquarians' were interested in the question of the sea level changes, and tried to study and illustrate the phenomena in the region of Brittany, through remarkable case study sites. Examples include the Neolithic passage graves of Lerret (Kerlouan) and Kernic (Plouescat), the Neolithic or Bronze Age of Menosach (Plouguerneau), and the Metal Age cist tombs of Penvénan which were long protected by dunes but totally disappeared in the 1970's. The position of all these monuments in the tidal area provides accurate data on sea level rise and coastal changes, as all these monuments were ereted in times when the coastal landscape was very different. The megaliths were obviously situated out of reach of the sea. Coastal changes mean that the main dunes of Northern Finistère are thought to be formed after the Bronze Age (Guilcher & Hallégouët 1991, Hallégouët 1971, 1978 and 1981).

Certain postcards picture coastal sites including submerged or tidal monuments, such as the Saint-Guirec oratory in Perros-Guirec, built between the 11th and 12th centuries, and nowadays submerged at high tide, or the "Mi-Lieue" cross at Saint-Michel-en-Grève (destroyed during WWII and rebuilt in 1993). Some of these photos are of historical interest, especially those featuring Brest bay, as this area has been intensively militarised over several centuries, changing radically since WWII. Following the destruction and bombing during the war, a lot of new structures have appeared in this area: enlargement of Brest harbour means that the Brest roman castle is no longer on sea edge, changes and construction work on Longue island which is now devoted to a nuclear submarine base, means public access is forbidden.

Some of these photos clearly show the impact of modern construction work such as at Sainte-Anne beach at Saint-Pol-de-Léon, were the natural pebble bar was transformed into a road in 1968.

3I.4.3 Ranking Maps and Charts

Several historical maps exist of the Northern Finistère and Trégor coastline, some of them dating back the end of the 17th century. 33 maps were assessed as part of the project (Figure 3I.27) using the methodology outlined in Section 2. 19 maps correspond to the whole case study area of Northern Finistère and 14 maps correspond to the specific area of Trégor and the estuary of the River Léguer. It should be noted that this study did not intend to be exhaustive, it simply aimed to highlight the potential for historic maps and charts to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums, libraries and galleries, as well as private collections has the potential to provide many more. The focus of this project was on the bay of Saint-Michel-en-Grève where the evolution of the coastline over the last three centuries is depicted. The maps were assessed and digitised to create map regressions of the coastline, this was later combined with other data sources (see below).

A total of 33 maps and charts were assessed and scored within this case study area (Table 3I.4). Most of those ranked are marine charts, which are closely linked to trade and military purposes. They generally depict ports, anchorage bays, and also reefs and rocks, and the main markers for seafaring and coastal sailing.

Notable military points along the coast are highlighted on the maps especially during wars (17th and 18th centuries), e.g. the Brest bay fortifications (the Mingan or Bertheaume forts, the Espagnols cape fortifications) while during the 19th century, the maritime data includes features useful for offshore fishing and navigation, such as the depth of the seabed, stream orientations or the nature of the seabed.

Land maps include very detailed documents such as the Napoleaonian 'cadastral plans' (19th century). Some charts concentrate on the presenation of the archaeological and megalithic record; they mainly concern the Molène archipelago (six maps) and provide information on the monuments and landscapes which have been subject to change or disappearance.

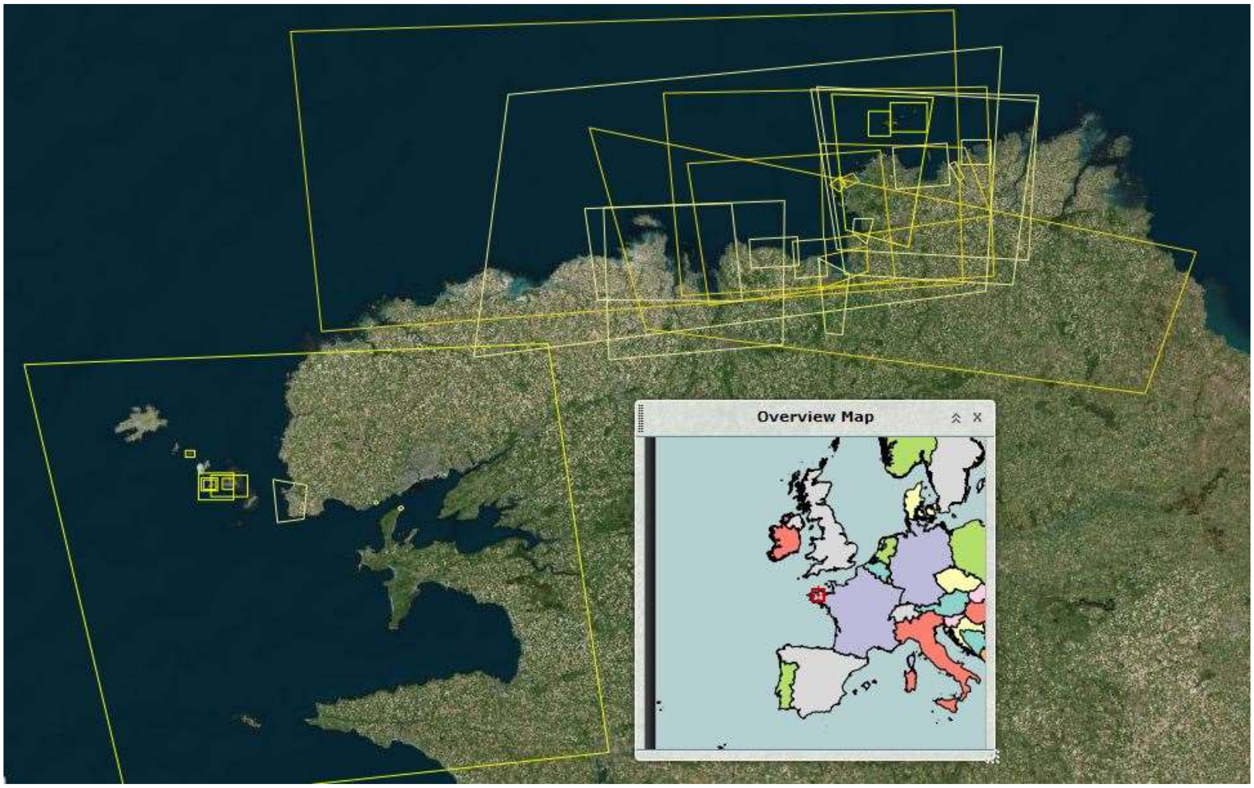

Figure 3I.27. Location of the maps assessed along the Trégor and Finistère coastline.

MAP _uid	Title	Year	Score Chrono-metric Accuracy	Score Topo-graphic Accuracy	Score Detail in non-coastal area	Score Geometric Accuracy
38	Plan cadastral parcellaire de la commune de Plestin	1814	60	30.55	100	100
39	Carte des ingénieurs du Roi – Léguer	1770	73.33	50	66.66	50
40	Carte des Ingénieurs du Roi – Baie de Saint-Michel	1771	73.33	50	66.66	66.66
41	Costes de France sur l'Océan et sur la Mer Mediterranée, coste de Bretagne	1690	73.33	50	33.33	33.33
42	Cadastre Pleumeur-Bodou Section A1	1826	20	16.66	66.66	83.33
43	Cadastre Ile Grande Pleumeur-Bodou	1826	73.33	50	66.66	66.66
44	Carte de France Lannion	1835	73.33	50	66.66	66.66
46	Carte géologique du Finistère	1844	73.33	38.88	33.33	66.66
47	Carte d'une partie de la côte du Nord de Bretagne	1754	73.33	41.66	0	83.33
48	Coste de Bretagne depuis les Sept Isles jusqu'à l'isle Molene et Lanion	1764	20	16.66	33.33	66.66
49	Carte particulière des costes de Bretagne qui comprend Morlaix Saint Paul de Leon les Sept Isles et l'Isle de Bas	1693	73.33	20.83	33.33	66.66
50	Carte de la côte de Lannion	1735	73.33	20.83	33.33	33.33

51	Embouchure rivière de Lannion	1756	20	20.83	33.33	50
52	Capitainerie de Lannion	1710	73.33	25	33.33	33.33
60	Ile Quéménès et son Lédénes	Unknown	13.33	16.66	66.66	66.66
61	Ile Trielen et l'île aux Chrétiens	Unknown	13.33	16.66	66.66	83.33
69	Perros-Guirec	Unknown	6.66	25	100	50
73	Saint-Jean-du-Doigt	Unknown	6.66	20.83	100	50
74	Locquirec	Unknown	6.66	20.83	100	50
75	Les Sept îles	Unknown	6.66	16.66	0	50
76	Les Sept îles	Unknown	6.66	16.66	0	66.66
77	Ile de Balanec	1962	13.33	16.66	33.33	83.33
78	Ile de Quéménès	Unknown	13.33	16.66	33.33	50
79	Ile de Trielen	Unknown	13.33	16.66	33.33	66.66
80	Ile de Trielen	Unknown	13.33	16.66	33.33	66.66
92	Plan particulier depuis Saint Mathieu jusqu'à Blanc-Sablon	1756	73.33	20.83	33.33	50
94	Carte particulière des côtes de Bretagne : Contenant les environs de la rade de Brest	1756	73.33	16.66	33.33	83.33
95	Plan des batteries haute et basse de la pointe des Espagnols	1695	73.33	33.33	66.66	100
96	Plan du fort de Mingan établi en 1688, comprenant les deux batteries, haute et basse	1754	73.33	25	33.33	83.33
106	Batterie de Trelevern; Port Blanc	1756	73.33	27.77	33.33	50
118	Costes de Bretagne [le Diben – Plouescat]	1740	73.33	27.77	33.33	66.66
119	Carte particulière de la baye de Morlaix	1754	66.66	33.33	66.66	83.3
142	Tréguier Port-Blanc	1771-1785	0	33.33	66.66	50

Table 3I.5. Top results for map ranking within the Trégor – North Finistère case study.

3I.5 FIELD RESEARCH STUDIES

Archaeological and palaeoenvironmental fieldwork were carried out for case study area of Western Trégor, this section outlines the field studies undertaken and the main results.

3I.5.1 Key Research Questions

The research questions to be answered through this approach were to determine the potential of archaeological and environmental data to inform on long term coastal changes in the Western Trégor area. Regional coastal changes were to be addressed on a multi-millennial timescale, with a focus on some specific periods, especially the Middle Ages.

3I.5.2 Approach to Information Gathering and Fieldwork

The program within the bay of Lannion study area comprised detailed field work (2011, 2012 and 2013) combined with desk based studies and analysis (radiocarbon dating combined with dendrochronology). Various kinds of documentation have been used, as well aerial photos, ancient maps and charts and historic documentation, in order to retrace the environmental and human history of this site. The fieldwork comprised several excavation campaigns on the foreshore and regular surveys (by foot and with a drone).

3I.5.3 Archaeology Field Data Gathering Results

The selected sites in the case study area have provided a lot of information illustrating the coastal evolution in the bay of Lannion, with a special focus on the Léguer estuary, and a very detailed study of the Servel-Lannion fish weir installations, which provided accurate evidence of change.

Archaeological data sources have been used for sites close to the banks of the estuary, this includes a Neolithic passage grave (which no longer exists) on the foreshore of Ploulec'h (Marchat and Le Brozec 1991). The Yaudet promontory cliff castle offers a broad chronological sequence site, with human occupation spanning mainly from the Iron Age to the Middle Ages (Cunliffe and Galliou 2004, 2005 and 2007). The archaeological objects found in the sand dredged from the estuary primarily reflect the Neolithic and Bronze Age cultures and, with less certainty, the Middle Ages. The fishing installations in the estuary cover the widest chronological scope, and are the subject of study and more accurate calibrations of chronology.

I1. Fish weirs of the Léguer estuary, bay of Lannion

Since 2007, the collective research program on the 'foreshore fish traps of Brittany' revealed the existence of 750 structures (Daire & Langouët, 2008 and 2010). Approximately 90% of structures are stone dams, several of them are today under the 0m Marine Level because of Holocene transgression, indicating their relative ancient age. The Bay of Lannion fish weirs have been subject to an extensive research program since 2011.

Location

The bay de Lannion is located in the Western part of the Trégor area (Côtes d'Armor department). The Léguer river flows east to west, crossing Lannion town and ending in a wide estuary bordered by steep wooded slopes (Figure 3I.28).

Why was the study site selected?

This area has been selected for the richness of the available data illustrating the coastal changes along the Channel. The estuary of the Léguer had multiple installations of fish trap dams. Since 2011 there has been an active research program studying the complex of the Petit Taureau-Lannion Servel, which has witnessed several development phases. The complexity of the archaeological phasing of the site led to the analysis of data in relation to the geographical context of the whole estuary Léguer. This provides information for a more comprehensive study of palaeoenvironmental conditions and ancient fish weirs in connection with coastal settlements. Indeed, this estuary is marked by the presence of several coastal fortified sites (cliff castles) sucha as Dourven (and perhaps also the Beg Léguer cape), the chronology of which remains to be clarified. The major site of Yaudet to Ploulec'h experienced a long period of human occupation, from the Late Prehistory up to the Middle Ages, as shown by the excavation program developed on the site for several years (Cunliffe and Galliou 2004, 2005, 2007).

The Léguer estuary comprises several fish weirs dating from various periods (Table 3I.1). Beyond the regional context and numerous fish trap remains presented above (Daire and Langouët 2008, 2010), it is interesting to note that the Léguer river is today considered as having higher numbers of fish, especially salmon, within the Côtes d'Armor department (Landre 1975).

The fish weirs of the Léguer estuary have probably benefited from this rich fish resource over time; additionally, the capture technique, based on wooden traps or stone dams is particularly well adapted to an estuarine environment, where marine and fluvial streams can be very strong, especially in the area surrounding the Yaudet promontory. Thanks to the field and lab research, these fish weirs have been characterised according to their architecture and their installation (Daire and Langouët, 2011a & 2011b; Langouët *et al.,* 2012a & 2012b and 2013).

In addition to the study of the fish weirs, since the 1950's the dredging upstream and downstream of Beg Léguer and Yaudet have provided interesting archaeological finds, the chronology of which goes from the Neolithic up to the Middle Ages, with the Bronze Age period being well represented (Giot 1969, Langouët *et al*., 2012a). These finds are linked to the presence of peat layers stratified between sandy levels. Most of the objects were found during the sand sieving on the Lannion harbour quays. Fortunately, the investigations by P.R. Giot during this period could provide precise indications about the sedimentary context and the geographic origins of the objects.

From the Neolithic period (U6 unit), we can identify two complete hafted stone axes, one of them having lost its stone part a moment after its discovery (Giot, 1958 & 1960). These objects probably come from the peat layers indentified at the bottom of the stratigraphic sequence (see below). The Bronze Age is represented by several objects, discovered about 1 km upstream, in a place of a ford probably in use during metal ages and historical times (Giot, 1967: 336-337; Briard, 1971; Mélin, 2011). This set of swords, dredged from this point of the Léguer estuary probably reveals a very important Bronze Age deposit close to the ford.

Later periods are less well represented. Despite the existence of the major settlement on the Yaudet promontory, mainly settled during the Iron Age and Roman period, the contemporary finds are scarce in the waters of the estuary. Coming from the sandy level, a small amount of pottery can be attributed the last stages of the Late Iron Age (3rd-2nd cent. BC). Coming from the same place, human bones (skulls), Roman and medieval pottery and querns (pre-Roman or Roman) were also mentioned (Langouët *et al*., 2012b).

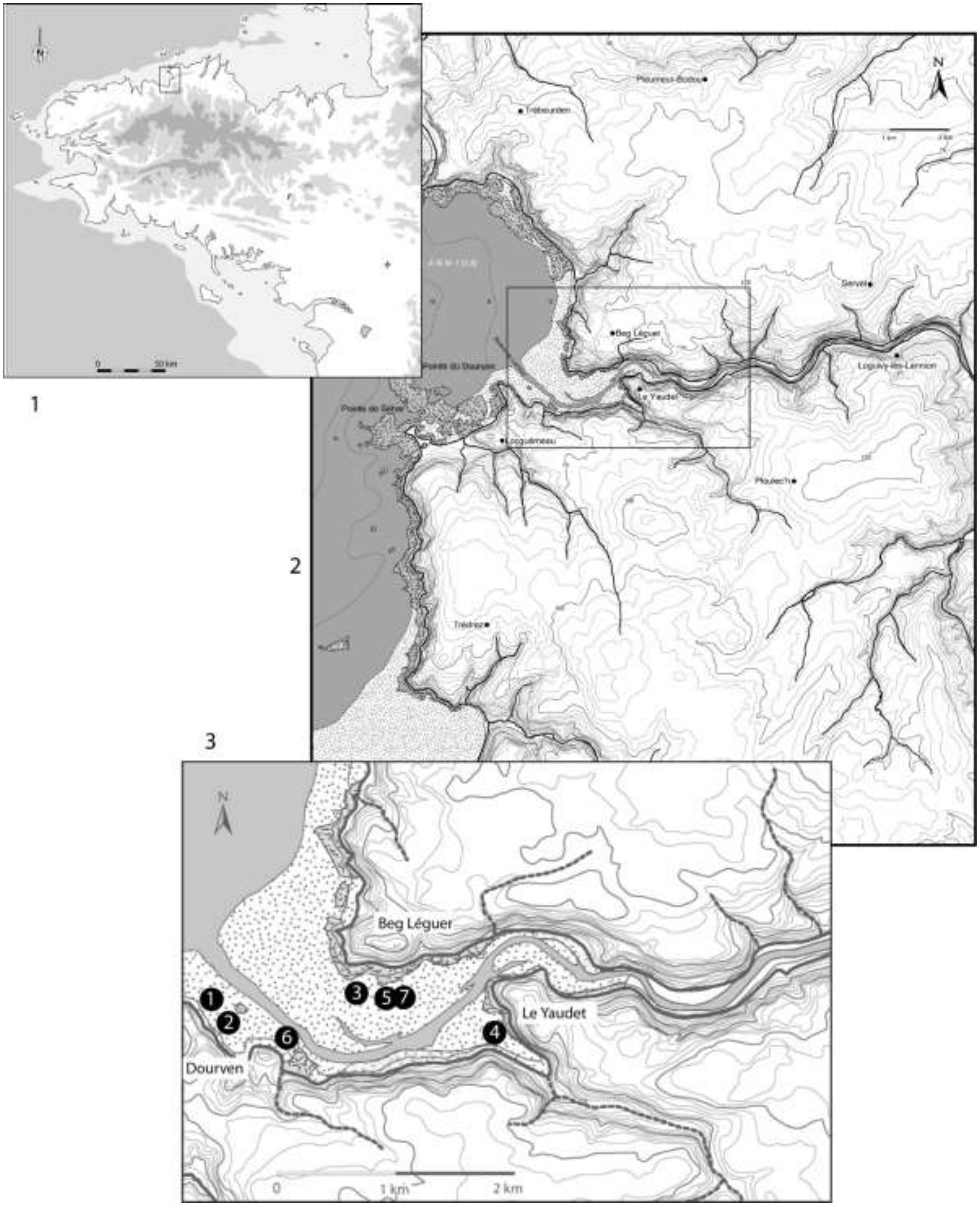

Figure 3I.28.Location of the Bay of Lannion and Léguer estuary (1 and 2) and distribution of the fish weirs in the estuary (3) (doc. L. Langouët and L. Quesnel).

Geomorphological setting

A map published in 1995 (Pinot 1995), based on aerial photographs shows the situation of the Léguer estuary in 1952 before sand extraction (n°1, Figure 3I.29). At this time, the Léguer flood drained away thanks to five channels visible near Servel point; nowadays, only one channel remains, drawn by the sand extraction near the Poull Mad Dogan point.

The sedimentary story of the Léguer estuary is partly accessible in the wider framework of the Lannion bay study, with two corings extracted in 1979 in this zone (Augris & Simplet, 2011: 80-83). Geologists have distinguished, amongst several layers, a level called U6, rich in organic materials and especially peat remains. It is interpreted as an estuarine deposit typical of the back foreshore of a bay (slikke), able to fill in the ancient channels. The radiocarbon dating of the organic materials gave, for U6 level, a date c. 6000 y cal BP (about between 4300 and 3000 BC). A layer above (U7) was composed of sands of various grains sizes; it is typical of marine conditions, formed by the transformation of sediments due to the action of waves. Layer U7 is dated around 2300 y cal BP (about 400 to 200 BC). This confirms that, during the Iron Age, the sediments deposition process was subject to waves and swells and Lannion bay was open to the maritime environment (Augris & Simplet, 2011: 80-83).

Additional data was collected during the 1960's, during the time when the sand of the estuary was intensively exploited, and following the discovery of a Neolithic hafted stone axe then others archaeological objects. P. R. Giot conducted a thorough investigation with operators of sand dredgers, especially those working in the surroundings of the Yaudet cliff castle; he could then obtain quite precise indications of the stratigraphy and collect some samples for radiocarbon dating and pollen analysis.

The stratigraphy was observed in two points of the estuary, corresponding to places of archaeological finds discoveries. The ‘big hole’ located between the Yaudet promontory and Beg Hent quay, at 100 m from the present southern shore) (n°1, Figure 3I.30), has shown (from top to bottom):

- a sandy/silty level (modern);
- then a layer composed of coarse reddish sand from the river, several meters thick (almost completely exploited); and
- a peat level, thin and foliated.

From this area come the human bones, medieval ceramics and two axe' antler hafts. The more recent objects probably originated from the red sand level as the prehistoric finds certainly come from the peat layers. A radiocarbon date was gained for the peat layer: 3075 + 110 BP, i.e. 1303 +140 cal BC (GIF 819), the transition between middle and late Bronze Age (Giot, 1969).

The ‘gué aux épées’ (Swords ford) is the second observation point; located about 1 km upstream from the previous one, in a probable ford location used in various times, this area provided a set of bronze weapons. The stratigraphy has shown (from top to bottom (Figure 3I.31)) :

- a sandy/silty level (modern);
- a coarse grey sandy level;
- a black thin peat layer (20 cm thick);
- a coarse sandy level, 2 to 4 meters thick depending on the location;
- a deposit composed of a blending of peat and clay, 30 cm thick; and
- a dense gravel level at the bottom.

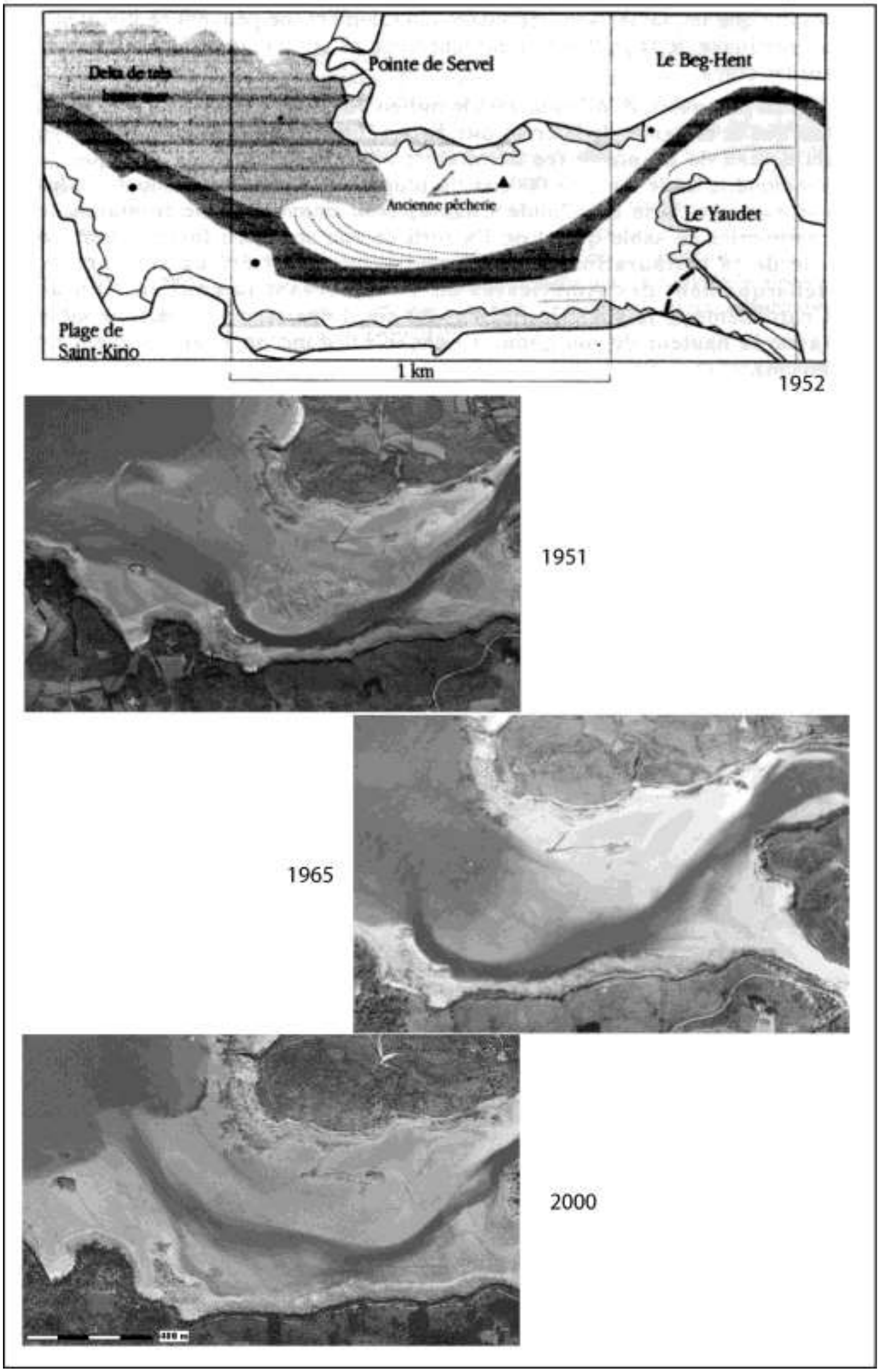

Figure 3I.29. Recent evolution of the Léguer estuary and flood channels, due to the intensive sand extractions (after Pinot 1995 and IGN, Langouët et al.. 2012).

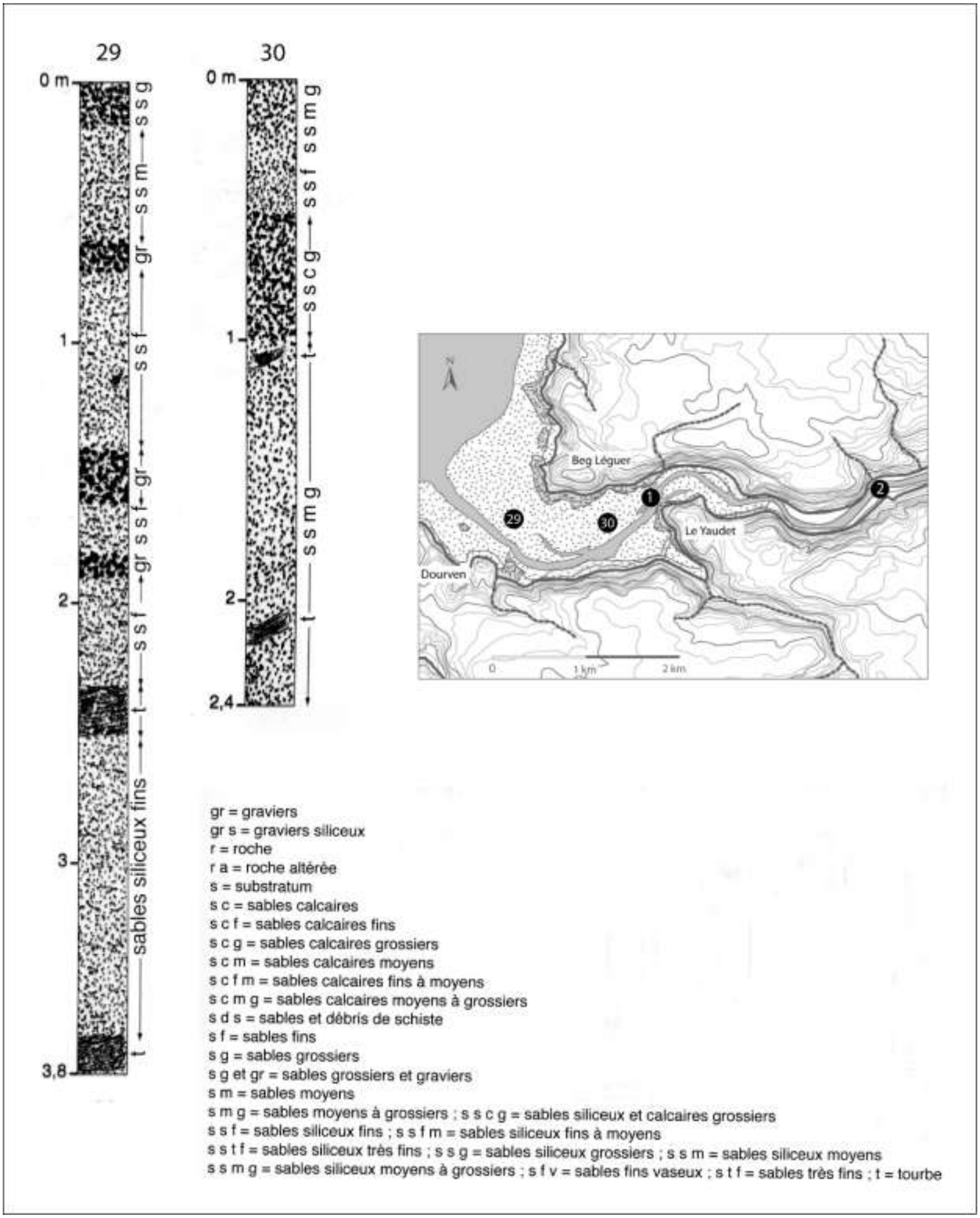

Figure 3I.30. Location and geomorphological characteristics of the cores carried out in the Léguer estuary (after Augris and Simplet, 2011, revised by Langouët et al., 2012).

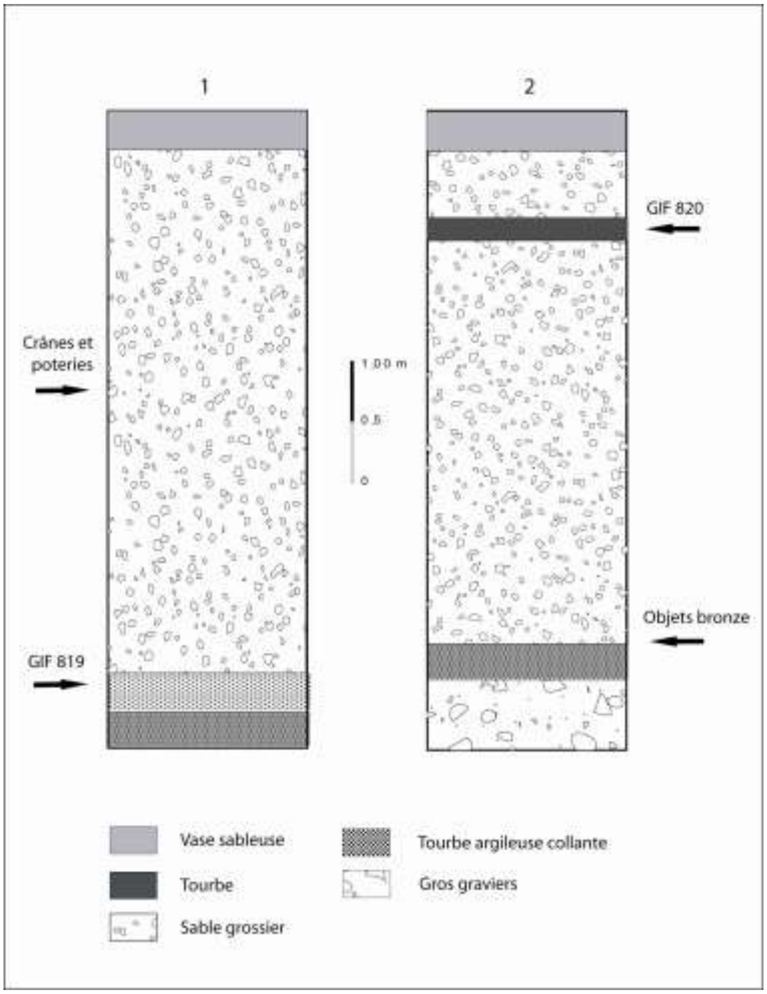

Figure 3I.31. Detailed stratigraphic reconstruction in the place of the 'Big Hole' sand extraction with location of the radiocarbon dating samples (after Giot 1969 and Langouët et al., 2012).

According to eyewitnesses, this part of the estuary was totally dry some years earlier, but the red sand exploitation reactivated the flooding of the channel. A second radiocarbon date has been gained for a peat sample from this area, the result of which is 1600 + 105 BP, i.e. 435 + 115 cal AD (GIF 820); this gives another illustration of the occupancy of the estuary, during the Roman or early Medieval periods.

The stratigraphy described above is comparable with the one observed during the excavations carried out on the Petit-Taureau fish weirs (see below): a brown coarse sandy level, rich in marine small shells appeared about 30 cm below the current soil surface; on this level were laid the big wooden installations of the dam from the early Middle Ages, as well as the plants layer and the stone installations at the base of the earlier building stage (phase D) (Langouët *et al.,* 2012b).

Key coastal risk management issues

The maritime façade of the Bay of Lannion is subject to intensive erosion, accelerated by sudden climatic events such as storms. One good example has been provided by the archaeological study of the Locquémeau-Dossen Rouz Iron Age site, which was excavated in 2009 following the big storm of February 2008 (Daire, 2011); during one single night, the coast lines retreated 9 m, causing extensive damage not only on the archaeological site but also in the tourist area and port installation (the sailing school was destroyed) and on the natural features (pebbles bar).

The main risk of anthropic origin in this area is the industrial project of marine aggregate and sand extraction in the Bay of Lannion, initiated in the 2000's by the Lafarge and Italcimenti concrete production group. Geomorphologists (IFREMER) and environmental defense groups (Le Peuple des Dunes) tried then to make coastal managers aware of the consequences of offshore extraction in the coastal area (http://lepeupledesdunes.com/IMG/pdf/tour.pdf and http://www.lemonde.fr/idees/article/2013/10/04/attention-a-la-destruction-de-la-baie-de-lannion_3489862_3232.html.

How can the sites inform coastal risk management?

The complete study of the fish weirs and especially the level or height at which they were constructed makes it possible to provide precise indications of the local sea level variation and coastal evolution in past times, this helps future coastal management, by understanding the processes and providing precise measurements. These fish weirs are presented below in chronological order, the evaluation of which results from the detailed study carried out since 2011 in the Léguer estuary (Table 3I.6 and Figure 3I.32).

N°	Site	Nb (m)	δ(BMME) (m)	Chronology
1	Trédrez, Dourven-A	0,40 ± 0,2	3,7 ± 0,1	Bronze Age
2	Trédrez, Dourven-B	0,70 ± 0,2	3,4 ± 0,1	Bronze Age
3	Servel, Corps de Garde	1,70±0,10	2,4 ± 0,1	Iron Age
4	Ploulec'h, Anse de la Vierge	2,38 ± 0,1	1,7 ± 0,2	Roman-early MA
5	Servel, Petit-Taureau (D)	2,45 ± 0,05	1,6 ± 0,1	650 AD
6	Ploulec'h, Poull Mad Dogan	2,80 ± 0,3	1,3 ± 0,3	early MA
7	Servel, Petit-Taureau (A)	2,90 ± 0,1	1,2±0,1	Late 15th cent. AD

Table 3I.6.Fish weir heights and dating proposals for their building, according to the variation of the PHBMME (Lowest Neap Tide level). The n° refers to the map, Figure 3I.32 (after Langouët et al. 2012).

Located at the eastern foot of the Dourven promontory, two ancient fish weirs have been dated from the Bronze Age, according to their level of construction compared to the sea level variation curves:

- a dam of a "V" shape (Daire and Langouët 2010: 12); the topographic level of its base is (Nb) is +0,40 ± 0,2 m/0 SHOM;
- another dam, also of «V» shape (n°2), the level of its base is Nb is +0,70 ± 0,20 m/0 SHOM.

On the opposite bank of the estuary, a fish weir of «V» shape is located at the foot of the Beg Léguer promontory (n°3). The level of its base is (Nb) is +1,70 ± 0,10 m/0 SHOM. The dam of the Vierge bay, (n°4), at the southern foot of the Yaudet promontory, is quite difficult to date in the way that the 1970's excavations have seriously disturbed the archaeological layers in the sluice area. The map (Figure 3I.13) shows the existene of two sluices; the level of the base of the dam and of one of the sluices is +2,38 ± 0,20 m/0 SHOM. Another dam, with a curved shape, situated between the Poull Mad Dogan conning-tower and the left site of the estuary (n°6), has a level of +2,80 ± 0,30 m/0 SHOM at the base of the wall.

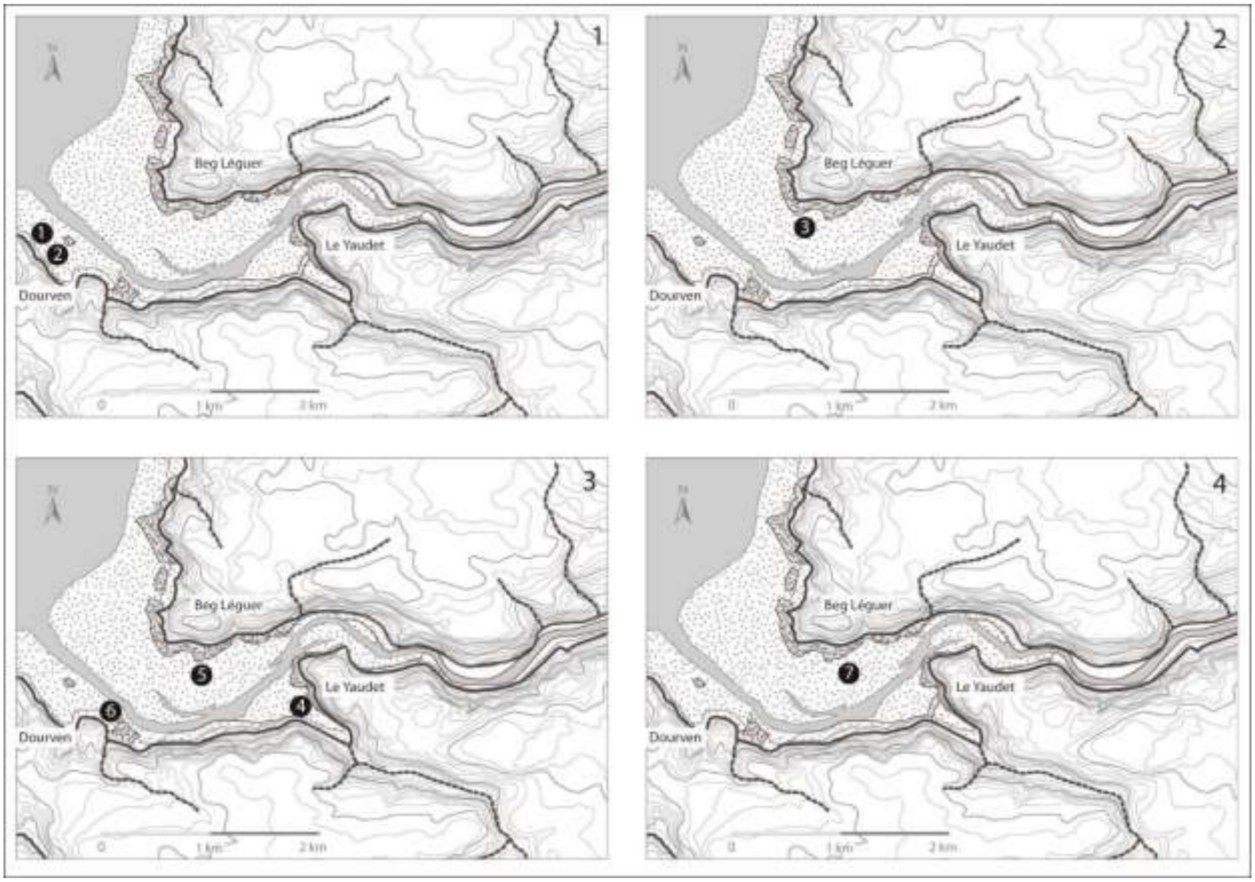

Figure 3I.32. Mapping of the Léguer estuary fish traps, according to their building date evaluation. 1: Bronze Age (2000 BC-800 BC), 2: Iron Age (800-50 BC), 3: Roman and Early Middle Ages (1st cent. BC-7th cent. BC), 4: Middle Ages (10th cent. AD and later) (doc. L. Langouët).

The topographic levels measured at the foot of the dam walls or in the sluice (Nb) provide a general idea of their dating, according to the hypothesis that the builders have probably taken into account the best efficiency of the dam, in terms of fish catching and of accessibility, at each low tide, whatever the tidal range. In this hypothesis, the level Nb of the dam theoretically corresponds to the ancient level of the Lowest Neap Tide level (PHBMME). This level is currently calculated linked with the local maximum tide range (MM): (PHMEME)act = 0,416*MM.

We can measure the Nb level for several fish traps of the Léguer estuary (Table 3I.6). The difference between Nb and the current (PHBMME)act gives, with a certain precision, and evaluation of δ(PHBMME), variation of the sea level since the time the dam was built (Daire & Langouët, 2010).

A quick analysis of the fish weir locations in relation to chronology shows the following general tendency: the older fish weirs are located in the current maritime zone at the mouth of the estuary and over time they were progressively installed further upstream, in more protected areas. This evolution goes in parallel with the terrestrial settlements and occupation evidence is located in the vicinity or the fishing installations. The new data obtained on the Petit Taureau fish weirs illustrates the relationship between humans and the environment during the Middle Ages (Langouët *et al.,* 2012b).

We must also take into account the sea level rise which, over the period being considered reaches several meters in this area; indeed, a fish weir dam stops being efficient when it becomes no longer reachable while low tide. The sea level rise has consequences, not only on the accessibility of the dam by the people, but also on the efficiency of the trap as the fish can escape from it if the water level is too high. This process could have combined with sediment filling phenomena within some of the dams which have ‘trapped’ the sand thereby raising the soil level within the fish weir, meaning the trap looses its efficiency for catching fish.

On the another hand, the sediment accumulations which progressively moved the flow channels could have impacted the fish circulation, providing an additional reason to move the location of some of the dams. Hence, the abandonment or displacement of fish traps can by explained by a combination of both processes – sediment accumulation and changes in fish movement patterns.

The scientific studies have underlined the importance of sand extraction of the mid 20th century on the transformation of the geomorphology of the estuary, providing historical evidence of the impact of such industrial exploitation. This impact is particularly visible on the fish trap remains, the visibility and conservation of which are a good indicator of the sediment budget evolution (see below).

Fish weirs of the Léguer estuary ranking score achieved: 100

I2. Servel-Lannion Petit Taureau Fish Trap

Location
The Petit-Taureau set of fish weir dams is located on the maritime territory of Servel-Lannion town (Côtes d'Armor department) and is located in the mouth of the Léguer river estuary (n°5 and 7 Figure 3I.32 above).

Why was the study site selected?
Within the general context of the Léguer estuary (and its fish weir remains, see above), the site has been selected because of its ability to provide environmental and archaeological data, regarding coastal changes, and the opportunity to carry out a complete field study. Previous to the fieldwork, the aerial photography analysis indicated the existence of several successive dams at this location, making it a high potential for chronological evolution (Figure 3I.37). This site has been subject to intensive field work in 2011, 2012 and 2013 (excavation and sampling) as well as a full analysis program (radiocarbon dating, dendrology, dendrochonology), providing the first references for tidal archaeology in Brittany (Daire *et al.* 2011a, Langouët *et al.* 2012b, 2013).

The research program including the Petit Taureau fishtrap dams and the other traps of the Léguer river estuary, could not be undertaken withoug studying their sedimentary environment. This is important for taking into account the processes that lead to the construction and shifting of successive dams, as well the historical context and relationships with settlements as the "natural" evolution of the fluvial-marine environment. On the other hand, if the environmental changes dictated the position of the building of walls/dams, it is also probable that the presence of dams had an impact on the flow of sediment and submarine river channels.

Research and expertise clarified the chronology of the various dams that have succeeded at the Petit Taureau (Figure 3I.33). The stony phase is the most visible on aerial photographs, but came after structures made from wood and wattle, established in 615 AD. The D1 dam had succeeded a previous wooden trap whose remains, found below the D1 dam, were dated by radiocarbon to between 580 and 660 AD.

Figure 3I.33. Aerial viw of the Petit Taureau fish weir showing a cumulative view of the various building stages (taken from a drone, doc M. Mahéo and L. Langouët).

Two lines of stones (B and C) were identified as the remains of walls associated with wooden structures made of vertical posts and wattle branches. The probable oldest dam B (600-660 AD) was quickly destroyed and replaced by the longer D1 dam. It seems that the fish trap in the D1 stage did not last long, despite a fairly complex technology. It was quickly replaced by another wattle installation bearing on the petit Taureau rocky amount and a small rock to the west.

D1 dam had associated wooden posts and stones (big pebbles) collected from the top of the beach. It was replaced by a dam C (660-730 AD), the same technology as that used for dam B, but built with bigger posts. D2 dam could correspond to a blockage of the remains of D1 in order to prevent its components interfering with the operation of the dam C.

Although the precision of radiocarbon dating does not distinguish them chronologically, it is likely that during the 11th-12th centuries AD, at least one wattle installation (with two arms) was set up and probably went through two phases. The synthesis of radiocarbon dating can demonstrate a medieval stage with two lines of wattle that had been identified and dated: 1037-1220 AD (Ly- 8874) and from 1026 to 1162 AD (Ly- 8875). Equally, in the east-west part of phase A building, two lines of wattle were found and dated: 1040-1100 or 1120-1140 AD and 1160-1260 AD.

The building of the phase A stone walls goes back at least to the second half of the 15th century (Clément 2011), when the wattle phase was replaced by the dam with 'squared' stones, which were accurately described in texts of the 17th century.

Geomorphological setting

Various specialists and observations have been used to create a better understanding of the potential of Petit-Taureau site in terms of geo-archaeology (Langouët *et al*. 2012a) (for the geomorphological features, see above).

The fish weirs of the Léguer estuary, and especially the Petit-Taureau dams, seem to play, over time, a game of 'hide and seek', as their visual detection varies from one period to another; this phenomenon is especially demonstrated in the photo-interpretation of aerial photographs available for a period between the 1950s and today (Figure 3I.34). We tried to analyse the causes of this phenomenon in a wider geographical framework for the entire mouth of the Léguer estuary.

The analysis of the aerial photos taken since 1952 shows, on the site of the Petit Taureau, a process of sediment thinning down, which reveals at least four architectural phases of the fish trap building (Daire and Langouët, 2011: 6-8) (Figure 3I.33). The explanation of this phenomenon is closely related to the recent history of the Léguer estuary, occupied by sandy-muddy sediments, combining alluvial river flows and input wind and marine (Pinot, 1991 and 1995).

Since the 1950s, the sediments of the downstream Léguer estuary have been intensively exploited, the materials being used by construction companies of the Lannion and Finistère areas, to rebuild the towns and buildings bombed during WWII. In total, approximately 2.5 million m^3 of sand were extracted from the estuary; the digging of the delta created a channel under the promontory of Yaudet and caused the migration of sand in the direction of the mouth estuary, then the foreshore level lowered (approximately 1 m) (Pinot, 1995: 109-111). This phenomenon not only explains the appearance of the remains of several fish traps on both sides of the estuary (Daire and Langouët, 2011a and 2011c), especially after 1977, but is at the origin of archaeological discoveries, documenting the human settlements in the area (see below).

Key coastal risk management issues for the frontage

We have highlighted in the previous section the general risks threatening the whole bay of Lannion and the estuary, as well the natural threats (coastal retreat due to erosion and storms) and the anthropic ones (offshore sand extraction in the bay of Lannion).

At the more restricted scale of the archaeological remains (dams), one risk is due to the local economy, as this area is devoted to shell collecting by professional. As we could see during our fieldwork campaigns, harvesting the shore generally requires removing stones and then destroying or modifyomg the ancient dams, with effects on the landscapes.

How the site can inform coastal risk management

The four successive dams of the Petit Taureau fish weir are located on the right side of the estuary, at the foot of a natural promontory (Beg Léguer). Recent fieldworks demonstrated the existence of four architectural phases, the wooden construction alternating with stone dams. Field excavation and desk based archives research permitted the dating of the various phases.

Thanks to the combination of radiocarbon and dendrological analyses, we can now assess that the oldest phase of construction (phase D) goes back to the early 7th cent. AD (Langouët *et al.,* 2012b). On the other hand, the recent study of the post medieval archives, concerning the latest stage of construction of the Petit Taureau fish weir, helped to find documents dating back to the second half of the fifteenth century (Clément, 2011). For this building phase, the level of the dam base is +2,90 ± 0,1 m/0 SHOM.

The construction of several dams during the centuries (Figures 3I.36 and 3I.37) indicates that it was probably necessary to rebuild the fish trap several times. For some stages, this can be due to problems in the conservation of raw materials (wood); but, for some others, we suspect that the impact of the dams on sediments flow and flooding channels location have obliged the local people to clean the installations, change the orientations of modify the general shape of the traps. The architectural history of the Petit-Taureau fish weir, and more generally on the maritime installations in the Léguer estuary, seem to be closely linked with the environmental evolution of the area.

As demonstrated above, a regular observation and monitoring of the archaeological remains inform us on the coastal evolution and transformation of the estuary.

Petit Taureau fish trap ranking score achieved: 100

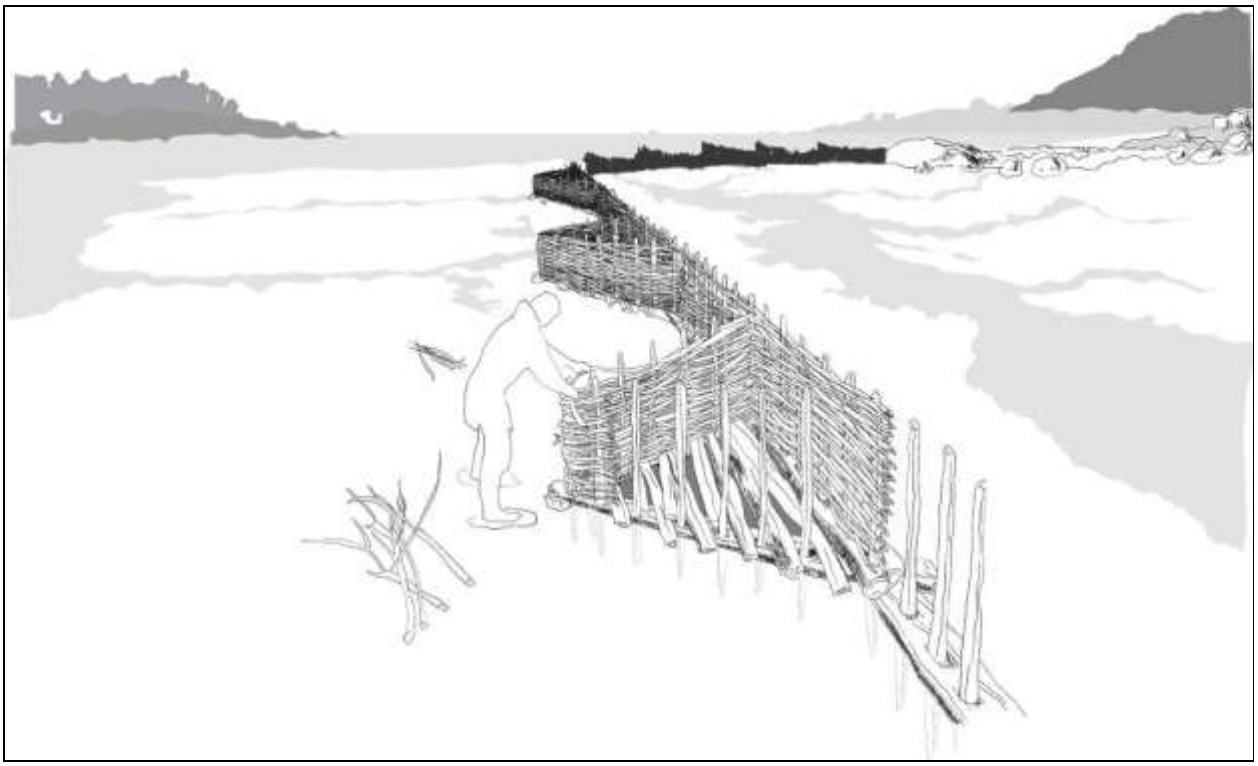

Figure 3I.34. Drawing proposing a reconstitution of the D1 dams' building phase (Petit Taureau fish trap, Servel Lannion) (doc. V. Bernard, CNRS).

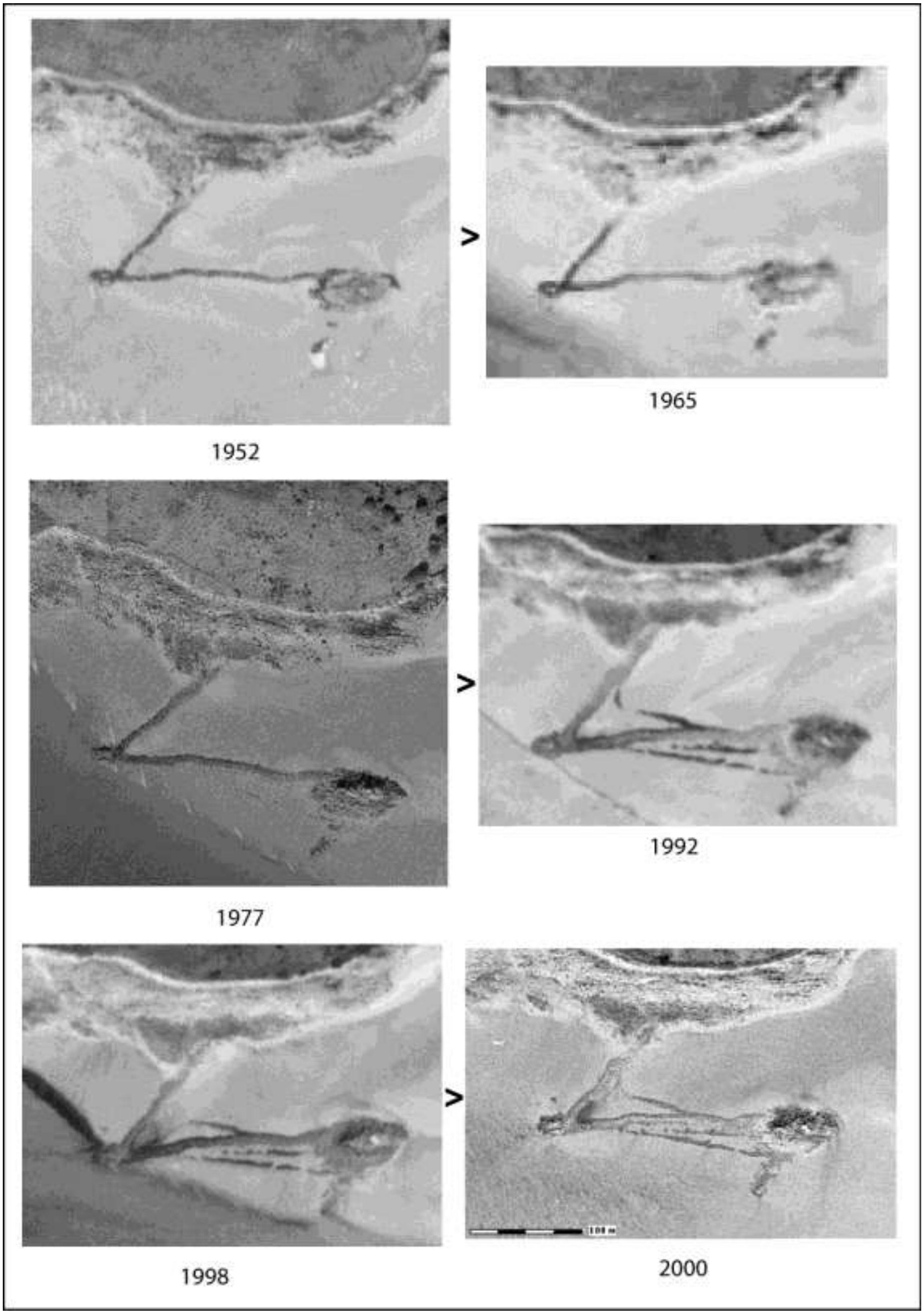

Figure 3I.35. Evolution of the visibility on the Petit-Taureau (Servel-Lannion) fish-traps, as a consequence of the sand extraction in the estuary and recent sedimentary evolution in the Léguer estuary (IGN photos, after Langouët et al. 2012).

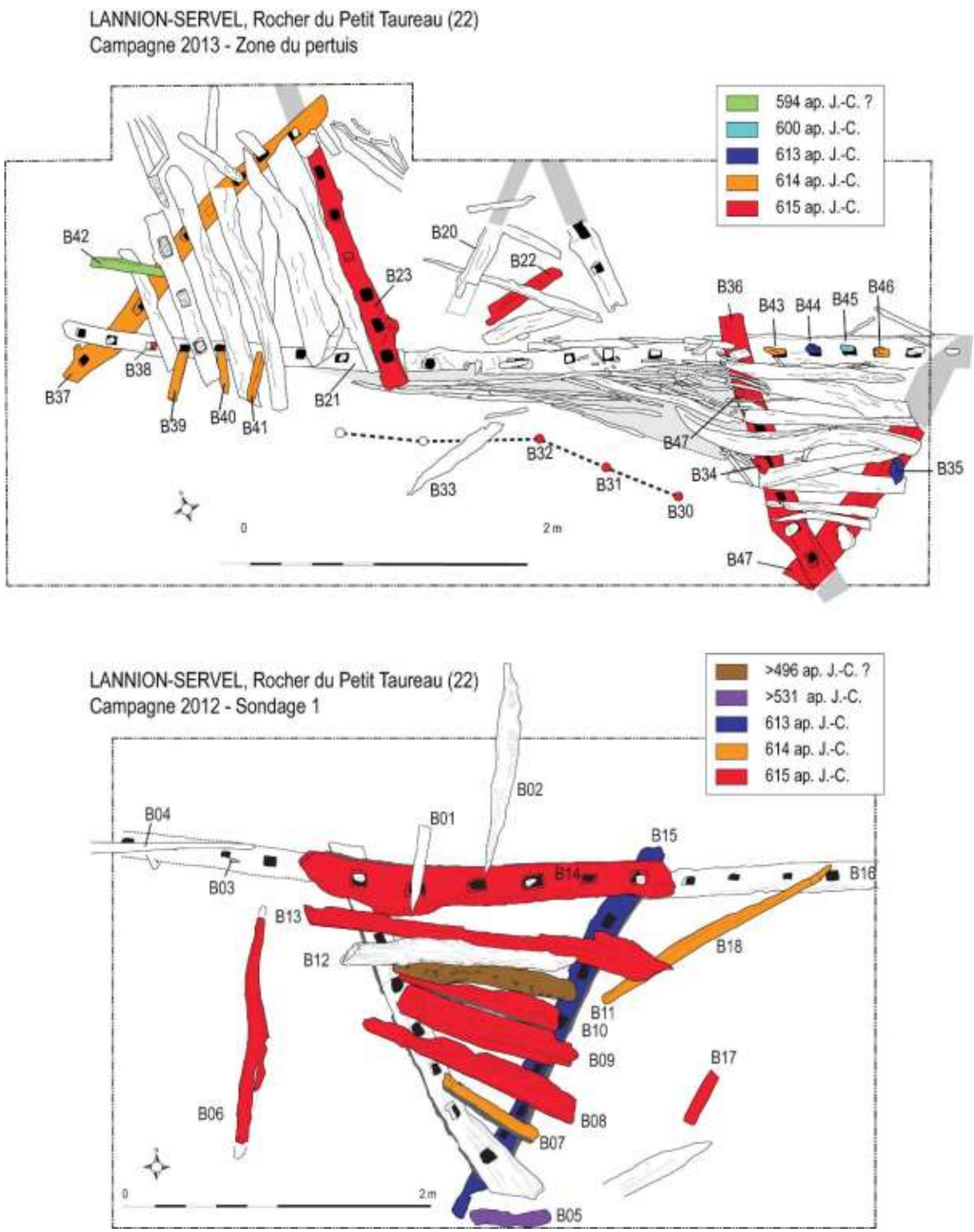

Figure 3I.36. Mapping of the wooden installation of the Petit Taureau fish trap and distribution of the dendrology dating (doc. V. Bernard, CNRS).

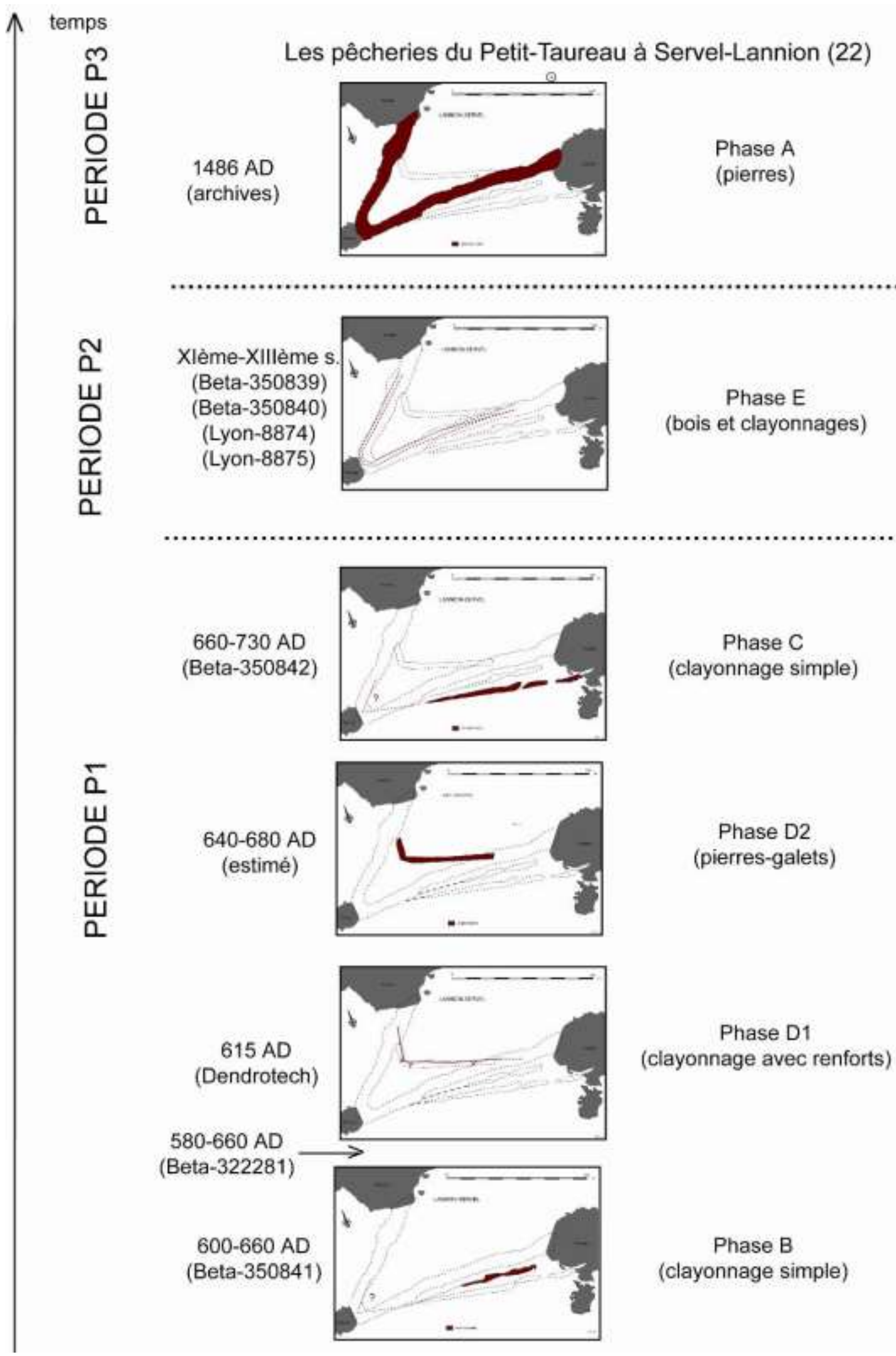

Figure 3I.37. Evolution and phases of dams' construction, Petit-Taureau fish weir (Servel-Lannion) (after Langouët et al., 2013).

3I.6 Art Studies

The case study area has been been depicted within a range of artistic media: paintings, photos, maps and charts. For each type of artistic material, field studies helped in the analysis of the informative value of the pictures as illustrations of coastal changes in the North Finistère and Trégor area.

The art approach benefited from the academic work led by E. Motte (Motte, 2013) in the Rennes 2 university. This work included consulting several art books and online resources (e.g. Joconde database). Ancient postcards used for the project were available either in private collections or though online resources; the main source of the ancient photos illustrating this coastal area was the collection of the Archéosciences laboratory (University of Rennes, ICARE project).

3I.6.1 Approach to Information Gathering and Fieldwork

Concerning art, the academic work of E. Motte partly consisted of a comparison of the paintings or artistic representations with the real current landscape, based measuring the detail of geomorphological changes (Motte 2013).

Sites represented on ancient photos were also subject to a field approach, comparing the current situation with the one pictured in the late 19th century and the early 20th century; in this approach, when possible, several photos of various dates, taken from different angles have generally been compared.

Historical maps in this area have been compared with present examples and with historical satellite images in order to assess the conditions of the coastline and changes that may have taken place over time. The IGN Database provides a huge collection of aerial views of Brittany from 1947, which have been compared with the aerial views of Brittany provided by GeoBretagne.

3.6.2 Art Field Data Gathering Results

The selected sites in the Northern Finistère and Trégor case study area were chosen to reflect coastline changes and human impact. The fieldwork element has been largely visual in terms of identifying the location of the paintings and making judgments, on site, of the role that art can fulfill as a qualitative or quantitative tool to support coastal risk management.

Either one particular map has been assessed, or a sequence of maps of the same area in order to examine changes over time. These have been reviewed against data from field observations. This helps establish a chronology of coastal change through the eighteenth and twentieth centuries.

I3. "Grandes roches au pied du sémaphore", by E. Lansyer, 1884

Location

Ushant island is located in the extreme western part of the study area, facing the Finistère coast. The painting represents a rocky cliff located on the northern coast of the island.

Why was the study site selected?

This site has been selected as representative of the wild landscapes of the northern coast of Brittany, which is less often pictured than some tourist areas, except by some painters such as E. Lansyer.

Geomorphological setting
The painting represents the typical granite and rocky landscape of Northern Finistère, with cliffs and rocky shores, without beaches.

Key coastal risk management issues for the frontage
Study of this painting shows the main risk threatening this part of Ushant island is erosion, as it appears very active at the foot of the rocky areas, subject to rain and sea water streaming, which damage the small vegetation which otherwise maintain the top soil levels (Figure 3I.38).

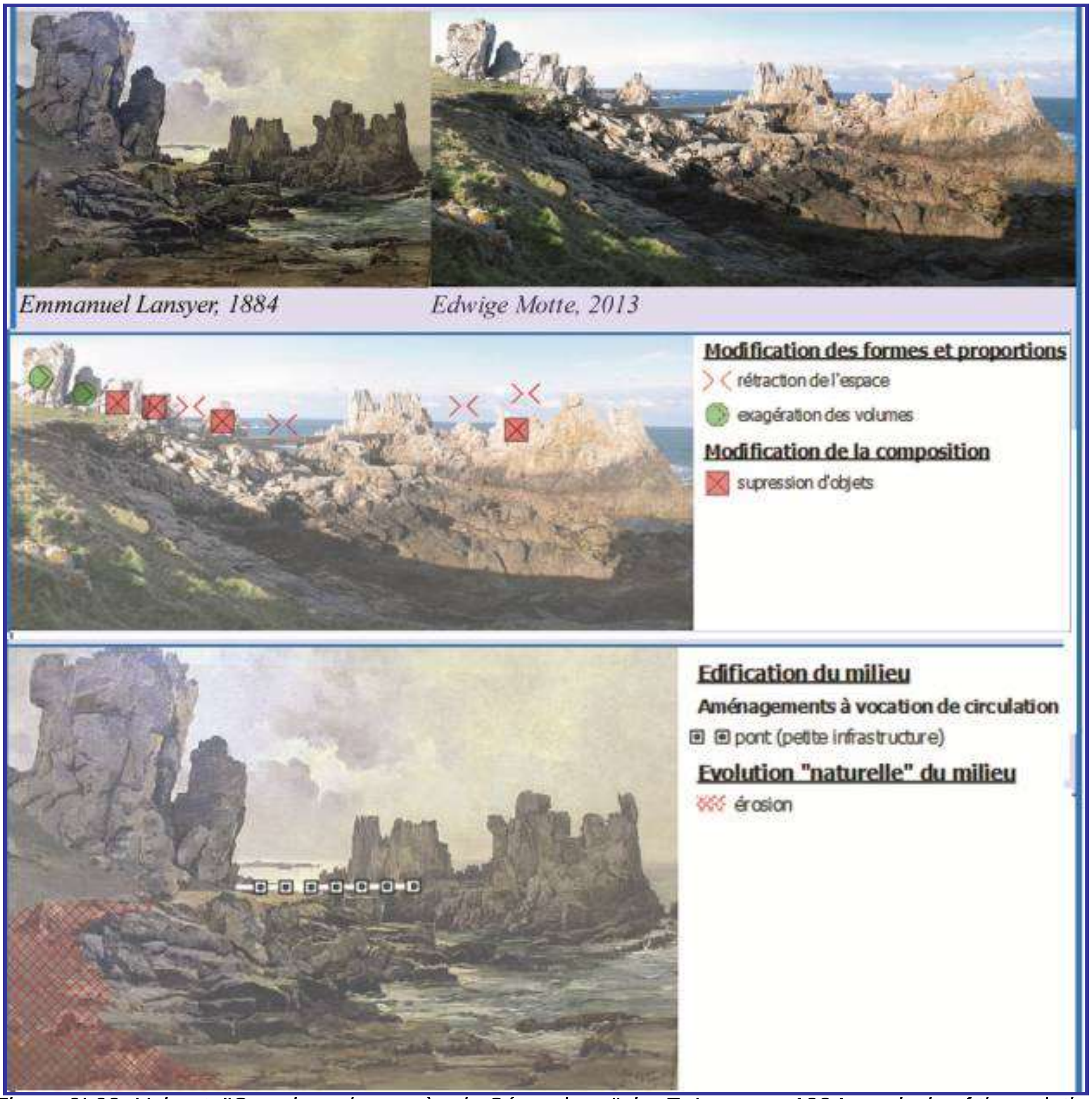

Figure 3I.38. Ushant, "Grands rochers près du Sémaphore", by E. Lansyer, 1884, analysis of the painting by E. Motte (after Motte 2013).

How the artwork can inform coastal risk management
E. Motte's work has underlined the fact that the painter (E. Lansyer) has taken some liberties considering the real landscape, e.g. narrowing or exaggeration of some distances. However,

some parts of this painting provide realistic representations of several features, such as the general shape of the rocks, the vegetation cover of the slope in the first stage (Figure 3I.38). As mentioned above, the erosive process on this sensitive formation can be noticed when comparing with the current field reality.

Where can the original artwork be viewed? In Saint-Brieuc fine arts museum.

"Grandes Roches…" Ranking score achieved: 51

I4. "Rivière près du Dourduff", by E. Lansyer, 1874

Location
The painting represents the mouth of the Dourduff river, in the bay of Morlaix (Northern Finistère) (Figure 3I.39).

Why was the study site selected?
This site has been selected as representative of the bay of Morlaix landscape; it is typical of quite densely settled tourist areas of the Trégor region.

In a comparative point of view, it seemed interesting to compare two different landscapes of the same case study area, comparing this view of the bay of Morlaix with the one of Ushant Island, presented above, especially as both of them were painted by the same artist.

Geomorphological setting
The area of the Dourduff river mouth is known under the name 'break of Dourduff'; this geological formation, i.e. the conglomerate containing pebbles of igneous rocks, includes lenses of limestone, containing fossils that have allowed us to date this geological formation back to the strunien (Devonian to Carboniferous passage). The Dourduff river flows to the sea through a wide estuary, of "*aber*" or *ria* type.

Key coastal risk management issues for the frontage
The study of this painting shows the main risks threatening this part of the Dourduff estuary are, on one hand, natural erosion, as it appears very active on the soft rocks and, on the other hand, anthropic pressure with coastal buildings (houses, dike, quay).

How the artwork can inform coastal risk management
E. Motte's work has underlined some features on the painting linked with coastal evolution and risk management (protective structures such as dykes on the left side of the estuary). This is linked to the development of housing and infrastructure in this area: the lack of bridge required the use of a ferry to cross the Dourduff. With the development of the railway, a railway bridge was built (linking Morlaix to Plestin-les-Grèves) in 1921, which was later converted into a road bridge in 1925.

Where can the original artwork be viewed? In the Maison Lansyer (Loches)

"Rivière près du Dourduff" Ranking score achieved: 40

Figure 3I.39. "Rivière près du Dourduff", by E. Lansyer, 1874, analysis of the painting by E. Motte (after Motte 2013).

I5. "Batteries du port de Brest", L.N. Van Blarenberghe, 1770' (Louvre museum)

Location

This painting represents the mouth of Brest harbour, viewed from the royal battery in the 1770's, painted by L.N.Van Blarenberghe (1716-1794) (n°1, Figure 3I.40).

Why was the study site selected?

This painting is an artwork from Louis-Nicolas Van Blarenberghe (1716-1794), a French painter famous for his representations of war and battles (especially during the Austria Succession war, 1745-46). During his travels in various European countries, he painted numerous marine oil paintings. His son was incorporated in the workshop of the Royal Corporation of the Geographers engineers (Versailles). His work is marked by his strong relationship with the aristocracy and several European royal families, who designated him officially as the "battles painter" (1769-1771 and 1978) and painters of the ports and coasts in 1975 (Maillet-Chassagne and Château-Thierry, 2004).

This site has been selected as representative of an ancient historic building set within the natural bay which has been strongly impacted and transformed. Since the time of the painting changes and transformations have occurred in this area, as shown by the comparison between the 18th century and present day view (Figure 3I.40).

Geomorphological setting
Brest harbour, accessible to larger vessels because of its depth, is a large body of water sheltered from the storms of the Atlantic Ocean through the Roscanvel peninsula that almost closes the harbour, leaving a relatively narrow passage (1.8 km), Brest Channel, between the tip of the "Pointe des Espagnols" and the north side of the harbour. There are several peninuslas that stick up into the bay.

The Rade de Brest topography, both above and below water, corresponds in part to the lower section of the Aulne valley, which was flooded by rising sea levels during the Holocene. Underwater this includes buried channels from rivers which once flowed into the Bay of Brest.

A boat anchorage is shown in the middle of the painting; an ancient map drawn in 1689 (n°3, Figure 3I.40) clearly represents a sandy bar in the middle of the bay, off the Brest castle, which probably corresponds to alluvial deposits of the ancient river channel and meanders, mentioned above.

Key coastal risk management issues for the frontage
The comparison of artistic documents (Figure 3I.40) illustrates humanly induced pressure on the bay of Brest, many of these developments are linked to risks to the town and harbour activities, they are also linked to destruction of natural landscapes, loss of ecosystems and pollution.

How the artwork can inform coastal risk management
Brest Castle, which dates back to the Roman period, and the harbour structures, have deeply transformed the natural landscape of this bay, over the past two millenia. However, on the Van Blarenberghe's painting (n°1, Figure 3I.40), some parts of the landscape still remain without structures around the castle; the comparison with the current situation (n°2, Figure 3I.40), shows the pressure from urbanization and industrial/trade port activities all around the bay which no longer remains 'natural'.

Where can the original artwork be viewed? The original painting is currently located in the Louvre museum in Paris.

" Batterie du Port de Brest" ranking score achieved: 93

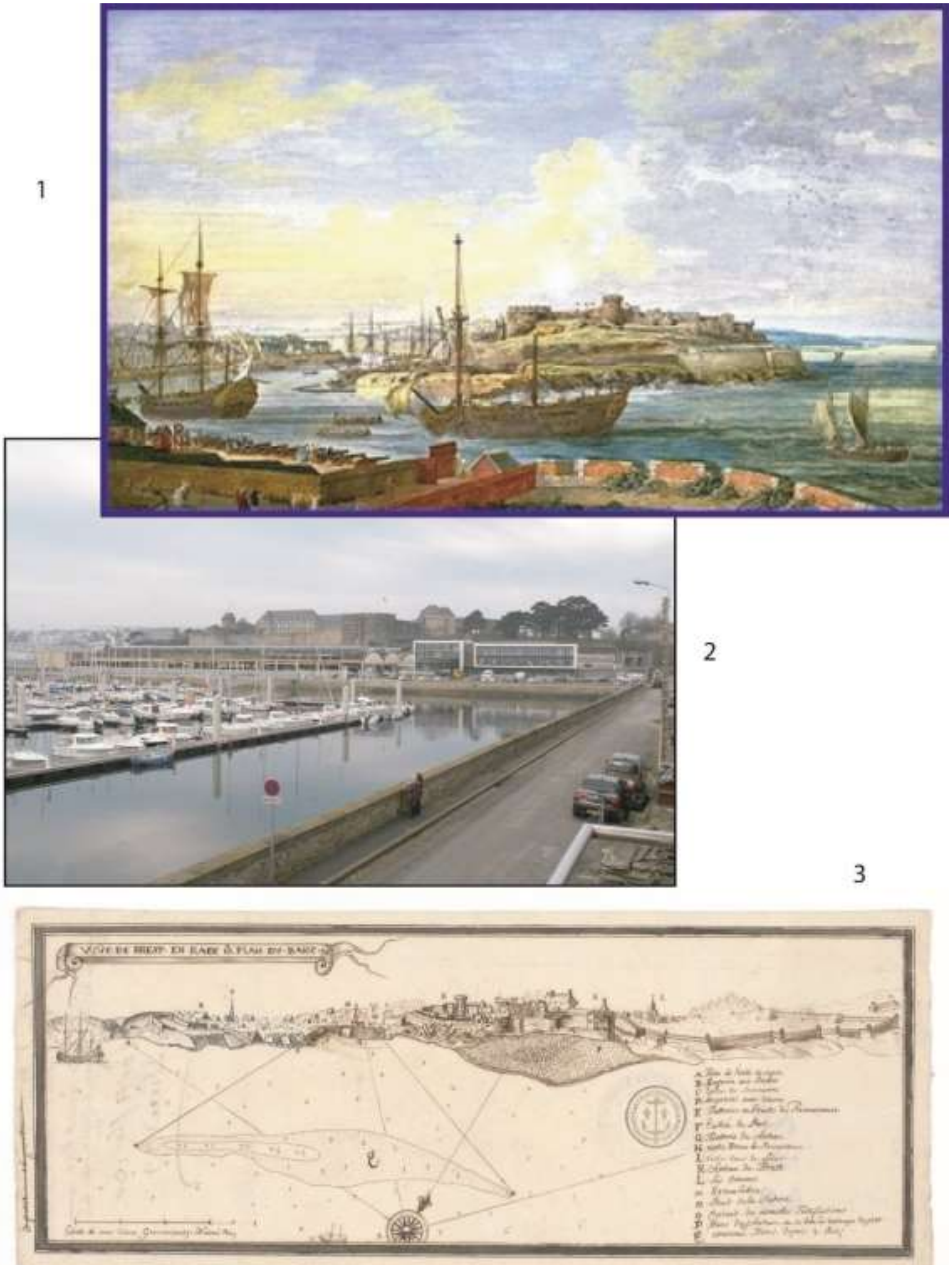

Figure 3I.40. Views of Brest harbour and castle. 1: "Batteries du port de Brest", painting by L.N. Van Blarenberghe, 1770' (Louvre museum); 2: current view of Brest castle and harbour, from the south-east (anonymous, online Immo-ouest.com/medias); 3: map of Brest bay "Ville de Brest, rade et plan du banc", 1689 (SHDMV).

I6. Plouguerneau, Men Ozac'h, by A. Devoir (c. 1910)

Location
The megalithic monument is located in the northern part of the Finistère department, in the tidal belt of the Plouguerneau village.

Why was the study site selected?
The site has been selected as an illustrative example of megalithic monuments which are now situated in the intertidal area (Figure 3I.41); as it was initially erected on the land, the present situation of this 'menhir' is an indicator of the sea level rise during the Holocene period. This monument has been used by the antiquarians and pioneers of archaeological studies, especially A. Devoir who was one of the first people to propose a scientific approach to sea level changes.

Geomorphological setting
The Men Ozach monument is located in a large flat sandy bay, in the estuary of the 'Aber Wrac'h' river, which is a geomorphological feature typical for this area of coast, called the 'Aber Coast'. This coasts belongs to the 'Low Shelf of Léon' formation (northern Finistère), comprising deep indentations and bordered by numerous island and islets; the rocky parts alternate with large sandy beaches. The importance of the tide range in this part of Brittany (c. 8 m) explains the importance of the territory and surfaces cleared of sea water during low tide. As shown on the picture, the small islands are then reachable on foot at low tide.

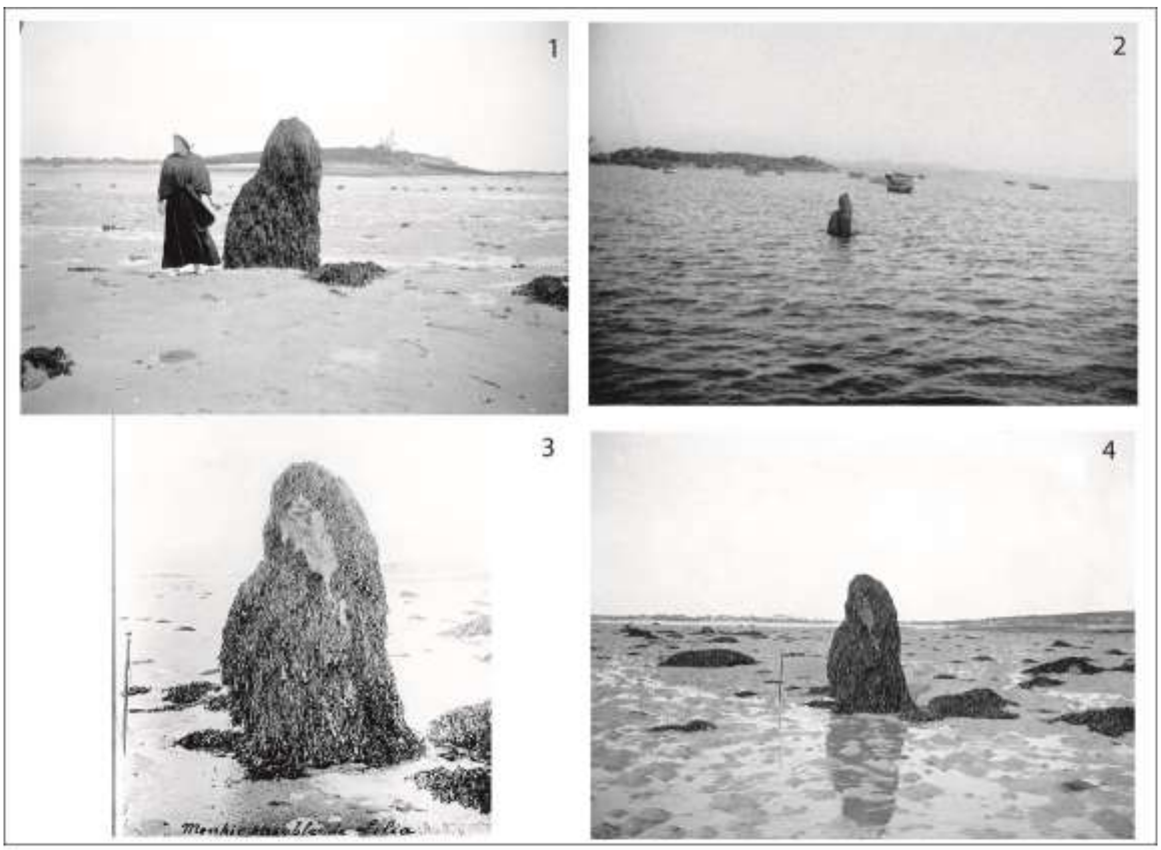

Figure 3I.41. Views of the tidal Men Ozach standing stone (menhir), Plouguerneau (Finistère) (photos by A.; Devoir, early 20th century) © Labo Archéosciences UMR 6566 CReAAH.

Key coastal risk management issues for the frontage
This area is subject to intensive coastal erosion, due to several factors:

- its geographical location, facing the west and exposed to the main storms;
- the tide and waves effects on the soft rocks formations; and
- the human buildings (ports, quays) which can modify locally the sedimentation processes and retain sand.

In addition, the food submersion risk threatens, more or less, some parts of this coastal area.

How the artwork can inform coastal risk management
Among the available pictures of the site (Figure 3I.41), n° 1 has been selected for ranking as it appears to be the most informative, due to the large view showing the landscape around the standing stone and also due to the fact that the lady standing next to the 'menhir' provides a scale for the size of the monument. The photo n°2 shows the monument at high tide and the n°3 details the presence of seaweeds attached to the monuments, both of them proving the current position of the 'menhir' which is regularly (twice a day) submerged by sea water.

Where can the original artwork be viewed?
The original view (glass photographic supports and positive papers) are part of the collection of the Laboratoire Archéosciences (Rennes University).

"Plouguerneau Men Ozach" photo ranking score achieved: 77

Comment: Despite the very high quality of palaeo environmental indications, the ranking score is not maximum due to the fact that menhir (standing stones) monuments are difficult to date with precision, as they are said to be erected from the Neolithic to the Bronze Age period.

I7. Kerlouan, Lerret by A. Devoir (c. 1913)

Location
The megalithic monument of Lerret, a Neolithic passage grave, is located in the northern part of the Finistère department, in the tidal belt of Kerlouan village.

Why was the study site selected?
The site has been selected as an illustrative example of megalithic monuments which are now located in the tidal area (Figure 3I.41); as it was initially erected on the land, the present situation of this megalithic burial is an indicator of sea level rise during the Holocene period. This monument has been considered by the antiquarians and pioneers of archaeological studies as witnessing the Holocene local sea level changes. During its construction, the monument stood on the banks of Quillimadec river, but the water level having risen, it is now regularly found submerged. Now this path is no longer covered by a single slab, which forms an upper chamber of 1.50 meter. Around the monument, traces of occupation were discovered, including a shale ring-disc in 1926, and a flint dagger in 1965. The village of farmers and breeders, where these megalith builders lived, was unearthed nearby in the coastal submerged peat layers of Tressény bay. Excavations have allowed the discovery of houses, stones to grind grain, flint, polished stone axes and Neolithic ceramics. The monument dates back to the period late 4th millenium-3rd millenium BC (Giot *et al.,* 1998, Sparfel & Pailler, 2009).

Geomorphological setting
The Men Ozach monument is located in Tresseny bay, which is an ancient *ria* featuring a deep indentation in the coast of Kerlouan. Just as the menhir described above (which is located 8 km

to the south west), the Kernic monument is located on the 'Aber Coast', belonging to the 'Low Shelf of Léon' formation. The importance of the tide range in this part of Brittany (c. 8 m) explains the scale of intertidal area exposed during low tide. During Prehistoric times, especially the Neolithic period, this area was a coastal plain where megalithic monuments were settled on the top of the small hills, which became islands due to the sea level rise.

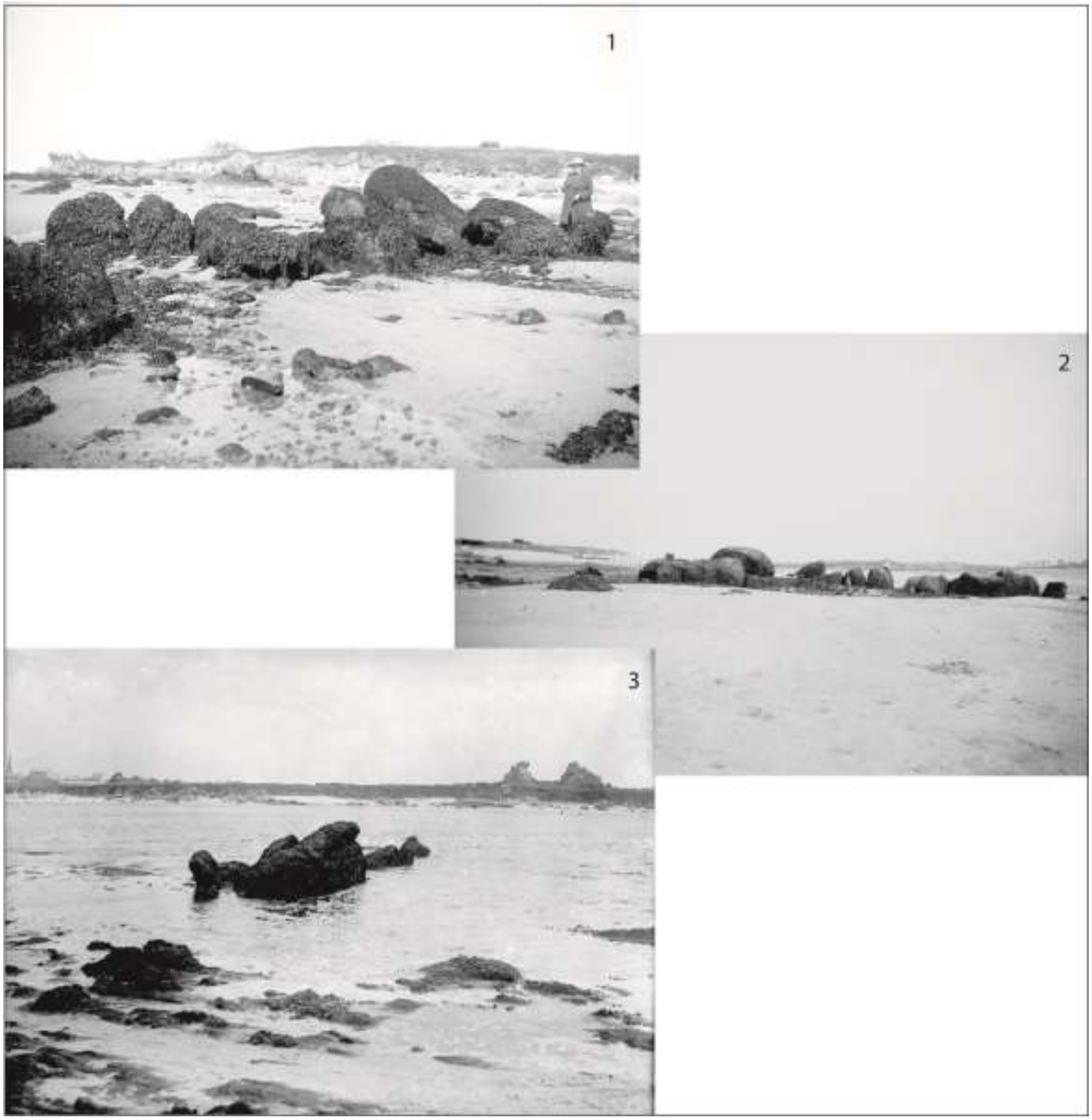

Figure 3I.42. Views of the tidal Neolithic passage of Lerret in Kerlouan village (Finistère) (photos by A. Devoir, 1913) © Labo Archéosciences UMR 6566 CReAAH.

Key coastal risk management issues for the frontage
Similar to the previous study site, this area is subject to intensive coastal erosion, due to several factors:

- its geographical location, facing the west and exposed to the main storms;
- the tide and waves effects on the soft rocks formations; and

- the human buildings (ports, quays) which can modify locally the sedimentation processes and retain sand.

The erosive process is clearly demonstrated by the fact that the monument has been progressively damaged by waves, with a loss of several architectural elements. In addition, the food submersion risk threatens, more or less, some parts of this coastal area.

How the artwork can inform coastal risk management

As shown on the pictures of the Lerret site (Figure 3I.42), the passage grave is regularly covered by sea water at high tide, which is confirmed by the presence of seaweeds stuck to the monuments, both of them proving the current position of the 'menhir' which is regularly (twice a day) submerged by sea water.

Where can the original artwork be viewed?

The original views (glass photographic supports and positive papers) are part of the collection of the Laboratoire Archéosciences (Rennes University).

Kerlouan, Lerret ranking score achieved: 100

I8. Penvenan, Port Blanc, Y. de Bellaing (1936)

Location

The site is located at the beach of Port-Blanc, town of Penvenan, situated in the Trégor region (Côtes d'Armor department). The city of Penvenan is characterised by a strong geographic presence of the sea with outstanding coastal areas, and an archipelago of islands. Two ports recently rearranged as 'Port-Blanc' and Bugueles, demonstrate the importance of these havens for fishing and coastal sailing, today and in the past. Many elements demonstrate the 'maritime dimension' of the town and are of archaeological origin dating back to the Neolithic period. The islands hosted the first occupation by coastal populations from across the Channel, especially the monks and early Chistians since the 6th century.

Why was the study site selected?

This photo represents the megalithic burials discovered in 1935 in the beach of Port-Blanc, locally named ‘Roch Bras’ (Figure 3I.43). The archaeological remains of this site indicate several environmental changes since their building during the Bronze Age (probably during the late 2nd or early 1st millennium BC) (Mazères & de Bellaing, 1936). Several cist stone burials, generally empty, appeared on the beach after storms during the 1930's. These burials were partially destroyed by natural erosion during the 1950's, as mentioned in scientific documentation.

Geomorphological setting

At the local scale, in the surroundings of the archaeological remains, observations mention the ‘old soil’ which contained archaeological remains dating back to the Metal ages, as well as four banks, perpendicular to the foreshore, quite regularly spaced, and fossilized by a sandy dune. This shows that ancient farming structures with field limitations can be traced back to the Bronze Age and early Iron Age.

The archaeological remains provide a date for the development of coastal dunes in this area.

Figure.3I.43. View of the Late Bronze Age or Iron Age burials, discovered in 1936 on the Port-Blanc beach (Roc'h Glas), Penvenan (Côtes d'Armor). Located at the base of sand dunes, partly destroyed by storms (photos by Y. de Bellaing, 1935) © Labo Archéosciences UMR 6566 CReAAH.

Key coastal risk management issues for the frontage
The main risk in this area is erosion that threatens the coastal formations which are mainly composed of soft rocks and sand dunes.

The beach dike of Port-Blanc was built during the 4th quarter of the 20th century (around 1970) (Figure 3I.44). It replaced an old sea defence wall. It is extended by a wall-embankment military defence, built during WWII. A blockhouse completes this defence. The wedges are of recent construction, apart from the wedge Rohanig at the end of the harbour front, which dates from the early 20th century. This protection wall has totally transformed the natural landscape and the coastline along the Port-Blanc bay, which in its current form should be consided 'artificial'.

How the artwork can inform coastal risk management
This archaeological site provides key information on the coastal landscape formation and its evolution:

- the formation of sand dunes and the history of some coastal areas, submitted to regular or episodic sand invasions, during the last three or four millennia; and
- the vulnerability of the sand dune formations facing the regular climatic events (wind, swell) or the sudden ones such as storms which regularly eroded the coastline before the construction of the dike.

Where can the original artwork be viewed? The original photo is part of the collection of the Laboratoire Archéosciences (Rennes University).

Penvenan, Port-Blanc photo ranking score achieved: 100.

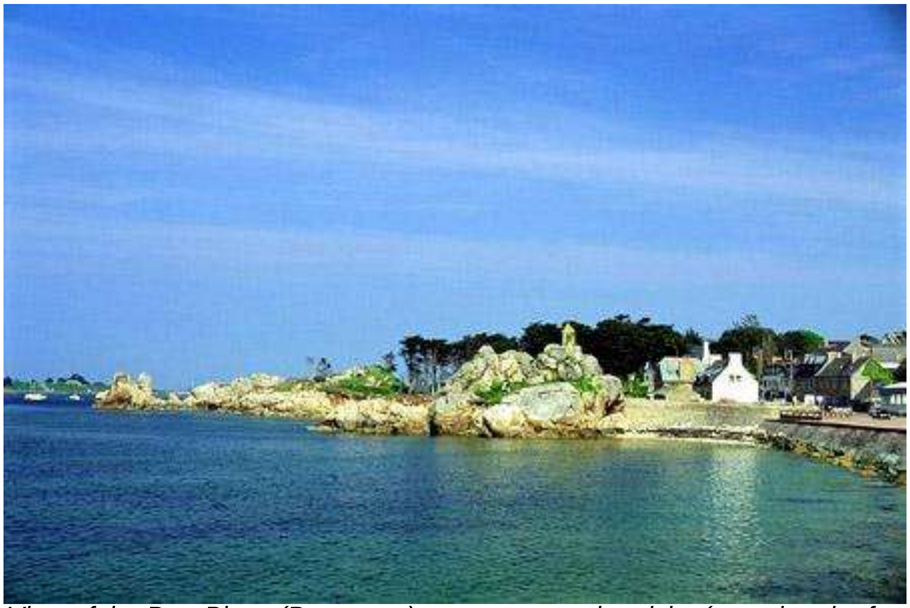

Figure 3I.44. View of the Port-Blanc (Penvenan) current protection dyke (note that the former dune has disappeared) (source jedecouvrelaFrance.com, link http://www.kamaxx.com/jdlf/img/photos/4877_1.jpg).

I9. Carte des Ingénieurs du Roi –St-Michel-en-Grève Bay

Location

The *Carte des Ingénieurs du Roy* was created during the second half of the 18th century with a military purpose, it is one of the first detailed representations of the whole territory of France, in this case the view of the Saint-Michel dates of 1771. The selected section of the charts represents the St-Michel-en-Grèves bay, which is located in the southern part of the bay of Lannion, at the limit between the Finistère and Côtes d'Armor departments (Figure 3I.45).

Why was the study site selected?

The Bay of Saint-Michel is especially interesting because it has been depicted with more or less detail in several maps. The oldest representation dates to 1690 and the coastal maps to the 18th and the 19th century, combined with aerial views provide information on coastal and geomorphological changes in this area ove at least three centuries. Besides that, the presence of a path across the beach which is probably of Roman origin and which was in use until the end of the 18th century provides information on sea level change over the long term.

Geomorphological setting

The Bay of Saint-Michel has changed significantly in the last two centuries due to human impact, it consists of a wide sandy beach surrounded by consolidated cliffs in the north and the south of the bay up to 50m; in the east, three streams of water have changed this channel during the 19th century.

Key coastal risk management issues for the frontage

St-Michel-en-Grève bay is threatened by several risks:

- its geographic position infers some peculiar sedimentary processes (accumulation in some parts and erosion in others), due to the marine streams which flow in the bay of Lannion (Augris & Simplet, 2011); and

- as a tourist destination seaside town, the town population and buildings are regularly increasing.

How the artwork can inform coastal risk management
In this area, we can clearly appreciate the environmental changes and the sea level rise, due to the accumulation of sediment and the human effect. In 1771, when the map was created, the route along the bay was still in use and it was protected from the streams Yar and Roscoat thanks to the sand bank that avoided them to pass through and their channel flowed near the city of Saint-Michel. The sand dredged in this area has provoked a progressive sea level rise and the change of the river channel, because the removal of the sank bank meant the river flowed toward the sea. First coastal defenses were created to protect the road and the railway, but this embankment wasnot always enough, and it has suffered during big storms.

Where can the original artwork be viewed?
The original of the document can be viewed in the Vincennes castle (Ministère de la Défense) but the association AMARAI has bought and owns an electronic copy of this document.

Saint-Michel bay map Ranking score achieved: 66.6

Figure 3I.45. Chart featuring the Bay of St-Michel-en-Grèves
(Carte des Ingénieurs géographes du Roy, 1771, doc. Ministère de la Défense, SHDMV).

Figure 3I.46 . Photo of the "Croix de mi-lieue" located along the ancient Roman pathway, which became a pilgrim road during the Middle Ages (author unknown, source: Degemer Mat, lien http://www.st-michel-en-greve.fr/vignettes/patrimoine/croix-de-mi-lieue.jpg).

I10. Carte des Ingénieurs du Roi – Penvenan, Port Blanc Cove

Location
The chart represents the area of Port-Blanc, town of Penvenan, situated in the Trégor region (Côtes d'Armor department) (Figure 3I.47).

Why was the study site selected?
This beautiful and detailed map covers Port-Blanc area (Penvenan), a place where numerous archaeological remains have been found. The limits of the coast, of the islands, and of the rocky islets are accurate and have been depicted with remarkable attention.
This handmade chart is certainly the first precise marine map of the coastal area from Tréguier to Port Blanc (source: http://www.histoiremaritimebretagnenord.fr/).

Geomorphological setting
The geomorphological setting has been presented for this area in the section above.

Key coastal risk management issues for the frontage
See the above section.

How the artwork can inform coastal risk management

The comparison between this ancient chart and the current landscape features shows how some sections of the coast have changed during the last three centuries.

Where can the original artwork be viewed?
The only version of this map is this original (as it has never been printed) and is preserved in the BNF (Bibliothèque Nationale de France, Division 3-folder 43 of the Marine Hydrographic Service).

Penvenan Port-Blanc cove map ranking score achieved: 50

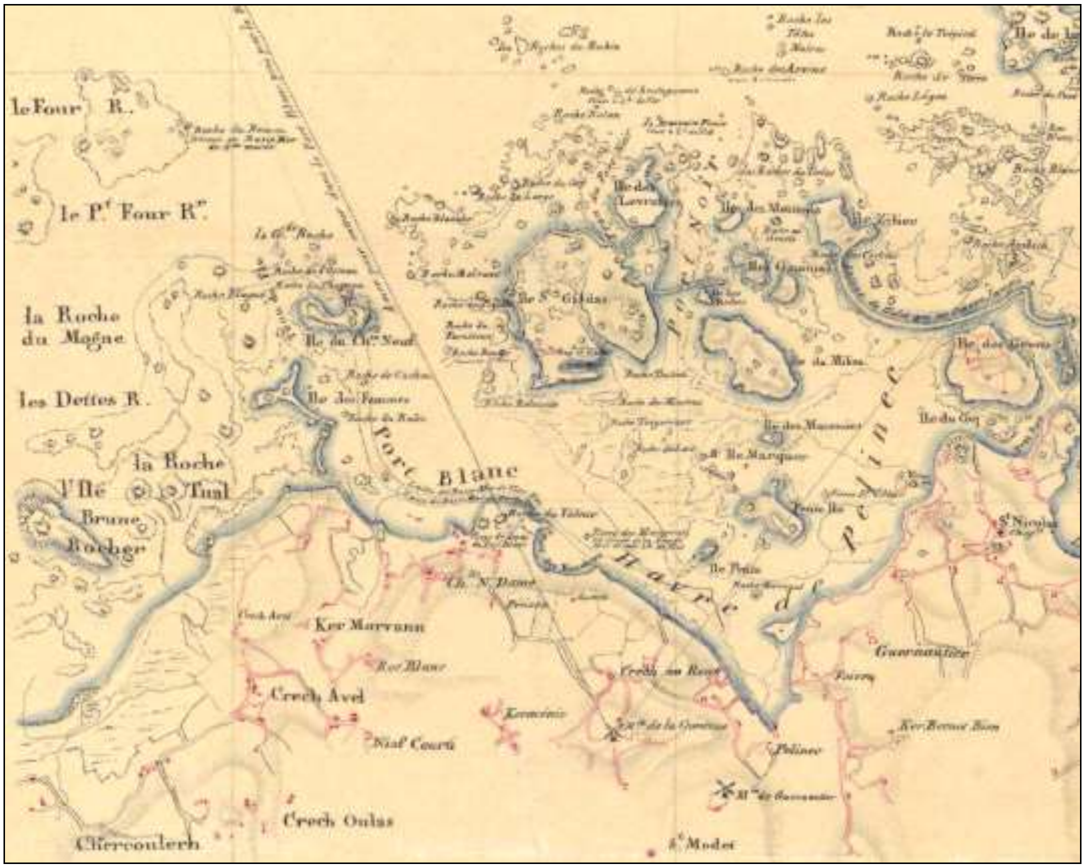

Figure 3I.47. Ancient map 'Tréguier Port-Blanc' (1771-1785) (Source SHM, Ministère de la Défense).

3I.7 Analysis

The Northern-Finistère and Trégor study has combined the use of archaeological and palaeoenvironmental data, paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve understanding of coastal change in the long and short term. The study area contains key elements which have been used for the reconstruction of the ancient (prehistoric) coastal landscapes and the curves featuring Holocene sea level variations. In Brittany, this area is long considered as one of the reference places for palaeoenvironemental reconstructions and this explains the richness of the available documentation (old maps and charts, photos and to a lesser degree, paintings).

Some recent works, either targeting archaeological problems or environment/geomorphology questions, have been applied to this geographic area, where coastal evolution can be studied at various times and spacial scales.

3I.7.1 Archaeology and Heritage Features

The archaeological assessment focussed on the megalithic monuments and archaeological layers, currently located on the tidal shore. The positions of these burials or monuments in a place were they are now regularly submerged clearly indicates that they were settled in a time when the sea level was lower. Numerous archaeological studies and environmental analyses provided accurate data for the building of local sea level curves. For more recent periods (from Metal Ages up to Historical times), the fish trap studies revealed some precise data on environmental changes, as demonstrated for the Léguer estuary and the Petit Taureau fish weir.

It is interesting to note that the study of sea level variations and the search for indicators of coastal change is not a new issue for scientists; indeed, the ancient documentary set of the Archéosciences laboratory (Rennes 1 university) has provided a range of unpublished documents dating from the early 20th century, revealing that several monuments and archaeological sites of the area have provided data for this study (Devoir, unpublished; Giot 1990). The selected sites were mainly megalithic ones, dating from the Neolithic and Bronze Age periods, passage graves, burials and standing stones, such as the one of Men Ozac'h the study of which has been detailed above (Figure 3I.48). For the first time, curves supporting past sea level variation have been proposed.

It is noticeable that such a scientific approach born in Northern Finistère, is due to the presence of numerous archaeological sites located in the tidal foreshore (Figure 3I.49). Later on, in the 1960's, the same sites have been reconsidered, while submerged peat deposits were subject to pollen analyses and radiocarbon dating (Morzadec, 1974), still with the aim of building a precise curve for sea level rise. These works have been recently updated by P. Stéphan, with the use of new scientific approach using lithostratigraphy and biostratigraphy (Stéphan, 2011 & 2012).

As demonstrated by the archaeological surveys, it is also interesting to note that a number of the archaeological sites which have significant potential for holding data to inform on coastal change are themselves likely to be lost through continuing erosion of the coast. This phenomenon is fully illustrated in the framework of the ALeRT project (Archéologie, Littoral et réchauffement terrestre) (Daire *et al*., 2012). This project underlines the vulnerability of the coastal heritage facing various kinds of risks, especially erosion, and highlights the need to gather data from those high and medium scored sites to capitalise on this information before it is lost (for more information, see:http://alert-archeo.org/).

For the Bay of Lannion, ancient sedimentary and stratigraphic observations, though sketchy, are fortunately interspersed with radiocarbon dating and archaeological discoveries, providing chrono-stratigraphic markers. From these observations, we now see that, in the Léguer estuary, due to marine transgression, sedimentation at the bottom of the bay, with levesl of accumulation of organic matter and river sediments, was followed by marine sedimentation. It was during this transition that fish weirs have gradually been installed on both sides of the estuary. The oldest fish traps detected at the mouth of the Léguer estuary go back to the Bronze Age (Dourven at Trédrez) and the Iron Age (Corps de Garde at Servel). The evolution of the implementation of these fish traps and their progressive displacement upstream not only follows the rhythm of a marine transgression in progressive slowdown, but also the very complex sedimentary history of this estuary (Figure 3I.50). If natural factors have largely determined the shaping of banks, human interventions at different periods are also responsible for deep changes in the network of channels of fluvial-marine flows.

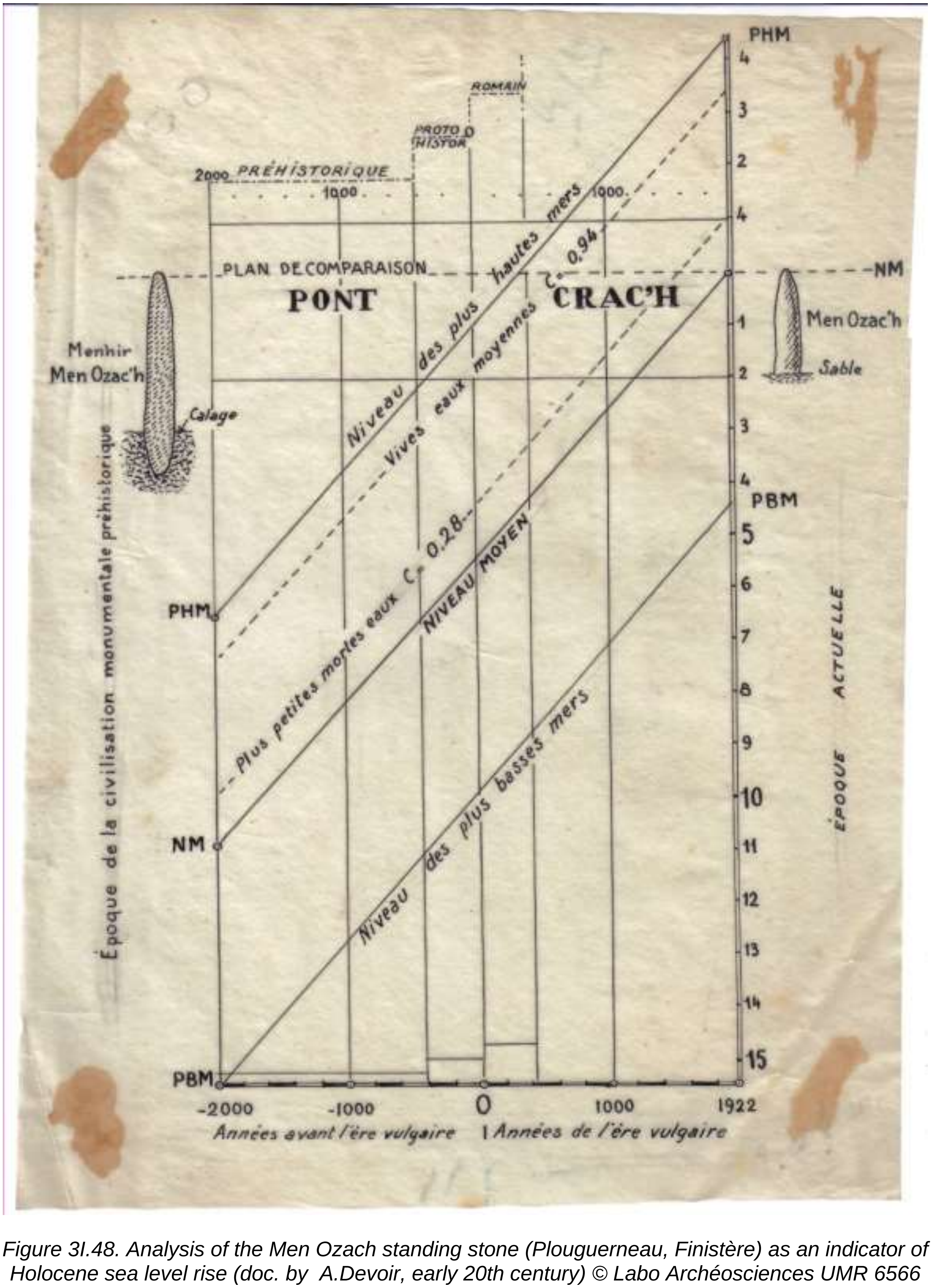

Figure 3I.48. Analysis of the Men Ozach standing stone (Plouguerneau, Finistère) as an indicator of Holocene sea level rise (doc. by A.Devoir, early 20th century) © Labo Archéosciences UMR 6566 CReAAH.

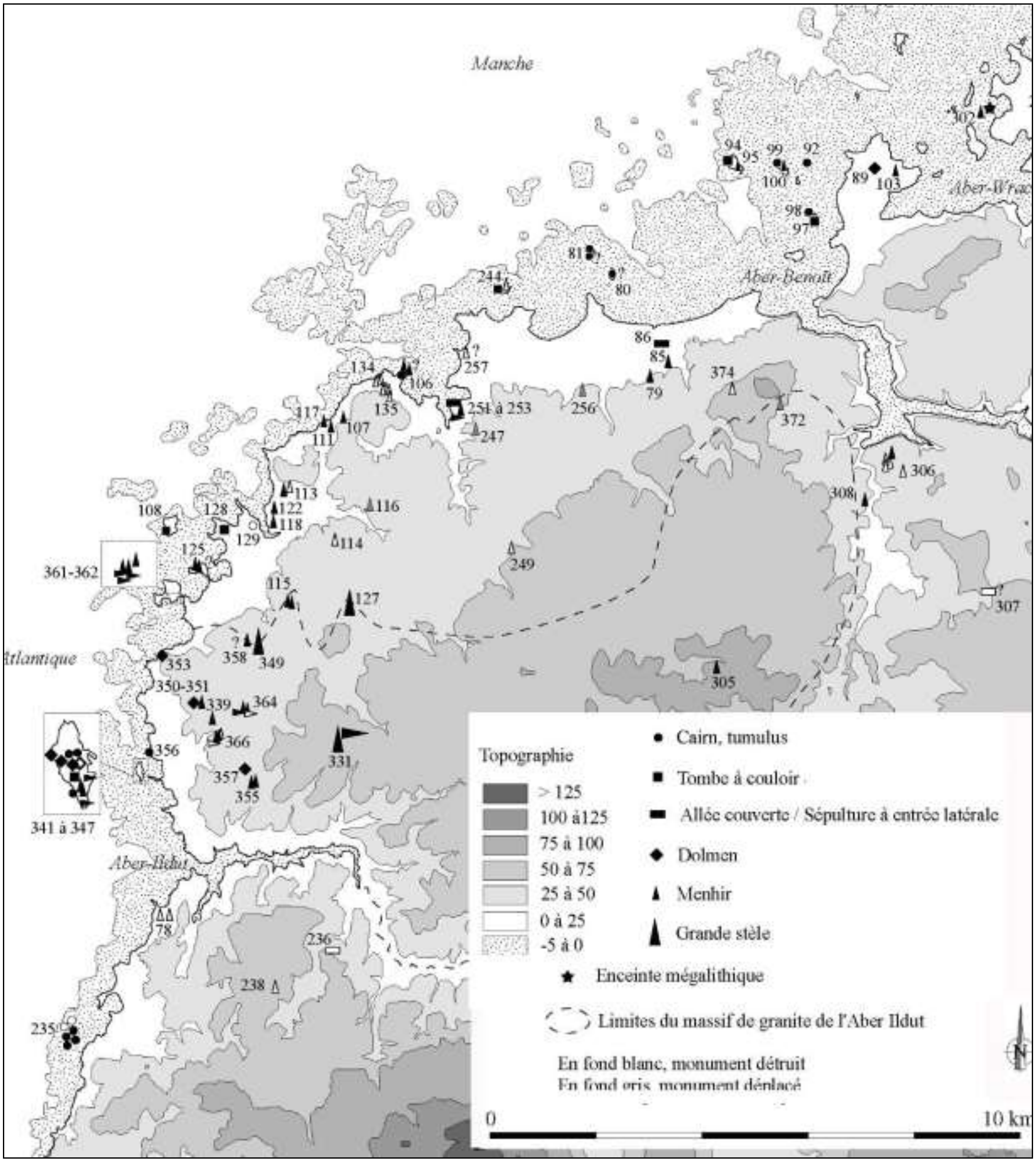

Figure 3I.49. Distribution of the Megalithic monuments (Neolithic and early Bronze Age) in the north west Finistère area, and their position regarding the topographic sea level (after Stéphan in Sparfel & Pailler 2009: 57). The map especially shows (in grey) the probable location of the ancient foreshore (Neolithic), which is currently submerged. This explains why a lot of monuments, formerly settled on the top of small hills, are now located on isolated islands or islets.

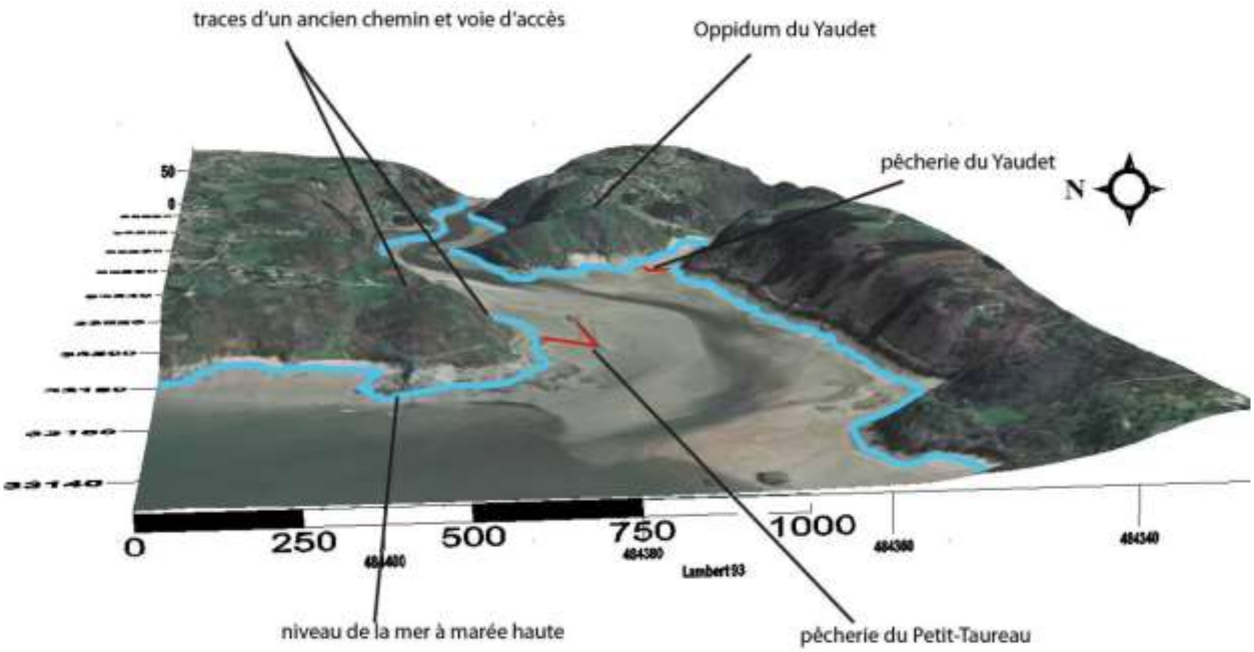

Figure 3I.50. 3D reconstruction of the Léguer estuary during Middle Ages, showing the location of the main fish traps and settlements (after Marie Poignant, Dijon University).

3I.7.2 Artistic Depictions

Following the research and location of a large number of photographic images of the study area coastline it was possible to rank their relative importance in terms of their value on informing on long-term coastal change. Several ancient maps and charts were also used. The art case study area was extensively covered by ancient photos; including taken by the pioneer scientists (collection from the Archéosciences laboratory, ICARE project; López-Romero and Daire, 2013) as well as those used for tourist purpose and edited postcards.

The ranking system directed research to the higher ranking case study locations usually where detailed accurate photos or maps were available as the artworks and especially the paintings were less numerous and illustrative in this area. Then, we selected the most representative photos, generally featuring archaeological sites witnessing sea level rise; in terms of the most helpful photos comparing coastal change, those representing the megalithic monuments of Northern Finistère area have been selected.

As well, the selected high scored ancient charts are those where, for example, beach levels are clearly indicated or where special features (sand bars, dunes) can be measured; a good example is provided by the Saint-Michel-en-Grèves bay.

3I.7.3 Combined Resources

Plouescat is a town in northern Finistère; its coastline is of about 13 km long with a succession of sandy beaches, dunes, and massive blocks of granite. Kernic Cove is a bay where there are extensive mudflats and sandbanks. One of the most famous megalithic monuments of the region stands on the tidal shore of the Kernic beach.

Among all the megalithic monuments of this area, the 'Guinirvit' passage grave has been fully excavated in the 1980's. This monument was damaged by the builders of the surrounding port, as many megalithic blocks were taken for the construction of the quays, mainly used by the seaweeds farmers. The ancient photo, taken at the early 20th century, shows the monument in a better state of preservation than it is today.

The passage grave measures 10 m long and is currently submerged twice a day; this is a good indication of sea level rise, which is locally estimated at 7 m since the Neolithic period. The excavations carried out in 1986 under the direction of the prehistoric antiquities of Brittany enabled evidence of this collective burial and its protective enclosure to be recorded. This research and other studies have uncovered an important set of potsherds and lithic materials: circular flint scrapers or blades, hammers, quartz fragments, polished axes, arrowheads and slag. This monument has been protected as Cultural heritage ('monument historique') since 1960.

The following image (Figure 3I.51) presents various views of the megalithic monument. The ancient photo, (n°1, Figure 3I.51) taken during the very early 20th century, shows the passage grave in an early stage, before the damage by the builders of the quays (n°6, Figure 3I.51).

As for the monuments presented above, these megalithic remains, nowadays located on the tidal foreshore, give an indication of the sea level rise since the Neolithic period, which is evaluated to 7 meters. However, this phenomenon is not the only reason for coastal changes in this area. As is visible when comparing the maps (n°3-5, Figure 3I.51), the sand dunes and river flood channel have changed in shape and location during the last four centuries. On the Cassini map (17th century) as according to the 18th century chart (n°3 & 4, Figure 3I.51), the area of the Curnic bay is only a sandy slope, formed behind a rocky bar that retains the sand and which is cut by the river meanders; as seen on the recent maps (n°4, Figure 3I.51), this area is currently submerged at high tide, probably because of a combination of a slight sea level rise and discharge of sand due to the river flow or to the marine streams.

This area is currently protected, as a natural zone for bird reproduction. The nature curators are aware that the coastal managers for tourism impact on this vulnerable area, especially sailing activity which could damage the sand dunes (http://inpn.mnhn.fr/site/natura2000/FR5312003/).

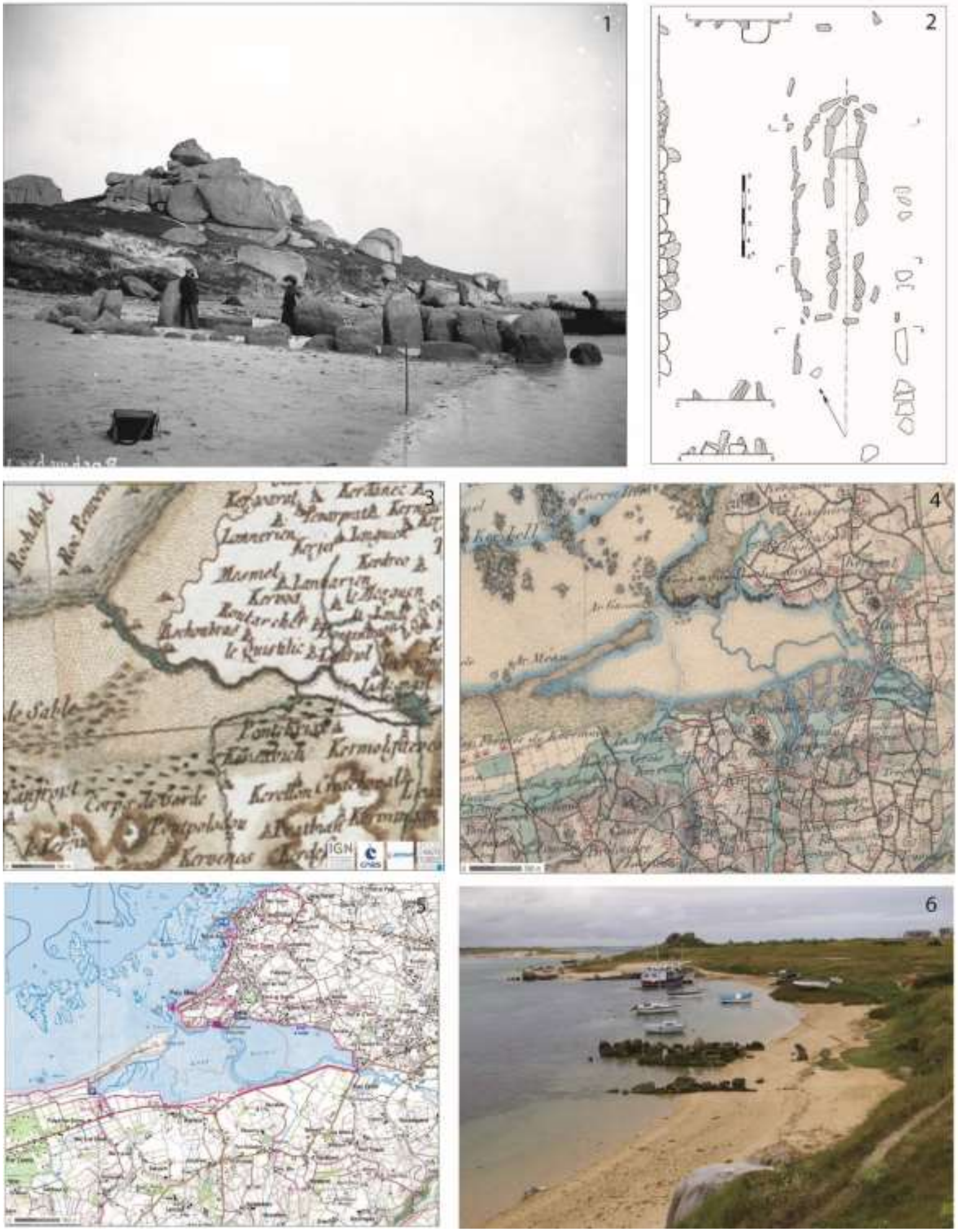

Figure 3I.51. Combination of visual documents of the Neolithic passage grave of the Kernic Bay (Plouescat, Finistère). (1) Early 20th cent. photo of the monument © Labo Archéosciences UMR 6566 CReAAH, (2) Map of the inner part of the megalithic remains (doc. J. L'Helgouac'h, 1965), (3) Cassini chart (17th cent.), (4) "Etat major" chart (1820-1866), (5) Current IGN map (source Géoportail), (6) present day (doc. M. Monros).

3I.8. Conclusions and Recommendations

Each of the resources listed above can provide detailed information about past environments and the position of the coastline, through combining these resources it is possible to provide more accurate information not just from one time period but over a longer term, this can inform on the rate, scale and pace of coastal change along the coastline. The data can not only provide quantitative information on coastline position, but can also provide qualitative information that can assist in illustrating coastal changes to a large audience.

In the case of Lannion bay, we can consider that the massive extraction of estuarine sands in the decades 1950-1970 has restored the Léguer estuary a former state, clear of recent alluvium, probably older than what was recorded by J. P. Pinot - the late 18th cent.; this state could be traced back to the Metal Ages if one believes the combination of sediment study, radiocarbon dating and archaeological data. Anyway, the fish weirs of the Léguer estuary provide information on thirty centuries of the history of fishing and peopling of the estuary. Sedimentary data (cores and surveys) and associated dating provide markers, actually quite sketchy in terms of calibration samples on the one hand to the Bronze Age (or Neolithic period) and, secondly, to the Middle Ages.

This observation should make coastal managers aware of the consequences of future sand and aggregate extractions, which are planed offshore in the bay of Lannion int the near future.

In the same way, the complex history of Kernic bay gives an opportunity to underline the benefit gained from analysing the past and especially the geo-archaeological evidence, in order to evaluate the impact of the current managment decisions. This is especially important when considering the soft rocks or sedimentary features of the coastal areas, which are vulnerable and very sensitive to any change, either of climatic or anthropic origin.

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3I.9 Case Study References

Apegit 1986-1996. *Iles du Trégor.* Annual bulletins of the Association pour la Protection l'éEtide et la Gestion des Îles du Trégor, n°1 to 10.

Augris C., Simplet L. 2011. *Atlas géologique de la baie de Lannion (Côtes d'Armor, Finistère).* Ed. QUAE, Versailles, 110 p. et 7 cartes.

Auvray B., Lefort J.P. 1971. *Tréguier (Côtes-d'Armor). Carte géologique de la France* au 1/50000, BRGM.

Bizien-Jaglin C., Galliou P., Kérébel H. 2002. *Côtes-d'Armor, Carte archéologique de la Gaule*, Coéd. Académie des Inscriptions et Belles Lettres, Ministères de l'Education Nationale et de la Culture et Maison es Sciences de l'Homme, 406 p.

Bardel J.P. 1984. *Les thermes gallo-romains de Plestin-les-Grèves*. Les Côtes d'Armor au naturel, Département des Côtes d'Armor, 28 p.

Batt M., Giot P.-R., 1980. Quelques observations d'archéologie du paysage en Finistère, *Bulletin de la Société Archéologique du Finistère*, tome CVIII, p. 17-25.

Biet M.C., Bouze O. 2010. *La Bretagne d'antan à travers la carte postale ancienne*. H.C. Hervé Chopin publisher, 176 p.

Boutouiller J., 2002. *Patrimoine et histoire du pays de Plestin, des origines au Moyen Âge.* Centre culturel de Plestin-les-Grèves, 60 p.

Briard J., 1971. Epées de Bretagne et d'ailleurs jetées dans les rivières à l'Âge du Bronze. *Annales de Bretagne,* 78, n°1, p. 47-58.

Cariolet J.M., 2011. Inondation des côtes basses et risques associés en Bretagne : vers une redéfinition des processus hydrodynamiques liés aux conditions météo-océaniques et des paramètres morpho-sédimentaires. Thèse de Doctorat de l'Université de Bretagne Occidentale, Brest - LETG - Géomer - Littoral, Environnement, Télédétection, Géomatique, http://tel.archives-ouvertes.fr/tel-00596426/fr/ oai:tel.archives-ouvertes.fr:tel-00596426.

Cariolet J.M. , Suanez S., Meur-Férec C. and Postec A., 2012. Cartographie de l'aléa de submersion marine et PPR : éléments de réflexion à partir de l'analyse de la commune de Guissény (Finistère, France) , *Cybergeo : European Journal of Geography* [Online], Space, Society,Territory, document 586, Online since 02 February 2012, connection on 16 February 2014. URL : http://cybergeo.revues.org/25077 ; DOI : 10.4000/cybergeo.25077

Clément J.-H., 2011. Les pêcheries de l'embouchure du Léguer (Côtes-d'Armor) à travers les textes, *Bulletin de l'AMARAI (Association Manche Atlantique pour la Recherche Archéologique dans les Îles),* 24: 45-53.

Collective 1992. La mer et les jours, XVe siècle – 1940. 5 siècles d'Arts et Cultures Maritimes en Côte d'Armor. Catalogue de l'exposition du Château de la Roche-Jagu, 20 juin – 1er novembre 1992. Conseil Général des Côtes d'Armor, 239p.

Collective 2008. Catalogue, *Henri Rivière: Graveur et photographe*, Musée d'Orsay exhibition.

Collective 2009. *La gestion du trait de côte*. MEEDM (Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer). Editions QUAE, 352 p.

Croix A., Guyvarc'h D., Rapillard M. 2011. *La Bretagne des photographes. La construction d'une image de 1841 à nos jours.* Presses Universitaires de Rennes, 502 p.

Cunliffe B., 2004. Le Mur de Pêcherie, in Cunliffe B., Galliou P., *Les fouilles du Yaudet, en Ploulec'h, Côtes-d'Armor. 1 – le site, Le Yaudet, dans l'histoire et la légende*, Oxford-Brest, p. 165-170.

Cunliffe B., Galliou P., 2004. *Les fouilles du Yaudet, en Ploulec'h, Côtes-d'Armor. T. 1 – Le site, Le Yaudet, dans l'histoire et la légende,* Oxford-Brest, Oxford-Brest, Oxford University Press et CRBC ed., 301 p.

Cunliffe B., Galliou P., 2005. *Les fouilles du Yaudet, en Ploulec'h, Côtes-d'Armor. T. 2 - De la Préhistoire à la fin de l'empire romain.* Oxford-Brest, Oxford University Press et CRBC ed., 390 p.

Cunliffe B., Galliou P.,2007. *Les fouilles du Yaudet, en Ploulec'h, Côtes-d'Armor. T. 3 – Du quatrième siècle ap. J.-C. à aujourd'hui,* Oxford-Brest, Oxford-Brest, Oxford University Press et CRBC ed., 207 p.

Daire M.Y., 2009 . Islands and archaeological research in Western France. Summary of a very long story of romance... *Shima, The International Journal of Research into Island Cultures*. Vol. 3, n°2, p. 52-69.

Daire M.Y. (ed.), 2011. *Sur les rivages de la Manche… Le site de l'âge du Fer de Dossen Rouz à Locquémeau-Trédrez (Côtes d'Armor). Etude pluridisciplinaire.* Les Dossiers du Centre Régional d'Archéologie d'Alet, n° AH, 159 p. (paru en 2012.

Daire M.Y., Hautenauve H., Le Bozec E., Le Nagard K., Nédélec F., *et al*., 2001. Un complexe artisanal de l'Âge du Fer à Enez Vihan en Pleumeur-Bodou, Côtes d'Armor. *Revue archéologique de l'Ouest*, 18: 57-94.

Daire M.Y., Langouët L. (eds) 2008. *Les pêcheries de Bretagne, archéologie et histoire des pêcheries d'estran*, Co-éd. CeRAA-AMARAI, Les Dossiers du Centre Régional d'Archéologie d'Alet, AE, 144 p.

Daire M.Y., Langouët M.Y., 2010. *Les anciens pièges à poissons des côtes de Bretagne, un patrimoine au rythme des marées*. Co-édition CeRAA-AMARAI, Les Dossiers du Centre Régional d'Archéologie d'Alet, n°AG, 165 p.

Daire M.Y., Langouët L., 2011a. *Lannion-Servel (22) ; pêcheries du Petit-Taureau*, rapport des sondages 2011, 32 p.

Daire M.Y., Langouët L., 2011b. Dater les anciennes pêcheries par les niveaux marins ; approche méthodologique et perspectives géoarchéologiques : le Bas Léon, nord Finistère, Bretagne, *Norois,* 220/3, 69-93.

Daire M.Y., Langouët L., 2011c*. Les pêcheries des Côtes-d'Armor, rapport des prospections thématiques* 2011, 45 p.

Daire M.Y., Le Brozec M., 1990. Un nouvel atelier de bouilleur de sel à Landrellec en Pleumeur-Bodou (Côtes d'Armor). *Revue archéologique de l'Ouest*, 7: 57-71.

Daire M.Y., Lefeuvre J.Y., 2001. L'île Melon, hier et aujourd'hui (commune de Porspoder, Finistère). *Bulletin de l'AMARAI (Association Manche Atlantique pour la Recherche Archéologique dans les Îles),* 14: 67-92.

Daire M.Y., López--Romero E., Proust J.N., Régnauld H., Pian S., Shi B. , 2012 **-** Coastal changes and cultural heritage: Towards an assessment of vulnerability through the Western France experience. *Journal of Island and Coastal archaeology,* 7, p. 168-182.

Delouche D., 2003. *La peinture en Bretagne*. Collection Patrimoine de la Région Bretagne, 84 p.

Galliou P., 2004. Le Yaudet, du mythe à l'histoire, 23-25, in CUNLIFFE B., GALLIOU P., Les fouilles du Yaudet en Ploulec'h, Côtes-d'Armor ; 1 – le site, Le Yaudet, dans l'histoire et la légende, Oxford-Brest.

Giot P.-R., 1958. Emmanchure avec hache polie draguée dans l'estuaire du Léguer ou rivière de Lannion (Côtes-du-Nord), Bulletin de la Société préhistorique française, 55, p. 704-705.

Giot P.R., 1960. Informations archéologiques, circonscription de Bretagne. *Gallia Préhistoire*, tome III, p. 159.

Giot P.R., 1967. Informations archéologiques, circonscription de Bretagne. *Gallia Préhistoire*, X: 336-337.

Giot P.R., 1969. Chroniques. *Annales de Bretagne*, 76-1: 153-162.

Giot P.-R., 1987. *Barnenez, Carn, Guennoc,* éd. Travaux du Laboratoire d'Anthropologie de l'Université de Rennes 1, Rennes, 2 vol., 212 p. et 57 pl.

Giot P.-R., 1990. Le niveau de la mer : changeant, fluctuant, mouvant, *Bulletin de l'A.M.A.R.A.I. (Association Manche Atlantique pour la Recherche Archéologique dans les Îles),* n° 3, p. 5-16.

Giot P.-R., Briard J., Pape L. 1995. *Protohistoire de la Bretagne,* Ouest France éd., Rennes, 423 p.

Giot P.R., Daire M.Y., Querré G., 1986. *Un habitat protohistorique : le Moulin de la Rive à Locquirec (Finistère).* Travaux du Labo. Anthropologie, Université Rennes I, 135 p.

Giot P.-R., Monnier J.L., L'Helgouac'h J. 1998. *Préhistoire de la Bretagne,* Ouest France, Rennes, 450 p.

Guilcher A., Hallégouët B., 1991. Coastal dunes in Brittany and their management. *Journal of Coastal Research*, vol. 7-2: 517-533.

Hallégouët B., 1971. *Le Bas-Léon (Finistère), étude géomorphologique*, thèse de 3ème cycle, Université de Bretagne Occidentale (UBO), Brest.

Hallégouët B., 1978. L'évolution des massifs dunaires du pays de Léon, *Penn ar Bed*, 11-95: 417-430.

Hallégouët B., 1981. Les crêtes littorales dunifiées du massif armoricain : formation et évolution, *Géographie physique et Quaternaire*, 35-2: 205-218.

Hénaff A., Meur-Férec C., Lageat Y., 2013. Changement climatique et dynamique géomorphologique des côtes bretonnes. Leçons pour une gestion responsable de l'imbrication des échelles spatio-temporelles, *Cybergeo : European Journal of Geography* [En ligne], Environnement, Nature, Paysage, document 654, mis en ligne le 27 septembre 2013, consulté le 16 février 2014. URL : http://cybergeo.revues.org/26058 ; DOI : 10.4000/cybergeo.26058

Landre N., 1975. *Fichier technique des estuaires bretons. Le Léguer*. Rapport préparé pour le CNEXO (contrat 73/804), Publications du Centre National pour l'exploitation des Océans, Paris, 36 p.

Langouët L., Daire M.Y. 2009. Ancient maritime fish-traps of Brittany (France): A reappraisal of the relationship between human and coastal environment during the Holocene. *Journal of Maritime Archaeology, vol.* 4, n°2, p.131-148.

Langouët L., Daire M.Y. 2012. Les pêcheries des Côtes-d'Armor, Rapport de Prospection thématique 2012.

Langouët L., Daire M.Y., Bernard V., 2012a. Les barrages de pêcheries de l'éstuaire du Léguer dans leur contexte sédimentaire. Apport à la géoarchéologie de la baie de Lannion (Côtes-d'Armor). *Bulletin de l'AMARAI (Association Manche Atlantique pour la Recherche Archéologique dans les Îles)*, n°25, 65-86.

Langouët L., Daire M.Y., Bernard V., 2012b. *Rapport de la fouille programmée 2012 des pêcheries du Petit-Taureau, à Lannion-Servel (22),* AMARAI et CREAAH, 34 p. + annexes.

Langouët L., Daire M.Y., Bernard V., 2013 – *Rapport de la fouille programmée 2013 des pêcheries du Petit-Taureau, à Lannion-Servel (22),* AMARAI et CREAAH, 37 p. + annexes.

Le Bihan J.-P., Villard J.-F., 2007. Archéologie d'une île à la pointe de l'Europe : Ouessant - Tome 1 : le site archéologique de Mez-Notariou et le village du premier âge du Fer. Centre Archéologique du Finistère éd., Quimper, 351 p.

Le Bihan J.-P., Villard J.-F., 2010. Archéologie d'une île à la pointe de l'Europe : Ouessant - Tome 2 : l'Âge du Bronze. Centre Archéologique du Finistère éd., Quimper, 588 p..

Le Du L. 1993. Quel littoral ? Les aménagements touristiques et portuaires du Trégor-Goëllo. *Norois*. N°158: 281-296.

López-Romero E., Daire M.Y., 2013. The ICARE project: an insight into the formation and consolidation of archaeology in western France (ca. 1850-1990). *Bulletin of the History of Archaeology* 23(1):3, 1-11. DOI: http://dx.doi.org/10.5334/bha.2313

Maillet-Chassagne M., Château-Thierry I., 2004. *Catalogue raisonné des œuvres des Van Blarenberghe,* Paris, Musée du Louvre-Musée de France.

Marchat A., Le Brozec M. 1991. *Les mégalithes de l'arrondissement de Lannion*. Collection Patrimoine archéologique de Bretagne, co-édition ICB et Travaux du laboratoire d'Anthropologie, Rennes, 102 p.

Mazères R., De Bellaing Y. 1936. Port-Blanc en Penvénan. Aperçu géologique et préhistorique. Bulletin de la Société d'Emulation des Côtes du Nord, LXVIII, p. 195-213.

Mélin M. 2011. *Les dépôts d'objets métalliques en milieu humide pendant l'Âge du Bronze en France*. Thèse de Doctorat de l'Université de Rennes 1.

Merckelbagh, A., 2009. *Et si le littoral allait jusqu'à la mer ! La politique du littoral sous la Vème république*. Editions QUAE, 352 p.

Monnier J.L. 1981. *Le Paléolithique de la Bretagne dans son cadre géologique*. Travaux du Laboratoire d'Anthropologie, université de Rennes1, 350 p.

Motte, E. 2013. *Représentations et évolutions du littoral en Bretagne.* Mémoire de Master 2, Université Rennes 2, département de Géographie, 23 p.

Morzadec-Kerfourn M.-T., 1974. *Variation de la ligne de rivage armoricaine au Quaternaire, analyses polliniques de dépôts organiques littoraux.* Rennes, Mémoires de la Société Géologique et Minéralogique de Bretagne, n° 17, 208 p.

Pinot J.-P. 1991. Histoire d'un estuaire : la rivière de Lannion, in *Mélanges offerts par ses amis à J. Charpy,* Brest, Fédération des Sociétés Savantes: 297-310, fig. 3.

Pinot J.-P. 1995. Quelques plages en voie d'engraissement ans la région de Lannion, *Norois* 42-165: 99-117.

Prod'homme L. 2012. *Reflets de Bretagne. Les collections photographiques du Musée de Bretagne.* Fage publisher, 256 p.

Sparfel Y., Pailler Y., 2009. *Les mégalithes de l'arrondissement de Brest.* Coll. Patrimoine archéologique de Bretagne, co-ed. CeRAA et ICB, Rennes, 290 p.

Stéphan P., 2011. *Les flèches de galets de Bretagne. Evolutions passées, présentes et futures*. Ed. L'Harmattan, Paris, 263 p.

Stéphan P. 2011. Colmatage sédimentaire des marais maritimes et variations relatives du niveau marin au cours des 6 000 dernières années en rade de Brest (Finistère). *Norois*, n° 220, 2011/3, p. 9-37

Stéphan P., 2012. Une régression marine au Bronze final en Bretagne ? Ou le reflet de changements morphosédimentaires importants à la côte. In Mélin M. et Mougne C. (dir.), *L'Homme, ses ressources et son environnement, dans le Nord-Ouest de la France à l'Âge du Bronze : actualités de la recherche*. Actes du Séminaire d'Archéologie de l'Ouest, 22 mars 2012, Université de Rennes 1. Mémoires Géosciences Rennes, Hors série n°8, p.131-140.

Stéphan P., Suanez S., Fichaut B., 2009. Variations holocènes du niveau marin en Bretagne occidentale, dans Sparfel Y., Pailler Y. (dir.), *Les mégalithes de l'arrondissement de Brest,* Coll. Patrimoine Archéologique de Bretagne, co-éd. Ce.R.A.A. (Centre Régional d'Archéologie d'Alet) et I.C.B. (Institut Culturel de Bretagne), Rennes, p. 10-11.

Suanez S. Cariolet J.M., Fichaut B., 2010. Monitoring of recent morphological changes of the dune of Vougot Beach (Brittany, France) using Differential GPS. *Shore & Beach*, 78-1: 37-47.

Stéphan P., Suanez S., Fichaut B. 2009. Variations holocènes du niveau marin en Bretagne occidentale, dans Sparfel Y., Pailler Y. (dir.), *Les mégalithes de l'arrondissement de Brest,* Coll. Patrimoine Archéologique de Bretagne, co-éd. Ce.R.A.A. (Centre Régional d'Archéologie d'Alet) et I.C.B. (Institut Culturel de Bretagne), Rennes, p. 10-11.

CASE STUDY 3J – CORNOUAILLES, FR (Brittany)

Case Study Area: Cornouailles, Brittany, France

Main geomorphological types: Soft cliffs, dunes, sandy beaches and saltmarsh.

Main Coastal Change Processes: Coastal erosion, dunes instability, beach change.

Primary resources used: Art and archaeology.

Summary: The study area comprises extensive sandy beaches and dunes which are subject to erosion and instability. Numerous megalithic monuments, located along the tidal belt, provide evidence of sea level rise while artistic depictions have enabled us to see the rate and scale of coastal erosion over the last few decades.

Recommendations: Coastal managers should use these resources when predicting future rates of erosion, as they provide hundreds of years' worth of data to assist in the understanding of the rate of change. There is then an emergency in registering the natural and cultural heritage of all these threatened sites, as the physical protections could only slow the process but not really prevent the damage.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

The Cornouailles area is one of four Brittany case study areas for the Arch-Manche project. This case study report introduces the study area and why it was chosen as part of the project. This report will mainly deal with the results of the art study, as no specific archaeological or palaeoenvironmental field work has been carried out during the project. However, as former field studies have provided data regarding coastal evolution in this area, the main results of such work will be mentioned. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. Further details about the project methodology applied can be found in Section 2.

Within the Cornouailles area, the archaeological and palaeoenvironmental resource and the available art resource have been researched, scored and analysed. The extent of the detailed study areas are shown in Figure 3J1 below. The area considered for archaeology and palaeoenvironment has been selected to provide a representative range of types of evidence across a range of periods spanning from the Palaeolithic through to more modern coastal heritage. The art, photograph and map case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time.

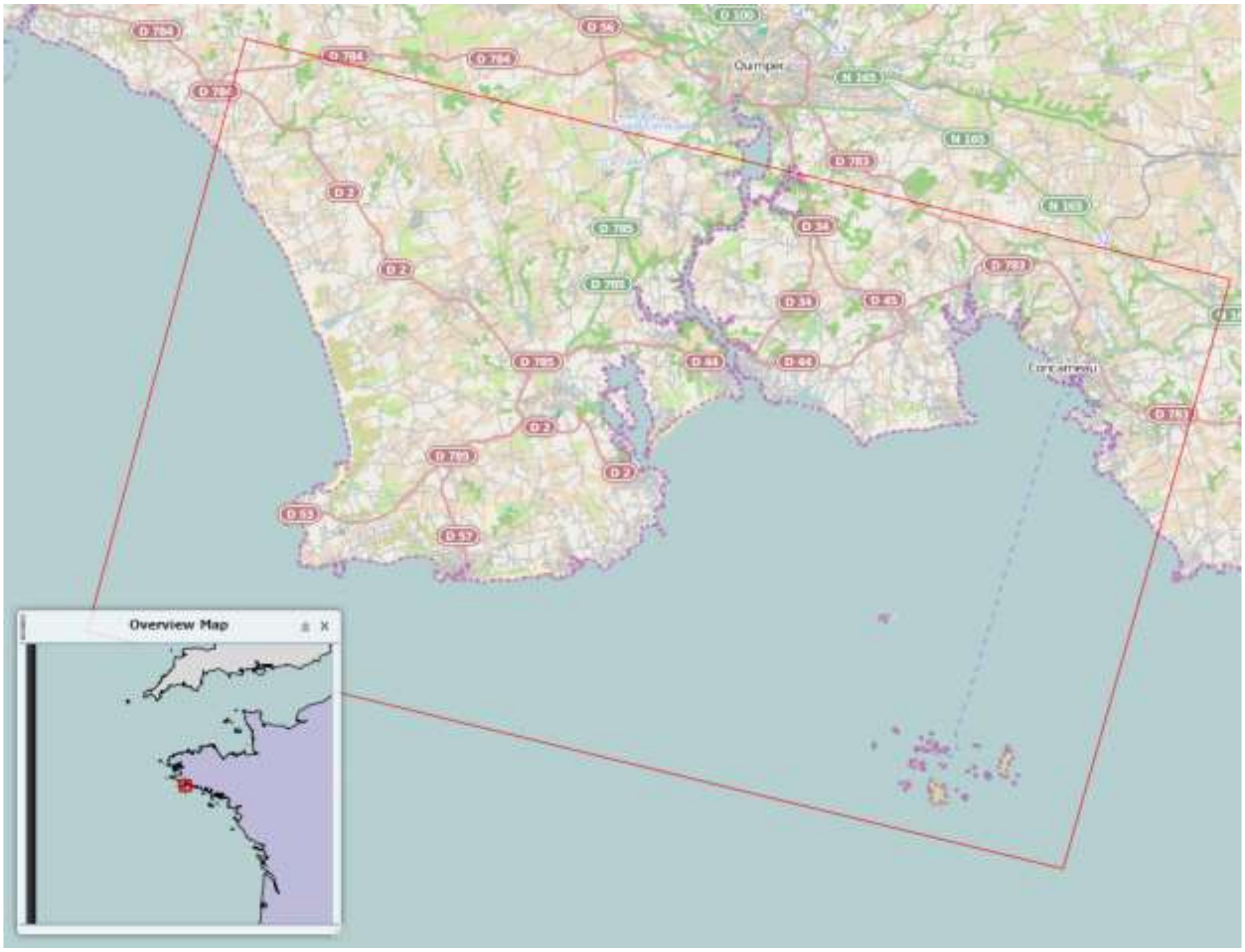

Figure 3J1. Map of the Cornouailles study area.

3J.1 Introduction to the Cornouailles study area

The Cornouilles case study area is located in south-west Brittany. It is bordered by the Atlantic Ocean to the west with the Audierne Bay and the Bay of Biscay to the south. Some islands are present, including the Glénan archipelago (about 22 islands and islets) and Moutons Island. It is part of the cultural area called "Pays Bigouden" which is an existing political and religious entity even today, where the economy and people's lives have a long association with the activities of the Sea. This economy evolved in the early 20th century, with the arrival of seaside tourism and in the years 1930-1950, especially in the Bay of Audierne with the birth of 'mass tourism'.

This region has interesting economic and historical assets, but also natural risks from coastal change. In recent centuries and decades the most usual response to protection of property and assets has been the construction of coastal sea walls and flood defences, especially in the exposed area of Penmarc'h and in the most settled and touristic towns (for example Bénodet, La Forêt Fouesnant and Lesconil. Coastal risk problems have often arisen because of a lack of co-ordination in the past between land use planning and development proposals.

3J.1.1 Geomorphology of the area

This section outlines the key geological and geomorphological features and processes within the study area. These factors have a significant impact on the on-going changes to the coastline and associated sites, deposits and features preserved related to the archaeological and heritage resource, in addition to being depicted through a range of art sources.

Geological History

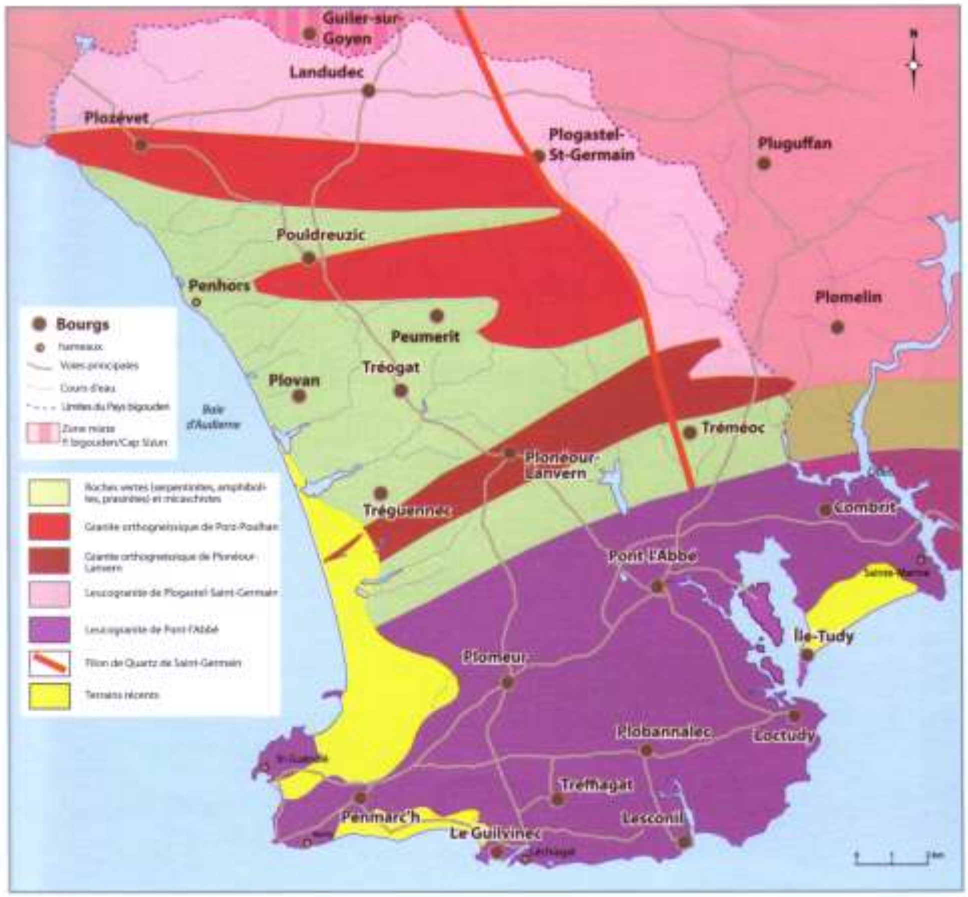

Figure 3J.2. Simplified map of the Cornouaillles geology (after Chauris 2011).

Geology (Figure 3J.2) can dictate the structures and landscapes on our shores. Geological formations have been subject to erosion over millennia which has created the landscapes that we currently have. Such erosion will vary according to the underlying geology and rock formations (e.g. chalk, granite). In this area, we are in a particularly flat landscape, especially in the west, with a few rocky points. Audierne Bay is a rather low side with a pebble bar (about 10 km long), and dunes and ponds (former tidal marsh cut from the sea) in the hinterland (Chauris, 2011).

In the northern part of the study area, the Pont Croix zone presents the following characteristic features (limited to the Pleistocene period, 1,8 Ma-0,01Ma) (Collective, 2002): there is a coastal formation of a pebble bar that blocks all the fresh water streams and causes the formation of tidal marshes in coastal rivers outlets. Locally, the bar has lost its effectiveness due to intensive exploitation and the balance of the coast is therefore often threatened (see below).

In the Concarneau area (Bechennec *et al.,* 1996) the coastal border of the continental shelf to the south of Brittany is characterized by the presence of several islands (Glénan archipelago

and Moutons island) and a shallow seafloor, which forms an offshore rocky ridge limiting the peri-coastal depression.
In the Pont l'Abbé zone, a detailed geological map doesn't yet exist but, as the areas mentioned above, the territory is mainly granitic, even if the islands geology is sometimes different (Jonin, 2010: 14-17).

Geomorphological Processes and Human Intervention
In this area, human intervention in sedimentary processes results in subsequent natural erosion further down the coast. In conjunction with this, swell on exposed shores, currents, vertical movements of sea level (caused for example by tidal cycles, storm surges and changes in barometric pressure) may cause extensive damage. Additionally, there are also continental processes that come into play: climate context (precipitation, wind, temperature, and humidity), infiltration and run-off, alternating freezing and thawing, chemical and biological processes (see Henaff *et al*., 2007).

Changes in this coastal region have been partly of anthropogenic origin for the last few centuries. In the absence of human occupation, this coastline has changed much more slowly (over the long term). Note that the various port facilities (e.g. dams and riprap) have caused a reduction in the rate of erosion on the nearby beaches.

We must not forget the important climatic events such as storms or tidal waves, which can alter the coastline temporarily or in the longer term. More than 40% of the observed erosion is caused by storms and marine activities (shore with the waves, flooding low-lying areas, etc (Henaff *et al*., 2007). This change in the coastline may cause subsequent changes to existing human activities (e.g. fishing, sailing) and therefore also to any associated infrastructure.

This risk is particularly acute in low-lying areas such as the Glénan archipelago (Figure 3J.3). There, archaeological and paleoenvironmental studies have shown relatively rapid evolution, in fact, one can imagine that there are 5000-6000 years of landscape change within a single large island the size of that of the Groix Island (Morbihan). Due to the rise in sea level, the lowest areas were flooded and the islands are separated. It is also estimated that, over the past 2500 years, the islands have lost around half of their extent (Daire & Hamon, 2013) (Figure 3J.3). Erosion is exacerbated by humans, with the amenities of rivers, aggregate extraction in river beds and sea drainage of coastal marshes, planting work impeding natural sediment transit; implantation of structure beachfront, followed by the establishment of building defense against sea erosion often accelerates erosion. The extraction of sand near sedimentary shores helps to further accentuate this erosion.

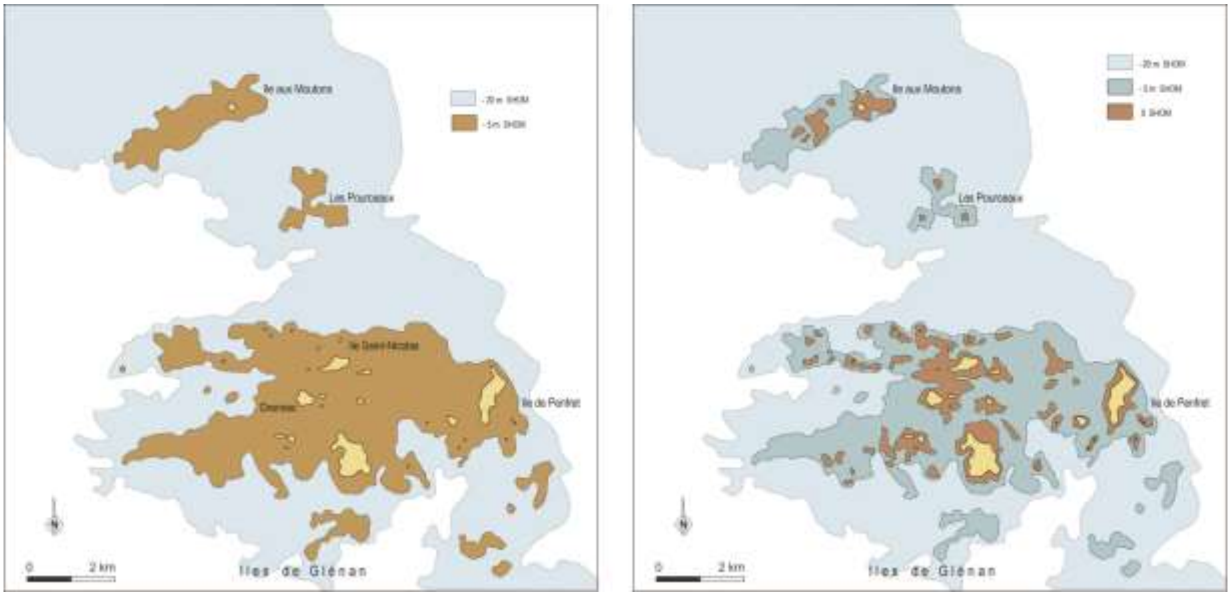

Figure 3J.3. Glenan archipelago (Finistère): hypothesis for the landscape evolution with the situation during early Neolithic period (left) and Iron Age (right) (doc. Daire & Quesnel, after Daire & Hamon, 2013).

3J.1.2 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for Project

The archaeological and palaeoenvironmental data has been obtained from the Atlas des Patrimoine (Culture Ministry), available online (http://atlas.patrimoines.culture.fr/atlas/trunk/), and from the databases of scientific research groups: AMARAI (Association Manche Atlantique pour la Recherche archéologique dans les Îles) association, CeRAA (Centre regional d'Archéologie d'Alet, Saint-Malo). Extensive documentation was also provided by the Archéosciences laboratory of the Rennes1 University, which is a component of the federative research group Unité Mixte de Recherche 6566 du CNRS- CReAAH (Centre de Recherche en Archéologie, Archéosciences, Histoire).

In this region, archaeological activity rests with several associations or institutions: the Archaeological Society of Finistère (created in 1846) which led to the discovery, excavation and study of several sites in the area (coastal or land); the Association Manche Atlantic Archaeological Research on the Islands (AMARAI, 1988), which addresses the archaeology of coastline and islands and initiates archaeological study and discovery. But the first detailed investigations are due to Finistérien Group Prehistoric Studies (PFEG) whose members were grouped around the Prehistoric Museum of St. Gwénolé Penmarc'h (López-Romero & Daire, 2013). These pioneers of scientific research have worked extensively in the region and left a legacy of many excavations and surveys (Bénard Le Pontois *et al*., 1919; Bénard Le Pontois, 1929), as well as some exceptional documentation, including photos preserved in the Archéosciences laboratory (University of Rennes 1), now curator for this documentary set (López-Romero & Daire 2013).

3J.1.3 Summary of the archaeology and history of the Cornouailles study area

As illustrated below, the area presents a very rich dataset concerning the archaeological and palaeoenvironmental record (Batt & Giot, 1980). However, the exploitation of the available data has not been systematic in this area, as there would be a huge amount of information to analyse. Accordingly, we have only exploited some sites within the case study area, which appear to be the most informative regarding the issues of the project; that is to say dated monuments illustrating the coastal changes and related current management issues.

Many archaeological sites have been destroyed on the coast for various reasons including both natural (e.g. erosion, climatic events) or anthropogenic phenomena (recovery, ignorance, construction). This is especially the case during WWII, with the establishment of the Atlantic Wall. Many concrete structures were constructed along the coast which destroyed archaeological and historical remains. In other areas sea level rise and sedimentary transformation have also been responsible for the disappearance of numerous archaeological remains. This is the reason why ancient documentation often appears as the ultimate witness of the existence of some landscapes or sites. Archaeological sites are present in the Glénan archipelago and on Moutons island (megalithic monuments, Iron Age setllements, etc), some which are currently submerged, either partially or permanently (Bénard Le Pontois,1929; Daire, 2013) (Figure 3J.4).

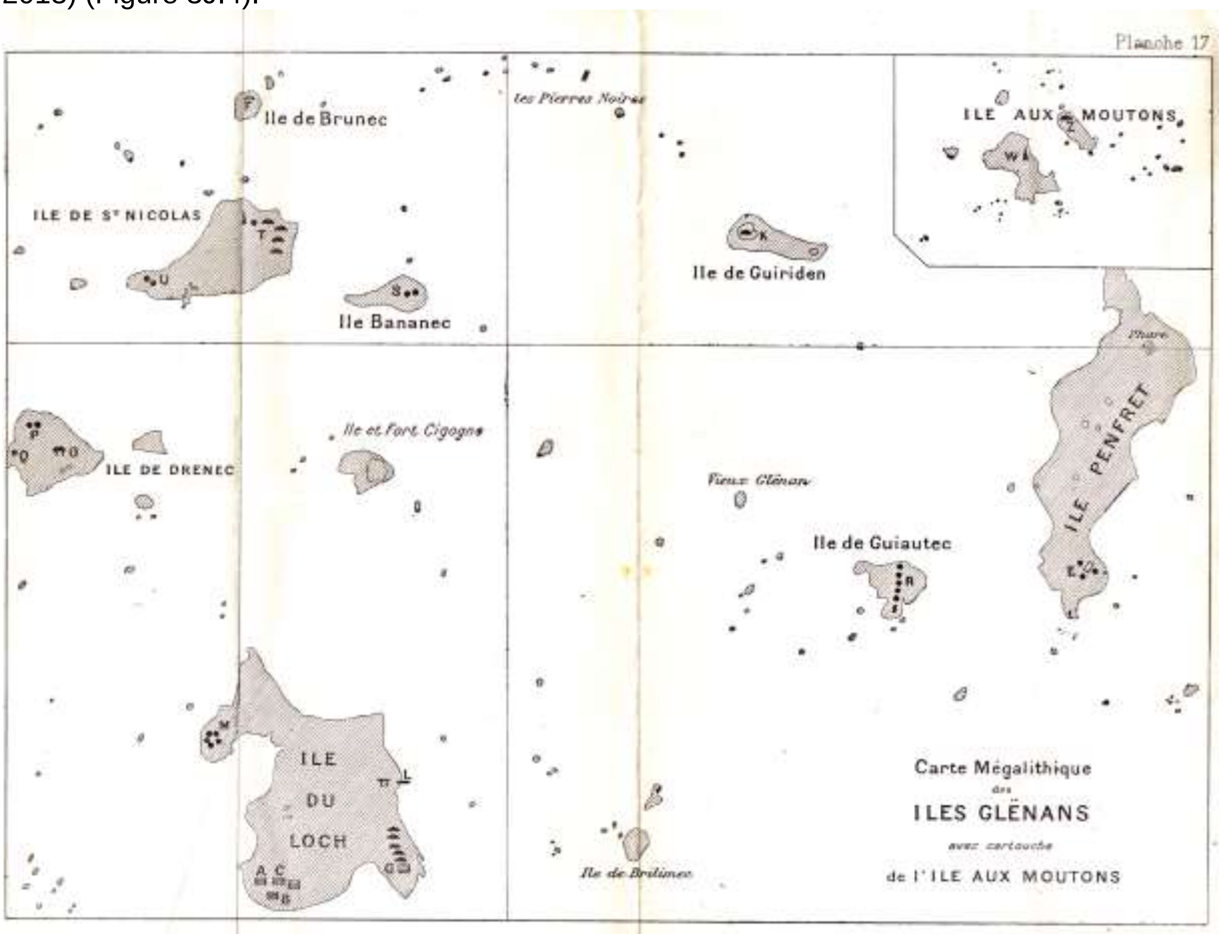

Figure 3J.4. Glenan archipelago archaeological heritage (monuments and settlements) (after Bénard Le Pontois 1929).

Early Prehistory (Palaeolithic and Mesolithic)

Several archaeological sites exist in the area dating back the Palaeolithic and Mesolithic periods. Most of them correspond with deposits located during surveys, not all of which have been subsequently excavated. Although located on the northern limit of the study area, we have to mention the major site of Menez Dregan, excavated in 1996 (Monnier *et al*., 1996). The prehistoric site of Menez Dregan is near the town of Plouhinec, Audierne and delivered remains of the former Palaeolithic habitat dating from 350 to 500,000 years BP, some of which from the lowest levels are among the oldest known in the world.

The Pointe de la Torch (Beg an Dorchenn in Breton) is a natural peninsula barring the southeast end of Audierne Bay in the town of Plomeur. This headland is home to traces of a human presence in Mesolithic (shell midden) and Middle Neolithic (dolmen). The promontory was long frequented during the Mesolithic period, when the sea level was 10 meters lower than today. Such occupants left an important shell midden, which has almost disappeared due to erosion and excavations indicating a diet of oysters, clams, cockles, winkles, limpets, and also crabs, fish and scallops. Evidence for hunting wild boar and deer was also found, along with traces of hearths, tools and a habitation structure (Bénard Le Pontois *et al.,* 1919; Giot, 1947; Dupont 2003).

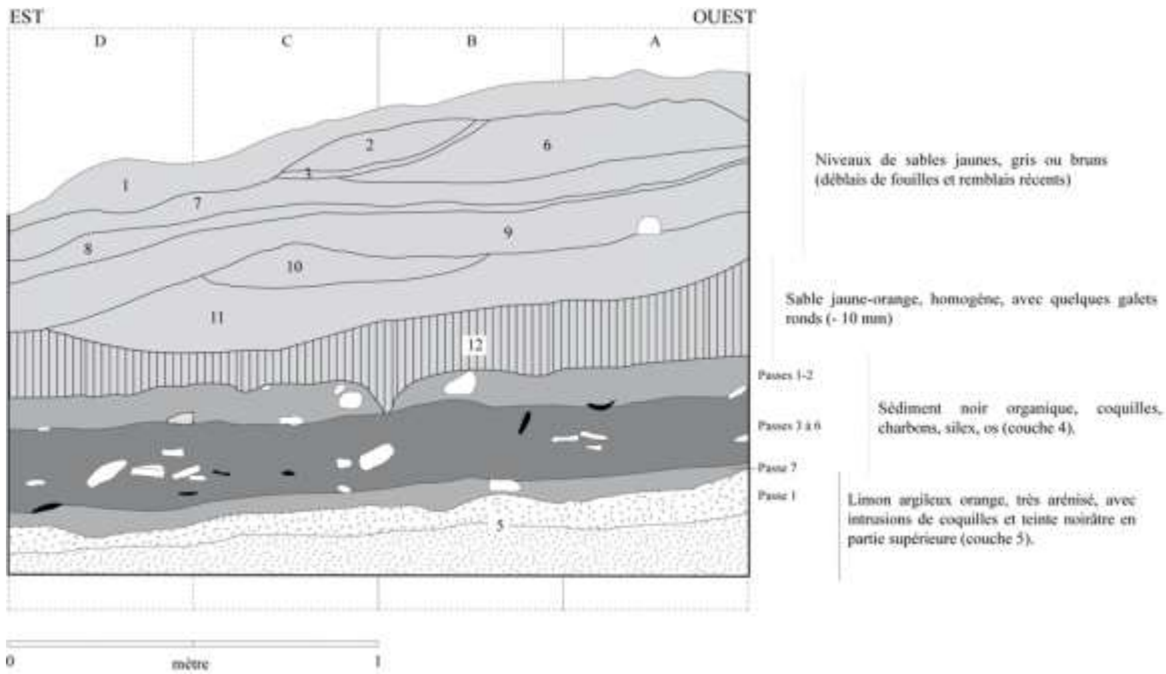

Figure 3J.5. Beg-an-Dorchenn (Pointe de la Torche), Penmar'ch, stratigraphy coupe du sondage 2001 (relevé et DAO : G. Marchand) (after Dupont 2003)

Later Prehistory (Neolithic, Bronze Age and Iron Age)

The Neolithic is a very well-illustrated in the archaeological record of the case study area, especially through the megalithic phenomenon. In addition, this area contains a lot of archaeological remains that provide evidence of coastal changes and sea level rise. Examples of such impact includes standing stones located in the tidal area, or a Bronze and Iron Age necropolis covered by thick sandy dunes.

Among all these records, some remarkable sites, illustrating coastal changes, must be mentioned:

- On the Pointe de la Torch (Beg an Dorchenn in Breton) promontory, a mound was built on top of a granite promontory during the middle Neolithic. There remains a short corridor dolmen and two side compartments, where human bones were found, dating from about 4,300 BC. Later still, the corridor lies on the slope of the promontory, "a sort of passage grave corridor" where later Iron Age materials were located (Figure 3J.5 & 3J.6). During World War II, German bunkers were built on the site, damaging the dolmen (Bénard Le Pontois *et al.*, 1919; Giot, 1947; Dupont, 2003).

- The Neolithic standing stone of Lehan (Tréffiagat) is nowadays partly submerged in a swamp, behind a sandy dune.
- The Neolithic standing stone of Penglaouic, at the limit of Loctudy and Pont-l'Abbé towns, is submerged at high tide in a side swamp of the Pont-l'Abbé river.
- The Neolithic dolmen of the Ezer beach in Loctudy (Figure 3J.7)was discovered in the 1950s after a retreat of the sandy bar due to a storm (Giot & Morzadec, 1992: 57). It seems that this dolmen has been destroyed some years later, when channelling works were carried out in order to dry the marsh behind the coastal bar (Giot & Morzadec, 1992: 59).

Numerous cists stones were discovered on several sites located on beaches, which are dated back to the Bronze Age or the early Iron Age, for example in Mousterlin bay (Fouesnant) or the Glénan archipelago (Figure 3J.8). The iron Age continues to be well represented in this area, through the hundreds of granite stelae (corresponding to burials or cemeteries markers) (in Saint-Jean-Trolimon, Kerviltré (at least 5), Combrit, Savenic near la Clarté, Tréogat, Tréguennec, Plomeur, Penmarc'h, Treffiagat, Plobannalec, Loctudy, Pont-l'Abbé, Fouesnant, La Forêt-Fouesnant and Concarneau). In Penmarc'h, during construction of the St-Gwénolé port, a coin from Agrigente (400 BC) has been found. A burial was located 600-800m west to Rosmeur, and contained charcoal, pottery sherds and a sword (Galliou, 2010: 273). In Treffiagat, on the Kervarch and on the Letty sites, and in Loctudy and in the La Forêt-Fouesnant bay, remains of settlements were associated with salt production workshops dating from the late Iron Age (Galliou, 2010: 438-439, 252 & 202).

Figure 3J.6. Mésolithic site and Neolithic passage grave of Pointe de la Torche/Beg and Dorchen (Finistère) (by P.R. Giot, C. 1950 © Labo Archéosciences UMR 6566 CReAAH).

Figure 3J.7. Neolithic standing stone lying in the tidal area in the Loctudy port (Finistère) (A. Devoir, c.1920) © Labo Archéosciences UMR 6566 CReAAH).

Figure 3J.8. Stone cists burial (late Bronze Age or early Iron Age), Loc'h island, Glénan archipelago (by C.T. Le roux, 1970) © Labo Archéosciences UMR 6566 CReAAH).

Roman Period

In contrast to earlier periods, Roman *villae* and remains are not numerous in the study area. We can mention the ancient road that goes along the Audierne bay in Plomeur and in various other points of the Cornouailles and some ceramics (Galliou 2010: 292). Remains of Roman buldings are scarcely mentioned, except in the Kerity port, where Roman tiles and bricks were discovered, as well as in the eastern part of the village where a Roman villa was discovered in the tidal area, although regularly covered by the sea. (Galliou 2010 : 273)

Medieval Period (AD500 – 1485)

The early medieval period is characterised by the appearance of many granite chapels (Chauris 2011). However, records from the later Medieval period are marked by only one major find: the Saint-Saturnin cemetery (or Saint-Urnel, Plomeur), dated back to AD 600 and located under a dune. The site was first excavated in 1920 and 1924 (Figure 3J.9) (Bénard, 1929), then again by P.R. Giot from 1946 to 1950, and from 1973-1975. Although first identified as an Iron Age cemetery, the new excavations allowed radiocarbon dating to be conducted (Giot & Monnier, 1977) which identifed the medieval burials (inhumations), with lower levels dating back to the Iron Age.

Some building at the coast are now right on the seafront, as with the 15th century chapel of Notre-Dame-la-Joie Penmarch (Figure 3J.10). This has been subjected to various storms that have led to the development of a dam, without which it would probably have been destroyed (the dam has already been destroyed due to storms). This is an example of the difficulty of coastal buildings and ensuing developments. In Concarneau, the first coastal defence rampart was built in 1373, followed by numerous modifications until the end of the 15th century, and later on with Vauban defence plan.

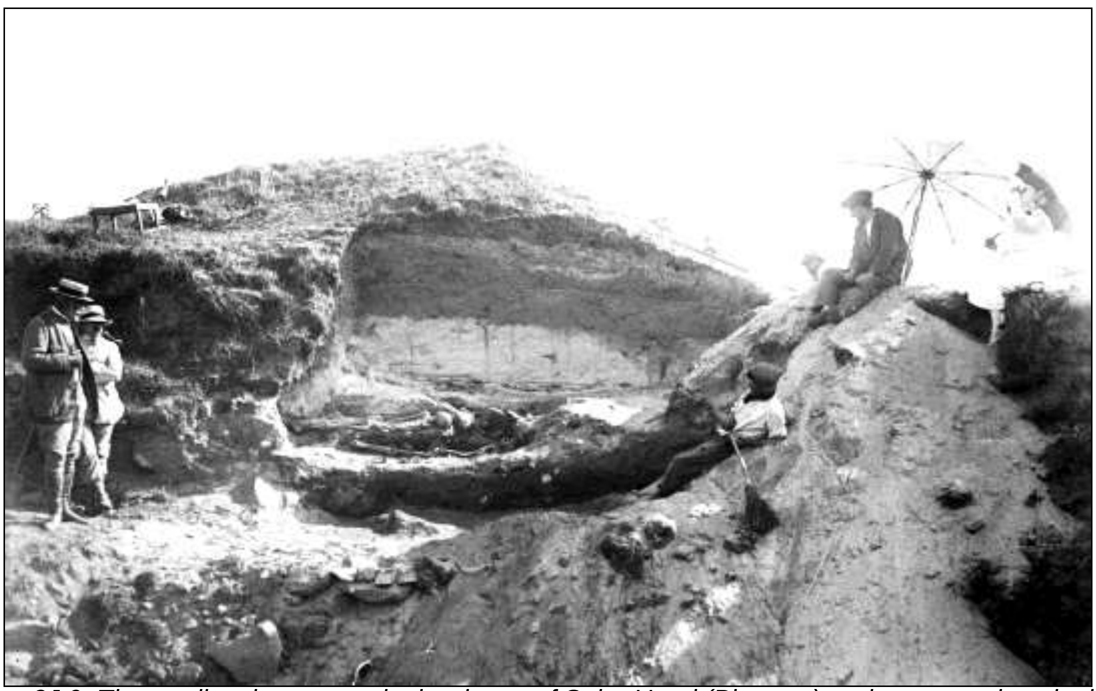

Figure 3J.9. The medieval cemetery in the dunes of Saint-Urnel (Plomeur) under excavations in the 1920s' by the Groupe finistérien d'Etudes Préhsitoriques (© Labo Archéosciences UMR 6566 CReAAH).

Figure 3J.10. The medieval chapel Notre-Dame-de-la-Joie (Kerity, Penmarc'h), ancient postcard from Villard c. 1900 (private collection).

Post-Medieval Period (AD1485 – 1901)

In the relatively flat Audierne bay, there is little human settlement and the major anthropogenic changes are relatively recent (20th century) and include features such as quarries. In contrast, the south of Cornouailles is more conducive to human settlements, with ports, a fortified town, facilities protection (e.g. seawall, jetty, etc).

The Audierne Bay is less altered through human action than the south of Cornouailles, because it is particularly inhospitable for ships. However, there is the presence of small fishing ports (landing ports, harbours for sheltering ships, etc) that leave a lesser mark in the landscape. In the south, there are more port facilities, some dedicated to fishing while others are marinas. Changes in ports are associated with changes in fisheries and vessels with an increasing tonnage (such as deep-sea fishing) or the development of tourism.

Prior to the 18th century, activity on the foreshore was restricted to a subsistence economy. The Industrial Revolution of the 19th century led to considerable changes to fisheries, shellfish and trade. At the end of the 19th century, the coastline became a privileged space for urban settlement, industrial and seaside tourism. The latter was witnessed through a new found fashion for sea-bathing combined with the democratization of railways and thalassotherapy. As a result of this the coastal areas are now experiencing an economic and ecological demographic pressure.

There are several types of traditional exploitation of the coast:

Seaweed gathering, originally harvested on foot or dredged at sea, is an ancient tradition throughout the 'bigoudène' coast (Figure 3J.11). Seaweed, itself very abundant, was used as fertilizer in the fields and dried fuel for the winter. But, in the second half of the 19th century and the first half of the 20th century it developed a soda industry. The coastal population, especially women and children gathered seaweed to be piled, before burning, in rectangular pits (4-5m long and 40cm wide). Kilns were then used to obtain soda bread which was subsequently treated in plants located in the Penmarc'h soda factory (in Saint-Gwénolé, Saint Pierre and Kérity) and Larvor and Loctudy to obtain iodine and other chemicals.

Figure 3J.11. Les ramasseurs de varech by Howard Russell Butler, 1886 (Smithsonian Institution). Seaweeds gatherers in the area of Concarneau.

The sardine fishery appears to have started during the 17th century, prior to which hake and herring were fished. Sardines themselves appearing on the coast from the 16th century as a result of the warming temperature following the 'Little Ice Age'. Initially, sardines were dried in the same manner as used for the herring catch, but this changed and the technique of the sardine press was developed.

The rocks of the coastline have also been worked by human forces, the traces of which are still visible. The extraction of stone could be made as ripper, career (for Public Works), or simply recovery rock to make stone, rubble or metalling. These stones are used for local construction (house, harbor, church/chapel, cross, roads, plinths, etc.) or for export to other regions. These quarries are often sporadic in their distribution and made visible by many small excavations, sometimes revisited and then discontinued (Chauris, 2011: 49-51).

At the foreshore of Mousterlin (Fouesnant), a "barricade" and concreting has been put in place by the owners of the holiday homes to preserve the coastline in its existing location. This point was originally a low rocky plateau which was divided into two spits whose wings barred the lagoons. Some modern ideas allow for a 'freezing' of the coast in its present state, but it is sometimes completely changed visually and in its very structure. Such changes, as described for Mousterlin, to allow the nature of the coastline to be 'frozen' lead to subsequently to sedimentary changes (Guilcher, 1990: 36).

Another example is the coastal construction on Île Tudy, formerly accessible through a connection to the mainland at low tide via a *tombolo*, at the tip of Combrit. During high tides or storms, such *tombolo* could have large gaps thus isolating the island. A dam was then built in 1852 to remedy this isolation. Currently, only the pond at Kermor remains witness to such marine incursions (located behind the dam) (Chauris, 2011: 124-131).

From the mid-19th century, we can see the emergence of tourism in France, including Brittany (Clairay & Vincent, 2008: 202-204). This seaside and health tourism is initially seen in specific sites for the aristocracy, evolving over time to encompass all layers of society with the introduction of paid holidays in 1936. Such tourism brought with it various facilities such as pathways for walks, houses along the coastline and the various institutions and establishments related to enjoying the beach. Some cities without an existing port created structures for the tourist boom in the form of piers for walking along. Those who already had small ports inshore, sometimes faced trouble in adapting to the changing face of sailing, notably the increase in vessel size and as a result develop marinas to meet the tourist demand (Clairay & Vincent 2008: 226). This tourism is important in south Cornouailles, largely encouraged by the arrival of the railways and these shores will undergo various alterations, largely favoured by the absence of a law preventing the long construction and on the coast.

Finally, there has also been tourism development to the Glénan islands since 1880, although the islands are not really affected by the majority of construction. The archipelago has long been left to the fishermen (of fish, shellfish and crustaceans), as well as the seaweed farmers who are few in number (less than 200). They suffered little compared to the other islands of Brittany, although we can see a very important development on the Cigogne island.

Modern

Fishing, mainly for sardines, was a very successful activity, especially during the second half of the 19th century (Figure 3J.12). But, from 1902 a crisis affected all fishing ports of the south coast of Brittany, and particularly those of Bigouden. In the 1920s, this resulted in a significant exodus, with many people moving to urban areas for economic reasons. These are mainly concentrated on the coasts, which in turn brings greater urbanization and exploitation of coastal and maritime resource (INSEE).

Figure 3J.12. The sardines preserve factory Cassegrain at Saint-Guénolé-Penmarc'h in 1920 (source http://www.archinoe.net/cg85/visu_affiche.php?PHPSID=ea422277651823bb63b7b0b3b8da7343&param=visu&page=1)

The majority of sites from the 20th Century comprise WWI and WWII defence systems, most famously the Atlantic Wall built by the Germans in the 1940s. This included the blockhouse built at Saint -Jean- Trolimon in 1942, which is now on the foreshore at Tronoën due to the changed coastline. In the Bay of Audierne Penhors (Poudreuzic) a pebble bar of marine origin is located on the coast as far as Tronoën. This has a length of 12 km, a width of 100m, a height of 5m and has promoted the formation of tidal marshes for about 600,000 years. Stones from the bar were originally used in small quantities for traditional architectures. During WWII, the bar was exploited extensively by the Germans and an estimated one million tons of pebbles was collected in three years. Removal of pebbles continued to a lesser extent after the war and resulted in the disappearance of a large part of the coastal strip in conjunction with a rapid shoreline retreat of about 2m per annum, exacerbated by wind and wave action (Chauris, 2011: 151). The bar is no longer a natural barrier for the adjacent inland areas and quite violent storms can dramatically alter the shoreline (e.g. by 20 to 25m in late 1989/early 1990), leading to the implementation of beach replenishment schemes.

The building of the Atlantic Wall and post-war construction has also influenced the dune system in the same area (e.g. Saint-Jean-Trolimon), having been largely gutted by a large cavity just behind the shoreline. These formerly consisted of sand dunes that were still being deposited in the 17th/18th century but which have retreated as a result of construction work and related attack by the sea. Some of the WWII construction also provides an illustrative example of the coastal retreat in the Audierne bay (Figure 3J.13).

Figure 3J.13. La Torche Plomeur, WWII blockhouse in the beach, Finistère (doc. M. Monros).

3J.1.4 Art History of the Area

This section presents the background to artistic representations within the area including key artistic schools and individuals, allowing a broader consideration of individual artworks within the study area. The Cornouailles area itself is the privileged through the attraction of Brittany to painters and the area seems to have grouped and amplified the Breton pictorial phenomenon (Collective 1993). The coastal region of Southern Finistère (Pays Bigouden) has been quite often depicted by painters, a major source of inspiration for artists from all over the world and where the Pont-Aven School of painters was created in the nineteenth century. The art study area itself extends for a distance of 50 km as the crow flies, from Concarneau in the south to Audierne in the northwest. This distance is much greater (c. 150km) when directly following coastline and including the islands and estuaries.

3J.1.5 Art Resource Consulted for the Project

The main resources used for the paintings of the area are located in a variety of places; several local museums own paintings representing this study area, as well regional ones (Musée des Beaux arts de Brest, Musée départemental Breton de Quimper, Musée Bigouden in Pont L'Abbé) and galleries located in Paris or other towns.

Additionally, some illustrated books provided a wealth of paintings and watercolour drawings (Delouche 2003). The main source used here is the remarkable collective work published in 1993 "*La route des peintres en Cornouailles, 1850-1950*", which includes a general overview of the schools of painting and artists who worked in Cornouailles (Collective 1993) (Figure 3J.14).

One very important resource was the Joconde online database. The Culture ministry database "Joconde" is the gateway of museum and public gallery collections in France. The catalogue contains nearly 500,000 records of objects of any kind (archaeology, fine arts, ethnology, history, science and technology) enhanced by thematic journeys, zooms and virtual exhibitions. Joconde is the result of an ongoing partnership between the office of the digital broadcasting service collections of museums in France and the participating museums.

For this area, art approach drew upon existing academic work (Masters) led in the Rennes2 University by E. Motte (Motte 2013). The theme of the dissertation was: "*Representation and Evolution of the Shoreline: What can regional paintings teach us about the Breton coastal environment*?". In order to establish the art resource available for this study, it was necessary to review the topographical paintings, drawings and prints held by the principal national, region and local collections covering the case study area.

In addition, some pioneers of early photographic techniques represented numerous parts of this area; especially due to the development of tourism and the creation of some seaside resorts. Photographic postcards related to such activity produced many visual records of coastal touristic areas. For the photos, the main documentary sources were firstly the collection of old photographs from the collection of the former Laboratory of Anthropology of the University of Rennes1 (López-Romero and Daire, 2013) and, on the other hand, vintage postcards, many of which are available online.

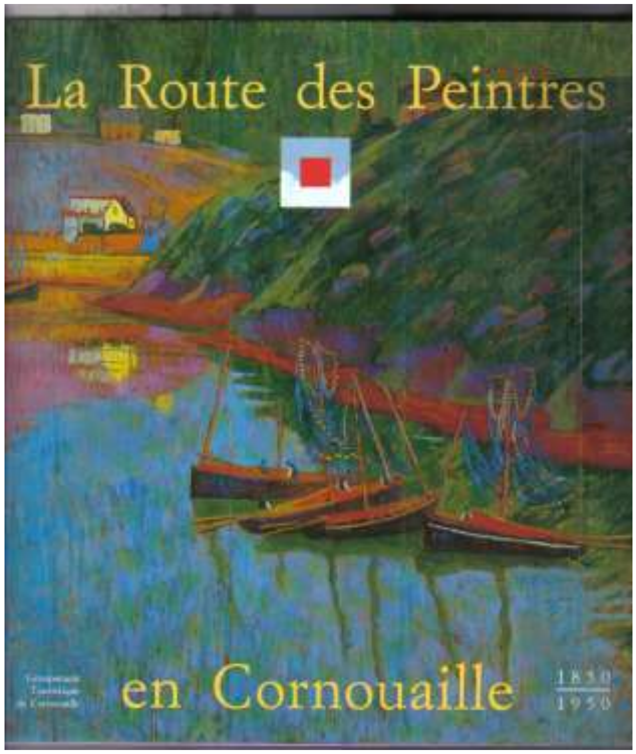

Figure 3J.14. Cover of the collective book "La route des peintres en Cornouailles, 1850-1950" (Collective, 1993)

3J.2. Current environmental impacts/threats and coastal management approach

This section considers the current environmental impacts and threats along the coastline and reviews the current coastal management issues and approaches.

3J.2.1 Review of key contributors to coastal change

Contributors to coastal change are common in various parts of Brittany and we will not revisit the elements presented in the previous sections related to the case study areas in Brittany, such as natural erosion, human activities, etc. But, some key factors are noted here, as specific to local contributions to coastal change:

- Exploitation of the pebble bar in the Bay of Audierne has caused a shoreline retreat that has been very notable since WWII. This is also the case with intensive farming of sand dunes located further inland.
- The intensification of coastal urbanization has increased (economic attractiveness) tourist pressure (mass tourism) resulting in coastal adaptation (see especially the southern part of the area, around the Odet estuary).
- Many activities (aquaculture, seaweed exploitation, biochemistry) require infrastructure and special operations, increasing the pressure on coastal zones.
- Significant weather events (storms, tides, waves, etc.) can cause temporary or permanent coastal retreat.
- Exploitation of aggregates can change the seabed.

All these processes and pressures lead to a change of the coastline (geomorphology) and natural habitats of wild fauna and flora.

3J.2.2 Summary of current coastal management approach

Coastal risk management is a responsibility of coastal local authorities in partnership with local associations for coastal defence. Through the shoreline management planning process the requirement for upgrading of coastal defences can be identified and a number of major projects have been undertaken along the Audierne bay, and more generally the Cornouailles coastal area. Such work has included the building of dykes in the southern area and dunes protection, in Audierne bay and Glénan archipelago. Coastal risk management falls within the overall framework of integrated coastal zone management, which has been actively developed along the study area coastline.

Figure 3J.15. Map showing the distribution of all the protection measures in the study area. (source Inventaire National du Patrimoine Naturel : http://inpn.mnhn.fr/carto/metropole/).

Many parts of the coast are protected by various organizations, which limits human impact on some areas (Figure 3J.15).

- As part of the Natura 2000 network (European Union, ratified by France in 1996, the Ministry of Ecology, National Inventory Mapping Natural Heritage), several sector within Cornouailles are protected: Glénan archipelago, Audierne Bay, Mousterlin marshes; Pont l'Abbé and Odet rivers, Penmarc'h rocky coast.
- The Conservatoire du Littoral owns a lot of lands in Cornouailles for example: some islands in the Glénan archipelago (Figure 3J.16).
- The National Nature Reserve of Saint-Nicolas Glénan was created in 1974 to protect one very rare endemic plant, the *Narcissus Glénans* (Natural Reserves France, Mapping the National Inventory of Natural Heritage).
- There are currently some biotope protection orders (applied in France since 1976, Ministry of Ecology, National Inventory Mapping Natural Heritage, the Environment Code) to the Moutons island (next to the Glénan archipelago) and Penmarc'h area, that allow "*preservation of habitats or other natural formations necessary for survival (breeding,*

feeding, resting and survival) of protected species on the list referred to in Article R 411-1 of the Environmental Code. Environment protection against activities that may affect their biological balance ".

- The Important Areas for the Conservation of Birds (European Union since 1979) The IBA which is a census of the most favourable areas for the conservation of wild birds; some of them concern the coast and islands in the Cornouailles area.
- The Conseil Général du Finistère has bought some areas in order to protect them and manage any natural heritage facing human pressure.

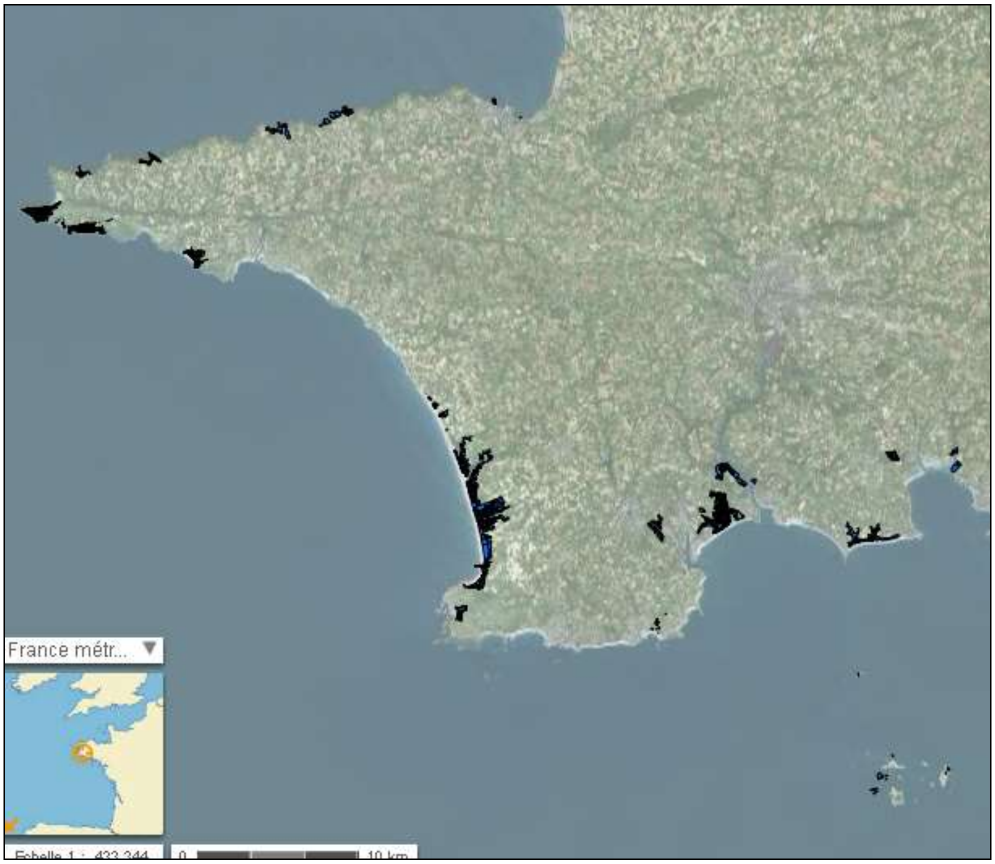

Figure 3J.16. Map showing the distribution of the areas own by the Conservatoire du Littoral in the study area. (source Géoportail).

3J.3 Ranking Artistic Depictions

The ranking systems developed for artworks, historic photographs, maps and sea charts were applied to each of the selected depictions, the results are described in more detail below.

3J.3.1 Art Ranking

The research undertaken selected seven exhibiting artists, among a large panel of artists having represented various landscapes of the area. The development of the ranking system has been described above. By entering the data on artwork type, medium, subject matter, time period and other parameters the database was then able to calculate the ranking scores for seven works of art from the case study site (Table 3J.1 and Figure 3J.17). Within the highest ranking artworks, in this area, artists tended to draw a precise depiction not only of the landscapes but also of the people and activities of the fields and the seashore. Among these artists, some of them illustrate coastal management and changes during the last decades:

- Gaston de Latenay (1859-1943) provided a representation of the Concarneau old harbour that has been deeply transformed during modern times.
- Lucien Simon (1861-1945) painted the chapel Notre-Dame de la Joie à Penmarc'h, which was located along the seaside; recently, a dike has been built in order to protect this area and prevent it from flooding.

A more detailed explanation of each site and the interpretation of the individual artworks is provided below.

ID No	Location	Artist	Date	Score type	Score style	Score enviro	Total Score
96	Chapelle de la Joie à Penmarc'h	Lucien Simon	1913	Oil	Topographical	Detailed view	66
121	Port de Concarneau	Gaston de Latenay	1859-1880	Fine pencil	Picturesque	General view	51
122	Arrivée du Pardon à Fouesnant	Théophile Louis Deyrolle	1881	Oil	Topographical	General view	44
264	Penmarch-Kerity	Charles-François Daubigny	1871	Oil	Picturesque	General view	40
265	Kerity Penmarch	Charle-François Daubigny	1867	Oil	Picturesque	General View	33
266	Chapelle Notre-Dame-de-la-Joie	Karl Daubigney	1846-1886	Oil	Picturesque	Detailed	48
267	Les Vanneuses	Karl Daubigney	1868	Oil	Genre subjects	Detailed	44

Table 3J1. Top art ranking results in the Cornouailles study area.

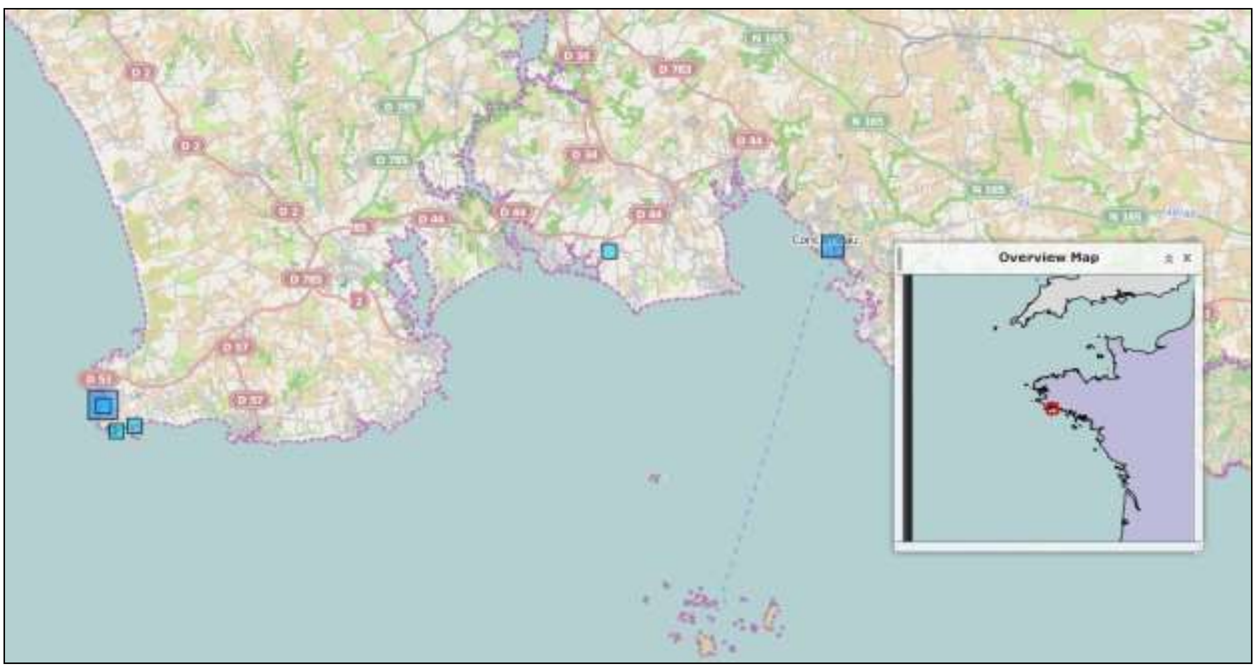

Figure 3J.17. Location of art images in the Cornouailles study area.

3J.3.2 Historic Photograph Ranking

Figure 3J.18. Location of historic photos in the Cornouailles study area

A total of 113 historic photos (Figure 3J.18) were assessed as part of the project, images were primarily chosen from locations along the coastline where historic paintings and archaeological sites were also known. The photographs were collected and then scored using the methodology outlined in the general section above. Hundreds of historic images exist for this stretch of coastline, it should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic photos to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums and galleries, as well as private collections has the potential to provide many more.

The Table 3J.2. below outlines the results of the ranking, note that photographs were scored as either a heritage view or a non-heritage view, see section above for details.

Img_uid	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
285	Menhir de Men Rouz (Plobannalec-Lesconil)	1900-1930	High		Good	100
293	Menhir de Men Rouz (Plobannalec-Lesconil)	2011	High		Good	100
354	Menhir de Lehan (Tréffiagat)	1922	High		Good	77
372	Menhir de Penglaouic (Pont-L'Abbé / Loctudy)	1922	High		Good	100
394	Nécropole de Saint-Saturnin (Plomeur)	1920-1924	High		Good	100
404	La plage de Conte (Plozévet)	1900-1925	High		Good	100
427	Ville Close (Concarneau)	1900-1930	Medium		Good	100
938	Pointe de la Torche (Plomeur)	1900-1908		High	Good	100
939	Notre Dame la Joie (Penmarch)	1900-1925	Medium		Good	55

942	Le sémaphore (Penmarch)	1896	Medium		Fair	66
962	Le Cap Coz (Fouesnant)	1900-1925		Medium	Good	100
972	Entrée de la Ville Close (Concarneau)	1900-1925	High		Good	100
989	La Roche Percée (Fouesnant)	1900-1925		High	Good	100
1189	Kerity Miln	1920	High		Good	55

Table 3J.2. Top photo ranking results in the Cornouailles study area.

The majority of photos assessed were of heritage views, containing features which can be identified today, the oldest photo assessed was taken in the late 19th century.

For the ranking table (Table 3J.2), we have selected high scoring photos (c. 100), generally of good quality and showing coastal changes, as compared with today's situation. For this area, 112 photos were available. Not a lot of sites were pictured by the protographers, but generally several photo exist for a given site, showing different views and angles. In such cases, the most representative photo has been selected.

A majority of these photos date from the first quarter of the 20th century, the most ancient dating from 1896. As this area was (and still is) very touristic, a lot of porstcards illustrate the land and the seascape. But, some areas were not pictured by photographers, for example the Glénan archipelago and this prevents us from comparison and evolution analysis in such areas. On the contrary, some areas encountered an early attractiveness and the iconic documentation gives an opportunity to study the landscape evolution: Concarneau fortified city, Bénodet (a seaside resort), Fouesnant, Cap Coz rocks, etc.

Scholars from Finistère provided us pictures highlighting the evolution of the coastline, through monuments: the Neolithic menhir of Lehan-Treffiagat is currently located in a swamp behind a dune coast; the Neolithic menhir of Penglaouic-Pont l'Abbé is regularly submerged at high tide; the Neolithic menhir Men Ruz (Plobannalec-Lesconil) which is submerged at high tide and now integrated into the port; the medieval necropolis of Saint-Saturnin Plomeur was buried under the dunes. Although not all of the photos have a precise geographic locations due to lack of visual clues, including; difficulty when the resumption of excavations by Giot (see above), to find the exact location.

We can follow a part of the evolution of the Notre-Dame-la-Joie Penmarch via photos and postcards. The first postcards, dated to the 1st quarter of the 20th century and we are presented with a beachfront chapel, with a little dam built made of rock and piled-up soil. One century later, we see a concrete dam, protruding from the ground.

3J.3.3 Maps/Charts Ranking

Several historical maps exist of the coastline, with some going back over 300 years (Figure 3J.19 and Table 3J.3). Eleven maps were assessed as part of the project using the methodology outlined in Section 2. It should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic maps and charts to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums, libraries and galleries, as well as private collections has the potential to provide many more. This could also be combined with the study of historic maps and charts where searches were carried out, for example in the Glénan archipelago.

Although the focus of this project was on the Cornouailles area, the majority of maps consulted depicted the whole of the southern Finistère department. These maps were only used in an illustrative purpose in this section. The majority of cards that we have at our disposal date from the 18th century, on which defensive points along the coast are highlighted (e.g. Concarneau). We could state the difficulty of properly representing the Glénan archipelago, because it has many rocks and islets. This problem is still present today, as the SHOM (Hydrographic and Oceanographic Service of the Navy) is struggling to establish an accurate map (including the number of islands) of the archipelago.

Figure 3J.19. Location of the maps assessed along the Cornouailles coastline.

MAP_uid	Title	Year	Score Chronometric Accuracy	Score Topographic Accuracy	Score Detail in non-coastal area	Score Geometric Accuracy
114	Carte particulière et topographique des isles de Glenans levée en aoust 1748	1748	73.33	16.66	66.66	83.33
115	Iles de Glénan	1771	73.33	33.33	33.33	66.66
65	Port de Lesconil	1863	6.66	50	66.66	83.33
107	Plan de Concarneau	1764	73.33	33.33	100	100
109	Plan de Concarneau	17th	20	19.44	66.66	66.66
113	Plan de Concarneau	1693	73.33	27.77	66.66	66.66
108	Carte particulière de la coste du sud de Bretagne dans la partie de Concarneau, pour faire voir le gissement des isles de Glenans	Un-known	73.33	20.83	33.33	66.66
66	Ile du Loch	1878	6.66	16.66	100	50
104	Anse de Bénodet et Odet	1771	73.33	33.33	33.33	83.33
105	Coste de Bretagne depuis Plouan et roches de Pennemark jusqu'à la baye	1764	73.33	33.33	33.33	83.33

	de la Forest					
143	Extrait de la Carte des Ingénieiurs Géographes du Roy	18th	0	33.33	66.66	50

Table 3J.3. Top ranking maps within the Cornouailles study area.

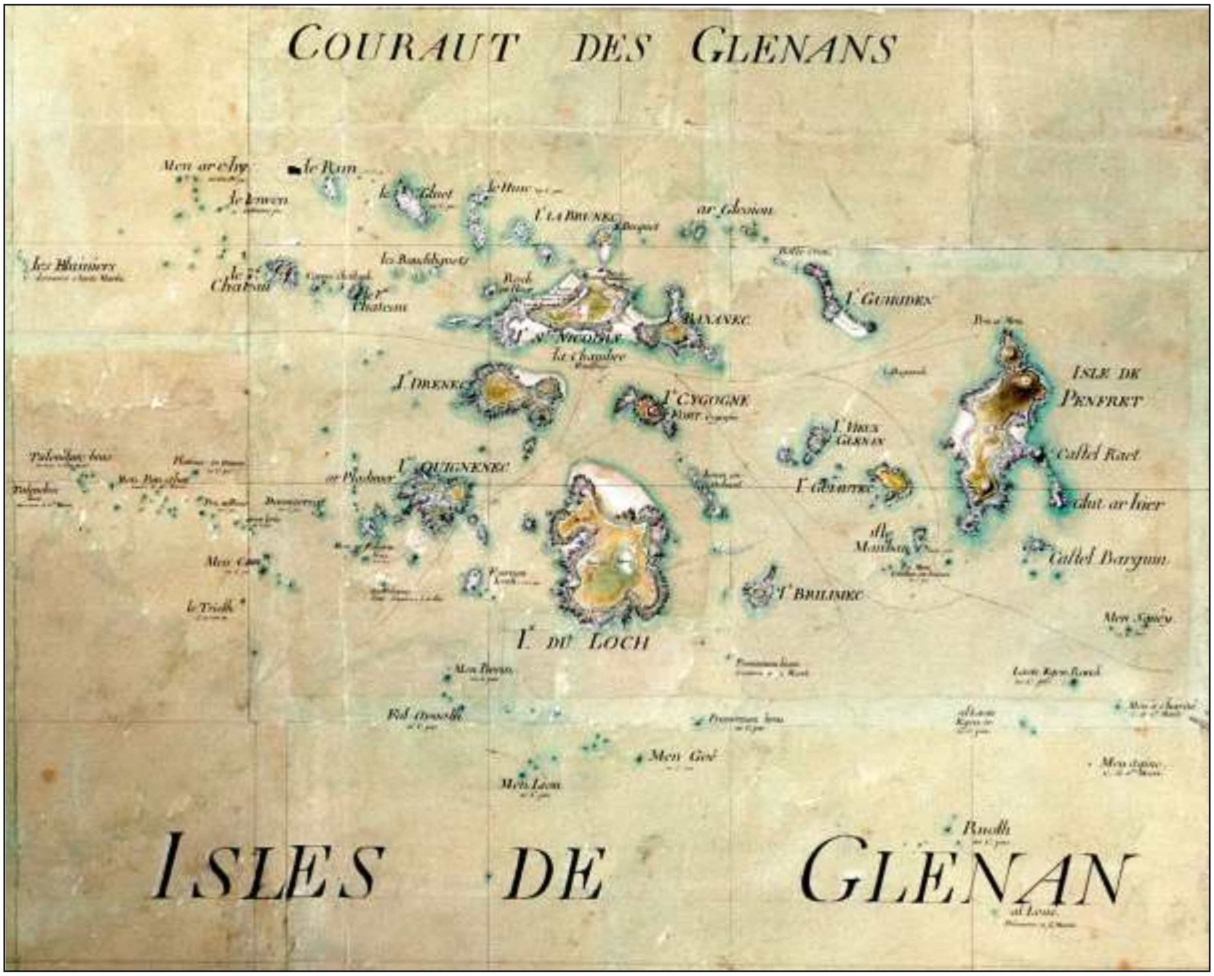

Figure 3J.20. Section of the 'Carte des ingénieurs Géographes du Roy' (18th century) featuring the Glénan archipelago (AMARAI archives).

Figure 3J.21. The Loc'h island, Glénan archipelago. (Left) Map 1878 (Archives départementales) (Right) Current aerial view (IGN Geoportail).

3J.4 Art and Field Research Studies

No dedicated archaeological and palaeoenvironmental fieldwork were carried out, within the framework of the Arch-Manche project, in the Cornouailles case study area, as the available documentation seemed to be numerous enough to develop some sites analysis. This section outlines the art research studies, demonstrating the relevance of research studies crossing pictures of different sorts (paintings, photos and maps). In addition to natural evolution, due to the touristic activity in this area, some parts of the coastline have been severely transformed during the last century. For example, in the Kerity-Penmarc'h area, as shown in the paintings of the great painters of the late 19th century and contemporary photographs, the coast, before the establishment of protection and constructions was really threatened by swell and storms.

3J.4.1 Key Research Questions

The research questions to be answered through the art representations, maps and photos concern:

- The visualization of coastal changes in selected area,
- The time scale and rhythms of the changes,
- The process and origins of the coastal transformation.

All these questions will contribute to a better understanding of the issues and help to propose solutions to the managers of the coastal areas.

3J.4.2 Approach to information gathering and fieldwork

Where it has been possible, fieldwork has been drawn (by E. Motte and M.Y. Daire) in order to assess the informative value of some paintings, maps and photos illustrating the coastal changes. Then, the following sites have been selected: the Kerity-Penmarc'h area (with several artworks and sites), the Loctudy village, and the Pont L'abbé river mouth.

3J.4.3. Art Field Data Gathering Results

J1. Kerity - Penmarc'h by Charles François Daubigny, 1871 (Figure 3J.22).

Location

The Kérity-Penmarc'h village is located in the Cornouaille area (Southern Finistère department), at the south western extremity of Brittany.

Why was the study site selected?
The site has been selected as it is one of the most exposed sites of the department; another point is that, as a touristic area, it has often been depicted by painters and photographers who left a great quantity of documentation nowadays available on various sources.

Geomorphologic setting
The geology of the area of Kerity-Penmarc'h is characterized by the presence of granite with very fine grains. On the whole area, the old Hercynian chain experienced a leveling phase which left two major sets of coasts: along the Bay of Audierne an impressive shingle bar that was intensively exploited for the construction of the Atlantic Wall during the WWII, and sandy dunes unfairly mined for construction.

Key coastal risk management issues for the frontage
These two formations, pebbles bar and dunes, are retreating under the onslaught of Atlantic swells, as evidenced by the position of German blockhouses which are now on the foreshore. However, human activities (quarries and construction) have also transformed the coastal landscape, until recently.

How the site can inform coastal risk management ?
The comparison between the Daubigny painting and present views (analysis carried out by E. Motte, 2013) shows that the shoreline has recently been protected by the construction of a dyke; some trees have been planted, probably in the aim of stabilizing the dunes. Nevertheless, some parts of the landscape have disappeared since the end of the 19th century, as well natural ones (rocks and dunes section) as private buildings.

Kerity-Penmarc’h village - Ranking score achieved: 40

Figure 3J.22. The Kerity village, by C.F. Daubigny (1871), analysis by E. motte (Motte, 2013).

J2. Kerity - Penmarc'h by Charles François Daubigny, 1867 (Figure 3J.23)

Location
Same as above.

Why was the study site selected?
Same as above.

Geomorphological setting
Same as above.

Key coastal risk management issues for the frontage
Same as above.

How the site can inform coastal risk management ?
Same as above.

Kerity-Penmarc'h village - Ranking score achieved: 33

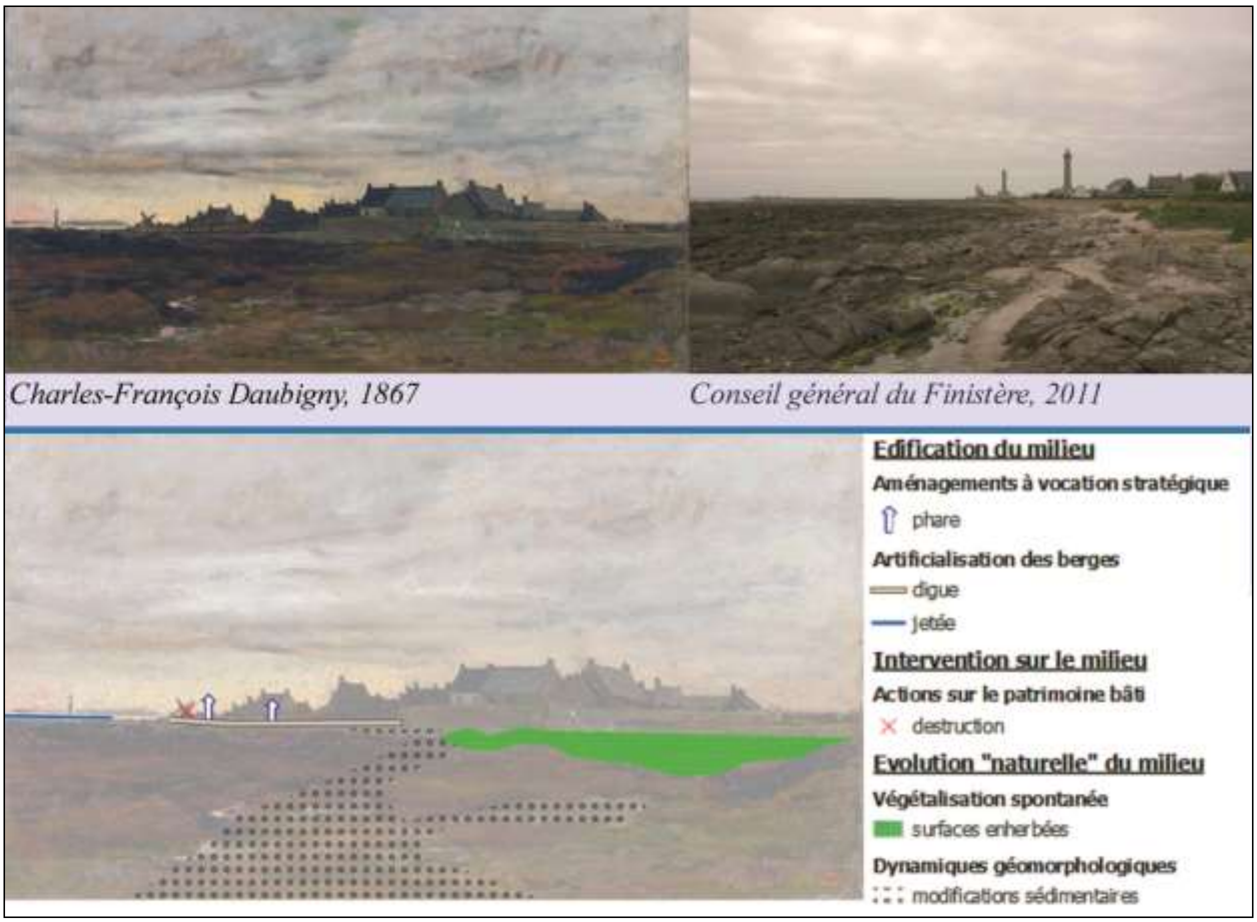

Figure 3J.23. Kerity - Penmarc'h by Charles François Daubigny, 1867, analysis by E. Motte (after Motte, 2013).

J3. Kerity - Penmarc'h miln, photo by Georges Chevalier, 1920 (Figure 3J.24).

Location

This mill is located in the Kérity-Penmarc'h village, in the Cornouaille area, at the south western extremity of Brittany.

Why was the study site selected?

The site has been selected as one old photo (early 20th century) was available in order to compare the coastal situation regarding the current one. This area has always been subject to important coastal changes through the centuries.

Geomorphological setting

The area corresponds to a flat coastal area.

Figure 3J.24. 'Kerity miln (Penmarc'h) (1) picture by Georges Chevalier, 26th of February 1920, (2) same area today (Source : panoramio.com) and (3) (© JLouis Guegaden, 2008 (source http://kbcpenmarch.franceserv.com/).

Key coastal risk management issues for the frontage

The key issue is to protect human installations and natural sites from erosion and sea submersion. The comparison between the ancient and recent photos also shows the evolution due to human pressure, as a modern road has replaced the sandy beach and landing port.

How the site can inform coastal risk management?

The small stone walls, visible on the photo n°1 (Figure 3J.24) reveals the poverty of local people as well as the low efficiency of such constructions which correspond to an attempt of protecting the land behind the shore.

Kerity-Penmarc'h miln - Ranking score achieved: 55

J4. Chapelle Notre-Dame-de-la-Joie by Charles François Daubigny or Karl Daubigny, late 19th century (Musée de Bretagne) (Figure 3J.25).

Location

Located between the port and the lighthouse of St-Gwénolé, the Kérity "Notre-Dame-de-la-Joie" chapel is one of the rare religious buildings settled along the immediate seashore, during the 15th century AD (Chauris, 2011).

Why was the study site selected?

The site has been selected as it is located next to the seashore and was subject to modifications illustrating risks and coastal management (see below).

Geomorphological setting

The geology of the area of Kerity-Penmarc'h is characterized by the presence of granite with very fine grains. On the whole area, the old Hercynian chain experienced a leveling phase which left two major sets of coasts: along the Bay of Audierne an impressive shingle bar that was intensively exploited for the construction of the Atlantic Wall during the WWII, and sandy dunes unfairly mined for construction.

Key coastal risk management issues for the frontage

The chapel was submerged by the sea in 1924. This monument is, for sailors and the local population, the symbol of the Virgin Mother protection facing every day life threats. A religious feast takes place there on the 15th of August (Chauris, 2011).

How the site can inform coastal risk management

As shown on the ancient post card and on the painting (n°1 & 3, Figure 3J.25), there was no physical protection until the 20th century, when a dike has been built all along the seashore. The dike is given to protect not only the chapel but all the buildings in the surrounding area from the submersion risk.

Chapelle Notre-Dame-de-la-Joie - Ranking score achieved: 48

Figure 3J.25. 'Chapel Notre-Dame-de-la-Joie , Kerity-Penmarc'h. (1) ancient post card (early 20th) century and (2 & 4) in 2012 (cl. M.Y. Daire), (3) painting by Karl Daubigney ? (Musée de Bretagne) (after Chauris 2011).

J5. Les vanneuses à Kérity by Karl Daubigny, 1868 (Musée des Beaux-Arts de Brest) (Figure 3J.26).

Location

The Kérity village stands along the immediate seashore, in the neighborhood of the Penmarc'h town.

Why was the study site selected?

The site has been selected as it is located next to the seashore and was subject to modifications illustrating risks and coastal management (see below).

Geomorphologic setting

The geology of the area of Kerity-Penmarc'h is characterized by the presence of granite with very fine grains. On the whole area, the old Hercynian chain experienced a leveling phase which left two major sets of coasts: along the Bay of Audierne an impressive shingle bar that was intensively exploited for the construction of the Atlantic Wall during the WWII, and sandy dunes unfairly mined for construction.

Key coastal risk management issues for the frontage

The painting insists on the vicinity of the seashore and the human installations and activities, such as seaweed collection and burning.

How the site can inform coastal risk management

As shown on the painting (Figure 3J.26), there was no physical protection until the 20th century, when a dike has been built all along the seashore.

Les vaneuse à Kérity - Ranking score achieved: 44

Figure 3J.26. Les vanneuses à Kérity by Karl Daubigny 1868 (Musée des beaux-arts de Brest, source: http://fr.wikipedia.org/wiki/Pays_Bigouden

J6. The Penglaouic prehistoric standing stone, Pont L'Abbé River (photo by A. Devoir) (Figure 3J.27).

Location

The standing stone is currently located in the mouth of the Pont L'Abbé River (Southern Finistère), in the tidal belt.

Why was the study site selected?

This monument/area was selected because it clearly illustrates the Holocene sea level rise. On the photo n°1 Figure 3J.27, the menhir appears partly submerged at high tide and the n°2 shows the marks of the repeated submersion of the standing stone.

Geomorphological setting

The geomophological setting is the mouth of the Pont L'Abbé River, which is a kind of ria under the influence of the maritime tides.

Key coastal risk management issues

The menhir appears here as an archaeological evidence of the sea level rise and coastal change in this area, as we can state that since it was erected, the shore has been the subject of a an important retreat. Currently, we can observe an increase of the sediment deposit in the river mouth, which progressively hides the base of the standing stone.

How can the sites inform coastal risk management?

The mudflats of the Pont l'Abbé River, that are part of the public maritime domain and straddle the communes of Pont l'Abbé and Loctudy, consisting of mudflats and marshes are an ZNIEFF (Zone naturelle d'intérêt écologique, faunistique et floristique) (Natural Area of ecological interest, flora and fauna) of 208 ha. hunting and wildlife reserve, especially a wintering area for many species of birds.

The Penglaouic standing stone: 100

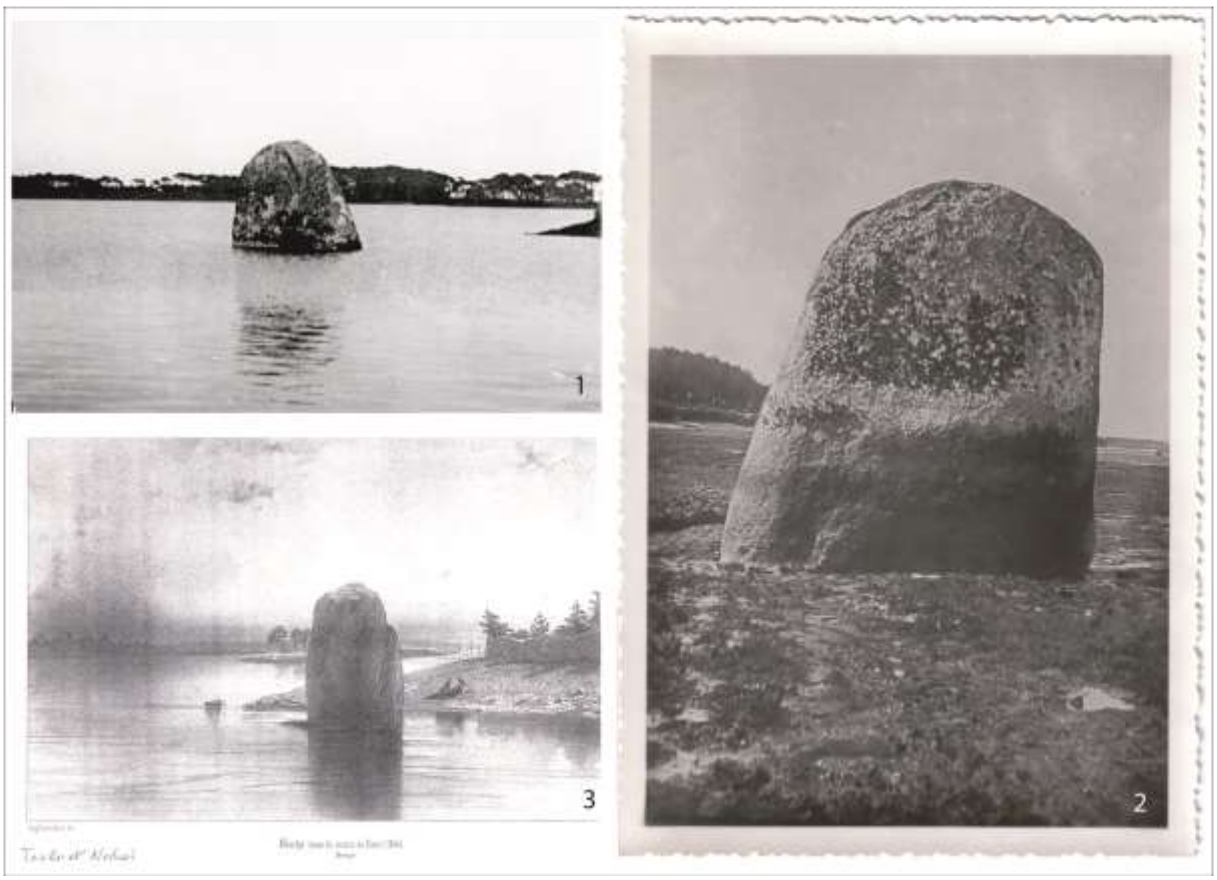

Figure 3J.27. The Penglaouic standing stone, Pont L'Abbé river mouth (Finistère) (1) photo by A. Devoir (c. 1910), (2) by P.R. Giot (c. 1960), (3) after Taylor & Nodier ((© Labo Archéosciences UMR 6566 CReAAH).

3J.5 Analysis

The Cornouaille area study has combined the use of archaeological and palaeoenvironmental data, paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve our understanding of coastal change in the long and short term. The archaeology and palaeoenvironmental data provides evidence of coastal changes mainly at the pluri-millennial scale, i.e. the scale of the Holocene period, as the Palaelolithic sites are scarcely represented in this area, except by the exceptional cave site of Menez Dregan. The medium and short scale changes are especially evidenced, in this zone, by painters and photographers. Some documents constitute an illustrative witness of a former state of the coasts.

3J.5.1 Archaeology and Heritage Features

As described in section above, the archaeological assessment focussed on the vulnerability of soft rocks, coasts and dunes of the Cornouailles area. Submerged deposits have been registered in the area, such as peat layers, sometimes showing some ancient traces of ploughing that could be dated back to the metal ages (Giot *et al*., 1982).

Although much work has been carried out on reconstructing the coastline from the medieval period, further work is required to understand the rate and scale of coastal change from the Palaeolithic. To this end, in the northern part of the study area, the Menez Dregan grotto, which was excavated in 1996, provides new data on one of the most ancient occupation of Western France (Monnier *et al*., 1991); if the site is nowadays located at the foot of a cliff exposed to marine waves, its human prehistoric occupation corresponds to a continental one, on the border of a large plain favourable to the observation and hunting of big mammals.

It is also interesting to note that a number of the archaeological sites which have significant potential for holding data to inform on coastal change are themselves likely to be lost through continuing erosion of the coast, especially the tidal megalithic monuments and the archaeological sites located behind the sandy dunes levels. A good illustration is provided by the small stone cists burials generally discovered on the beaches of southern Finistère after the winter storms. The constant erosion of these sites (see the ALeRT project assessment) highlights the need to gather data from those high and medium scored sites to capitalise on this information before it is lost.

Concerning more precisely the palaeoenvironmental approach, we can mention the discovery of ancient forests in the bay of Concarneau (Delanoë & Pinot, 1977). During pre flandrian regression, rivers were running across Concarneau Bay towards the south-east. Holocene transgression came through the main valley into the pre-littoral depression, where it built pro-estuarine accumulations at several levels, in front of the river mouths, and coastal spits, namely 47m, 37m and 27m below similar forms seen today. The relations between these forms and the alluvial terraces make it possible to find some correlations between the climatic characteristics of the streams and the major sea-level stands. When the sea level was about 37 m below the present one, alluvial sheets of coarse materials have been deposited in wide divagating valleys. In a later stage, when it reached 23m below the present level, rivers have cut narrow valleys into these coarse deposits. The coring studies gave also data concerning the coastal evolution during the Holocène. Some of these forests of the Concarneau bay regularly re-appear after winter storms and are subject to new studies and analyses (by V. Bernard, UMR 6566 CReAAH, and E. Werthe, Phd in progress). The oak trees of the Sables Blancs beach have been dated back to the Néolithic period (- 5000 BP) (Figure 3J.28).

Figure 3J.28. The Neolithic tidal forest (oak trees) of the Concarneau beach, as it could be recently seen (19/02/2014). Source: http://www.letelegramme.fr/img/diaporamas/CONCARNEAULAFORETFOS-20140219/PHO05.jpg

3J.5.2 Artistic Depictions

Following the research and location of a large number of artistic images of the study area coastline it was possible to rank their relative importance in terms of their value in informing on long-term coastal change. The art case study area was extensive in the Kerity Penmarc'h area, as many painters represented the coastal activities and sites in this area.

Concerning the regional artistic depiction, the story of this area is dominated by the painting school names "Ecole de Pont Aven". Lower Brittany had indeed become a trendy area, the "Bretonneries" selling well at the Salon of French artists, the area became a favorite destination for painters. Attracted by a rural civilization still intact, the small town of Pont-Aven and the surrounding countryside were a source of inspiration. From the summer of 1866, a dozen artists, most of them being American or English are present at Pont-Aven. In 1880, a second wave of artists frequented Pont-Aven, which became the "new Barbizon", there are forty artists, English or American landscape painters, and painters from northern Europe such as Denmark (Collectif, 2003). As they often painted the coastal areas, it has been possible to compare these detailed views with the current ones, in order to assess local coastal change. In addition, several historic photographs and maps were also assessed, which provided helpful information, especially regarding the coastal and tidal megalithic monuments providing well dated benchmarks for the coastal evolution.

3J.5.3 Combined Resources

As demonstrated above, several megalithic monuments of the case study area illustrate the coastal changes and the sea level rise. The following image (Figure 3J.29) shows another standing stone, located in the port of Lesconil. This site is very interesting as it shows a combination of natural evolution of the site and human transformation.

As for the Pengalouic menhir (see above), the early 20th century photos (n°1 & 2 Figure 3J.29) show a standing stone (dating back to Neolithic or Bronze Age) located in the small port of Lesconil (southern Finistère). The standing stone was, in that time, regularly submerged while high tide. We have recently tried to re-examine this monument and it appeared very difficult to find it back, as the Lesconil port was severely transformed during the second half of the 20th century (Figure 3J.30).

Figure 3J.29. Combined document used for the analysis of the coastal change in the Lesconil port (Finistère, Cornouaille). (1) View of the standing stone, early 20th century (© Labo Archéosciences UMR 6566 CReAAH).(2) Location on the Etat major map (19th century),

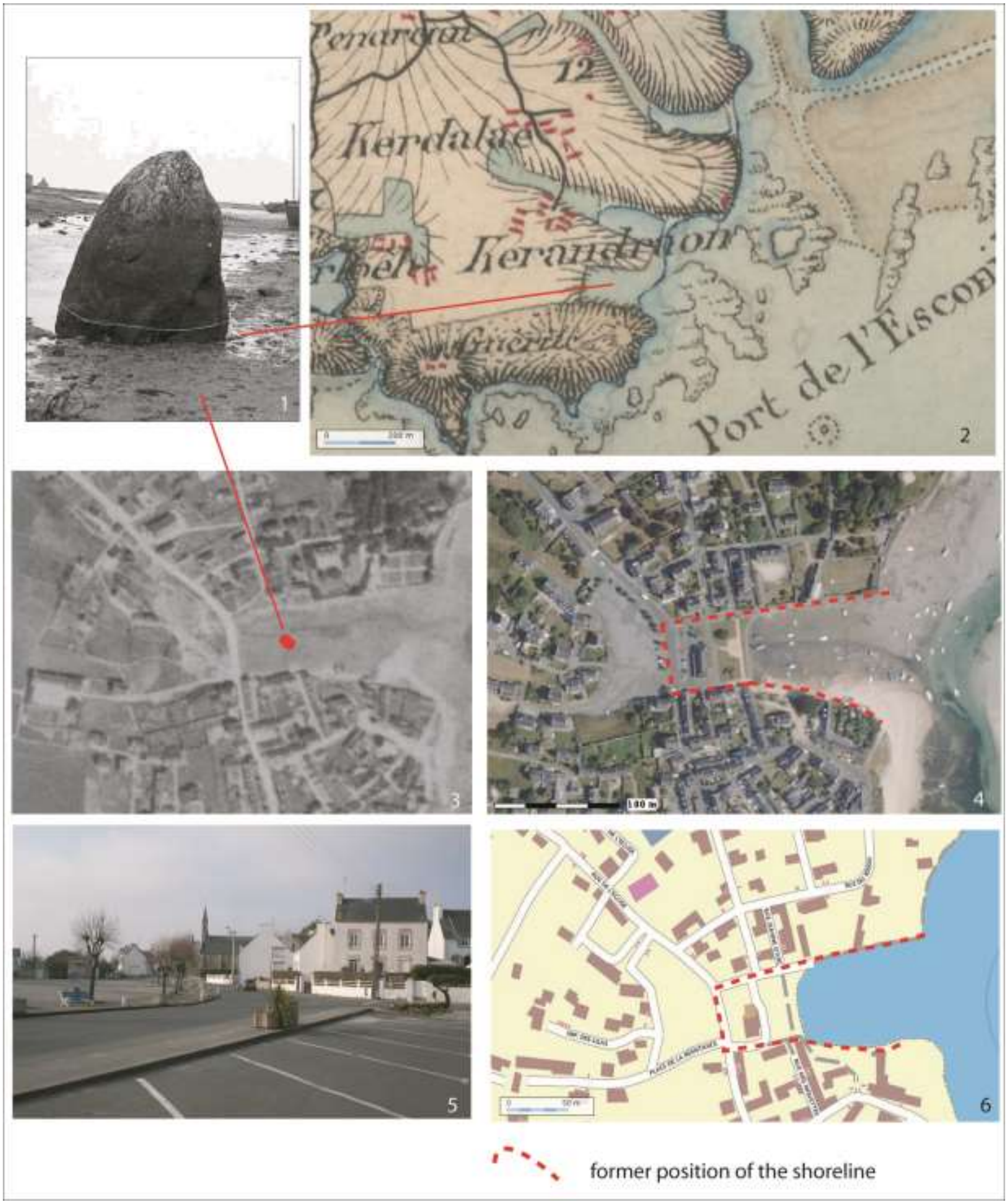

Figure 3J.30. Combined document used for the analysis of the coastal change in the Lesconil port (Finistère, Cornouaille). (1) View of the standing stone, early 20th century (© Labo Archéosciences UMR 6566 CReAAH).(2) Location on the Etat major map (19th century), (3) IGN aerial view 1952, (4) IGN aerial view 2006, (5) Current view of the filled in area (cl. by M.Y. Daire), (6) IGN map 2006.

The study of aerial photos of various periods (since 1952 to 2006) (n°2 & 3, Figure 3J.30) indicate that land has been reclaimed in the area where the menhir was standing, in order to build a car park and a new post-office (n°4 & 5, Figure 3J.30). The menhir was then included in the new wall surrounding the port, and is currently only partly visible in the construction (n°3 & 4, Figure 3J.30). The small river which was ending in the bay and port has been either covered or canalised in a drain.

Combining the documentation on the Lesconil monument allows us to retrace the ancient and more recent evolution of the shore line at a local scale, but gives also a good indication of the consequences of the coastal management by authorities. This is a good illustration of submersion risk in link with the submersion by the sea as well as the human pressure on settled coastal areas.

Figure 3J.31. Combined document used for the analysis of the coastal change in the Lesconil port (Finistère, Cornouaille). (1) IGN aerial view 1952, (2) IGN aerial view 2006, (5) Current view of the filled in area (cl. by M.Y. Daire), (6) IGN map 2006.

3J.6. Conclusions and Recommendations

In the Cornouailles case study area, the vulnerability of the soft coasts has been assessed through several examples, demonstrating how fast changes can occur, especially during winter storms. This phenomenon combines with the long term erosive process. Nowadays, due to the sea level rise, some low areas (such as the Islands of Sein and Glénan archipelago) are really threatened with inundation.

The Sein island has an area of only 0.5 km² and is low-lying, its average height being only 1.5 meters. It was several times almost overwhelmed by storms with those of 1830, 1868 and 1897 being marked by their extraordinary power; old people remember ancient generations who went to take refuge on rooftops to avoid being swept away. In the bay of Audierne, the sandy dunes are subject of special attention from coastal managers, one part of them being protected and belonging to the Conservatoire du Littoral. These dunes are, in essence, mobile and extremely fragile coastal changing formations, threatened both by climate events faced by the human action (Guilcher & Hallegouët, 1991).

There is then an emergency in registering the natural and cultural heritage of all these threatened sites, as the physical protections could only slow the process but not really prevent the damage. Concerning the protection of natural sites, the prefectural authority fixed measures relating to the conservation of a particular biological environment necessary for feeding, breeding or resting some endangered species. These orders can protect dunes, marshes, coastal heath land. Such protection is a little bit extended and exploited by human space. The problem is that they are limited in time.

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3J.7 Case Study References

Batt M., Giot P.-R., 1980. Quelques observations d'archéologie du paysage en Finistère, *Bulletin de la Société Archéologique du Finistère*, t. CVIII,: 17-25.

Bechennec, F., Guennoc, P., Guerrot, C., Lebret, P., Thieblemont, D., avec la coll. de Carn, A., Delanoë, Y., Giot, P.R., Hallegouët, B., Le Meur, S., Monnier, J.L, Morzadec, H. 1996. *Notice explicative, carte géologique France (1/50 000), feuille Concarneau (382)*. Orléans, BRGM, 129p.

Bénard Le Pontois C., Favret P.M., Boisselier G. 1919*. Importance archéologique de la presqu'île de la Torche, Penmarc'h, Finistère*, Quimper, Jaouen, 1919.

Bénard Le Pontois Ch., 1929. *Le Finistère préhistorique*. Publications de l'Institut International d'Anthropologie, n° 3. Librairie E. Noury, Paris.

Chauris, L. 2011. *Pays Bigouden : des pierres et des hommes. Impacts du sous-sol dans le bâti d'un territoire cornouaillais*. Ed. Skol Vreizh, Morlaix, 160p.

Clairay, P. et Vincent, J. 2008. Le développement balnéaire breton : une histoire originale. *In Annales de Bretagne et des Pays de l'Ouest*, 115-4: 201-233.

Collective 1993. *La route des peintres en Cornouailles*, 1850-1950. Groupement touristique de Cornouailles publisher, 130 p.

Collectif 2002. *Notice explicative, car géologique France (1/50 000), feuille Pont-Croix (345)*. Orléans, BRGM, 49 p.

Daire M.Y., Hamon G. (eds), 2013. *L'Île aux Moutons (Fouesnant, Finistère), Un établissement gaulois dans son contexte atlantique. Etude pluridisciplinaire*. Les Dossiers du Ce.R.A.A., supplément n°AJ, 234 p.

Delanoë Y., Pinot J. P., 1977. Littoraux et vallées holocènes submergés en Baie de Concarneau (Bretagne méridionale). In Bulletin de l'Association française pour l'étude du quaternaire - Volume 14 - Numéro 3 - 1977. pp. 27-38. doi : 10.3406/quate.1977.1309 http://www.persee.fr/web/revues/home/prescript/article/quate_0004-5500_1977_num_14_3_1309

Dupont C., 2003. Les coquillages alimentaires des dépôts et amas coquilliers du Mésolithique récent/final de la façade atlantique de la France », *Préhistoires Méditerranéennes*, 12 | 2003: 221-238.

Galliou P. 2010. *Carte archéologique de la Gaule. Le Finistère*. Ed. Académie des Inscriptions et Belles Lettres, Ministère de l'Education Nationale, Ministère de la Recherche, Ministère de la Culture et de la Communication, Maison des Sciences et des Hommes, Paris, 495p.

Giot P.R. 1947. Le tumulus mégalithique de Beg-an-Dorchenn en Plomeur (Finistère), *Gallia*, 5: 167-170.

Giot P.-R., Batt M., Morzadec M.-T., 1982. *Archéologie du paysage agraire armoricain,* éd. Travaux du Laboratoire d'Anthropologie de l'Université de Rennes 1, Rennes, 76 p.

Giot, P.-R. & Monnier, J.-L. 1977. Le cimetière des anciens Bretons de Saint-Urnel ou Saint-Saturnin en Plomeur (Finistère). *Gallia*, 35-1: 141-171.

Giot, P.-R. et Morzadec, H. 1992. Des dolmens à couloir au péril des mers actuelles», *Revue Archéologique de l'Ouest* 9: 57-66.

Giot P.-R., Briard J., Pape L., 1995. *Protohistoire de la Bretagne,* Ouest France éd., Rennes, 423 p.

Giot P.R., Monnier J.L., L'Helgouac'h 1998. *Préhistoire de la Bretagne*, Ouest France éd., Rennes, 452 p.

Guilcher, A. 1990. Sur le recul actuel des rivages meubles de la Bretagne de l'Ouest. *In Revue Archéologique de l'Ouest. La Bretagne et l'Europe Préhistoriques, mémoire en hommage à Pierre-Roland Giot*, sup. 2: 31-36.

Henaff, A., Michard, B., Le Visage C. 2007. Erosion côtière : c'est la nature qui commande. http://www.bretagne-environnement.org/Mer-littoral/Les-menaces/L-erosion-cotiere/Erosion-cotiere-c-est-la-nature-qui-commande.

Guilcher A., Hallégouët B., 1991. Coastal dunes in Brittany and their management. *Journal of Coastal Research,* vol. 7, n° 2, p. 517-533.

Hénaff A., Bodéré J.-C., Lageat Y., 2002. Érosion côtière et vulnérabilité du trait de côte en Bretagne, rapport annuel, année 1, *Rapport PRIRE*, LETG-Géolittomer-Brest, 29 p.

Jonin, M. 2010. *Géotourisme en Finistère, petit guide géologique pour tous*. Biotope, Mèze – Muséum National d'Histoire Naturelle, Paris (col. Géotourisme), 96 p.

López-Romero E., Daire M.Y., 2013. The ICARE project: an insight into the formation and consolidation of archaeology in western France (ca. 1850-1990). *Bulletin of the History of Archaeology* 23(1):3, 1-11. DOI: http://dx.doi.org/10.5334/bha.2313

Monnier, J.-L., Hallégouët, B., Hinguant, S., Van Vliet-Lanoe, B., Falguères, Ch., Laurent, M., Bahain, J.-J., Marguerie, D., Mercier, N., Geigl, E. et Molines, N. 1996. Menez Dregan (Plouhinec, Finistère) et le Paléolithique inférieur à l'ouest de la France, in: *Actes du XIIIe Congrès UISPP*, Facchini, F., Palma di Cesnola, A., Piperno, M. et Peretto, C., (Éds.), Forlì, ABACO éd., vol. 2 - Lower and Middle Palaeolithic: 99-108.

Motte, E. 2013. *Représentations et évolutions du littoral en Bretagne*. Mémoire de Master 2 soutenu à l'Université Rennes 2, département de Géographie, 23p.

CASE STUDY 3K - QUIBERON PENINSULA and MORBIHAN, FR. (Brittany)

Case Study Area: Quiberon peninsula and Morbihan, FR (Brittany)

Main geomorphological types: Rocky cliffs, sandy beaches, dunes, islands and estuaries.

Main Coastal Change Processes: Coastal erosion, cliff instability, beach change.

Primary resources used: Archaeology, palaeoenvironment, art, photography.

Summary: The study area contains diverse landscapes: cliffl ines, sandy dunes and beaches which are subject to erosion and instability, and numerous islands corresponding to former hills separated from the continent by Holocene sea level rise. Archaeological and palaeoenvironmental records have enabled us to see the rate and scale of this erosion over the last millenniums.

Recommendations: Coastal managers should use these resources when predicting future rates of erosion in this area, particularly where one of the main natural features - dunes and sandy bars, are so vulnerable to coastal erosion. An agreement between the various management policies is recommended, in order to define priorities within a global landscape strategy, and to combine policies on this territory, which due to its extent and diversity is highly complex (Cavalie, 2001).

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

Quiberon peninsula and Morbihan is one of four case study areas within the Brittany area of France. The area has been extended to include a large part of the Morbihan region in order to consider artistic resources including maps, charts and photographs, in a wider landscape context. This case study report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented along with the results of the art study. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. Further details about the project methodology can be found in Section 2.

Within the Quiberon peninsula area, the archaeological and palaeoenvironmental resource and the available art resource have been researched, ranked and analysed. The extents of the detailed study areas are shown in Figure 3K1 below. The area considered for archaeology and palaeoenvironment has been selected to provide a representative range of types of evidence across a range of periods spanning from the Palaeolithic through to more modern coastal heritage. The art, photograph and map case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time.

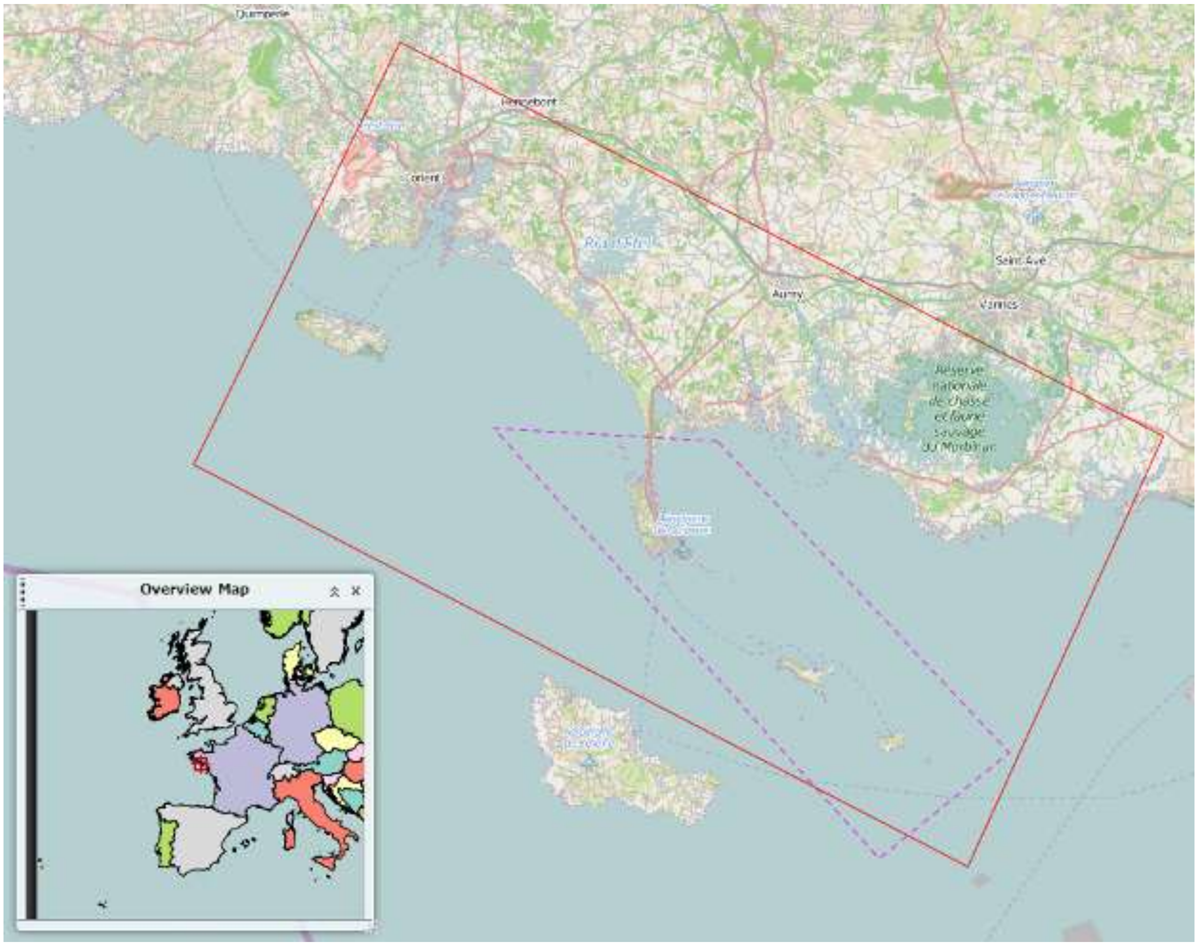

Figure 3K1. Map of the Quiberon peninsula and Morbihan study areas. The dotted line represents the extent of the archaeological and palaeoenvironmental research and the red line represents the extent of the art study area.

3K.1 Introduction to the Quiberon Peninsula Study Area

Located in the Morbihan department, the Quiberon peninsula is linked to the mainland at the southern coast of Brittany. This cape, orientated north-south, represents two very different coastal facades: one facing west is very exposed to wind and swell, with a wild landscape marked by a large number of archaeological sites of great importance. The eastern coast is much more protected and is now densely settled, while the southern part is the most touristic, containing the starting point of cruises and ferries to the islands (Belle-île-en-Mer, Houat and Hoedic).

This means that coastal engineers along the Quiberon peninsula have to manage with very different issues, some of them originated from natural risks and others being linked to seasonal human pressure (Figure 3K2). In recent centuries and decades the most common response to the protection of property and assets has been the construction of coastal sea walls and flood defences.

In this case study area, we will demonstrate the informative value of the archaeological and palaeoenvironmental studies, particularly the work carried out at the Beg-er-Vil Mesolithic site and the ancient fish weirs located in the southern part of the peninsula. Thanks to the huge amount of scientific documentation collected, the issues of coastal management will be thoroughly analysed as well as the efficiency and the sustainability of the current solutions.

3K.1.1 Geomorphology of the Area

This section outlines the key geological and geomorphological features and processes of the study area. These factors have a significant impact on the on-going changes to the coast and associated sites, deposits and features preserved relating to the archaeological and heritage resource, in addition to being depicted through a range of artistic resources.

Figure 3K2. Various features of the Quiberon peninsula coastal landscapes (top: Western "Côte sauvage", bottom: the protected Eastern coast) (after http://www.atlasdespaysages-morbihan.fr).

The rocky cape of the Quiberon peninsula advances 14km into the sea, and is in fact an ancient island connected to the continent by a sand bar. At its narrowest point, at L'Isthme de Penthièvre, the peninsula measures less than 100 meters across. To the west, facing the Atlantic Ocean, the 'Côte Sauvage' area contains a remarkable wild landscape of indented cliffs, while the eastern coast facing the bay, is protected from the predominant winds and is densely settled and visited by tourists.

Geological History

The Quiberon peninsula is a granite unit, belonging to a series of topographic high points, slightly parallel to the continental coast of Morbihan. This alignment is an inheritance of the hercynian structures, comprising the Groix island and the Glénan archipelago to the North and the Houat and Hoedic islands to the South (Audren *et al*. 2003, Lardeux 1996, Menier 2004). The peninsula and the islands mentioned above contrast with the Belle-Île island, which is of micaschist substratum (Figure 3K3).

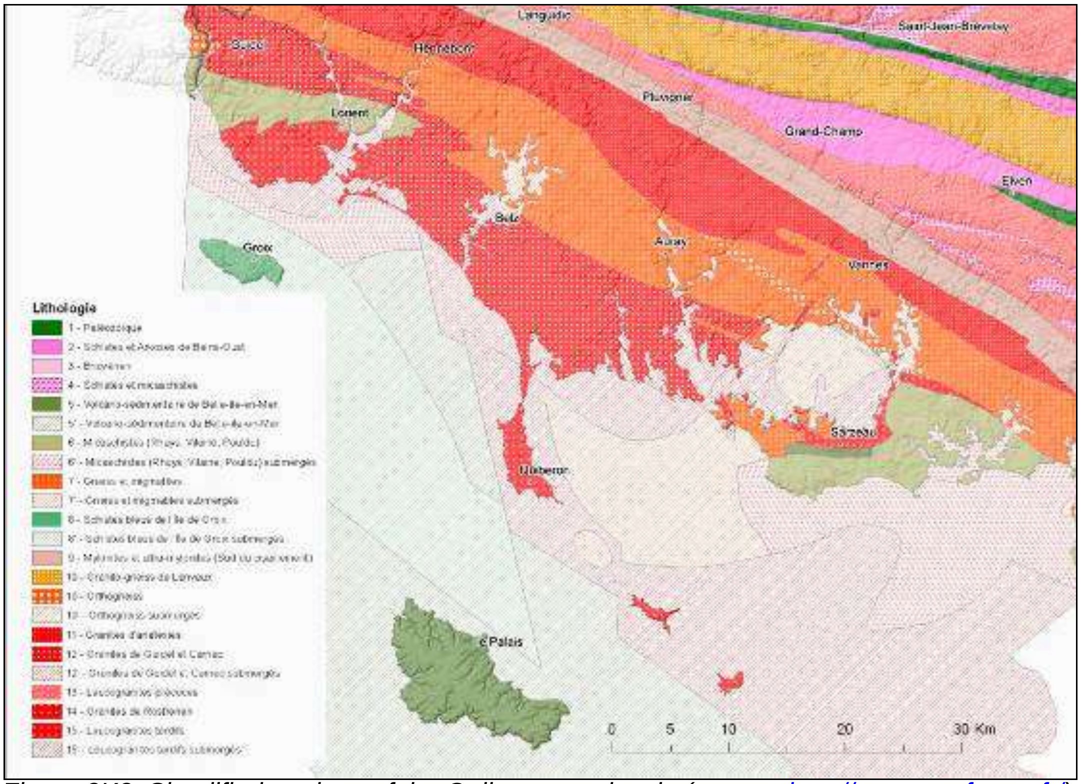

Figure 3K3. Simplified geology of the Quiberon peninsula (source: http://www.geoforum.fr/).

Geomorphologic Processes and Human Intervention

Located in the department of Morbihan, the coastline between the Gâvres peninsula south of Lorient and the Quiberon peninsula is representative of the largest wilderness coastline in Brittany. It covers nearly 2,500 ha, with almost 35 km of continuous natural shoreline. The wild coastline of the Quiberon peninsula is of international importance and includes the huge cordon dune stretching 25km to Lorient. The main feature of this large site lies in its unique geomorphologic unit: either end, two granite peninsulas are attached to the Continent by two large "tombolos" dunes which are interrupted by the mouth of the river Etel. This geomorphologic symmetry results at the landscape level in a contrast between rocky coasts and large dune arcs (Audren *et al.,* 2003).

The changing position of the shoreline due to sea level variations inferred that Quiberon was sometimes an island and sometimes a peninsula linked to the mainland by a sandy bar. Nowadays, with the current sea level rise (about 1,5 mm/year), the Gâvres – Étel –Penthièvre sandy bar is retreating. This phenomenon can be observed at Penthièvre, where the *tombolo* becomes very narrow and is currently limited to the cumulated width of the road and the railway.

This narrow stretch, called L'Isthme de Pentièvre, would have disappeared without human intervention and coastal management, consisting of the building of embankments and sea walls along the most exposed areas (Bournérias & Pomerol 1999). In some locations efforts have been made to stabilize the sand dunes.

Several reconstructions of the palaeolandscape evolution in the area have been proposed and synthesized by Le Pessec (2011) (Figure 3K4 & 5). As well as this, several hypotheses and chronologies exist concerning the periods of separation of the Quiberon Island from the mainland. These opinions are generally based on various observations of the northern sandy narrow and its evolution due to the marine streams and wind orientation (Le Pessec 2011) (Figure 3K5).

Concerning human intervention, the coast of Quiberon is relatively well served by a network of pathways and roads. The coastal road from the western coast gives access to the granite cliffs. As mentioned earlier Quiberon contains two very opposite landscapes, the first is the so called ‘Wild Coast’ ('Côte Sauvage'). Its aesthetic and cultural qualities have been recognized for over a century as it contains spectacular view points, especially during storms, and attracts crowds of tourists. The second feature, lesser known is composed of dune arcs, remarkable by their size and barren nature, quite a typical landscape in the country. Beyond these geographical and ecological aspects, the military past of the area creates a special atmosphere. Indeed, these landscapes also have a common military history, illustrated by the Chouannerie museum and Fort Penthièvre, and later by the large amount of WWII bunkers scattered throughout the coast.

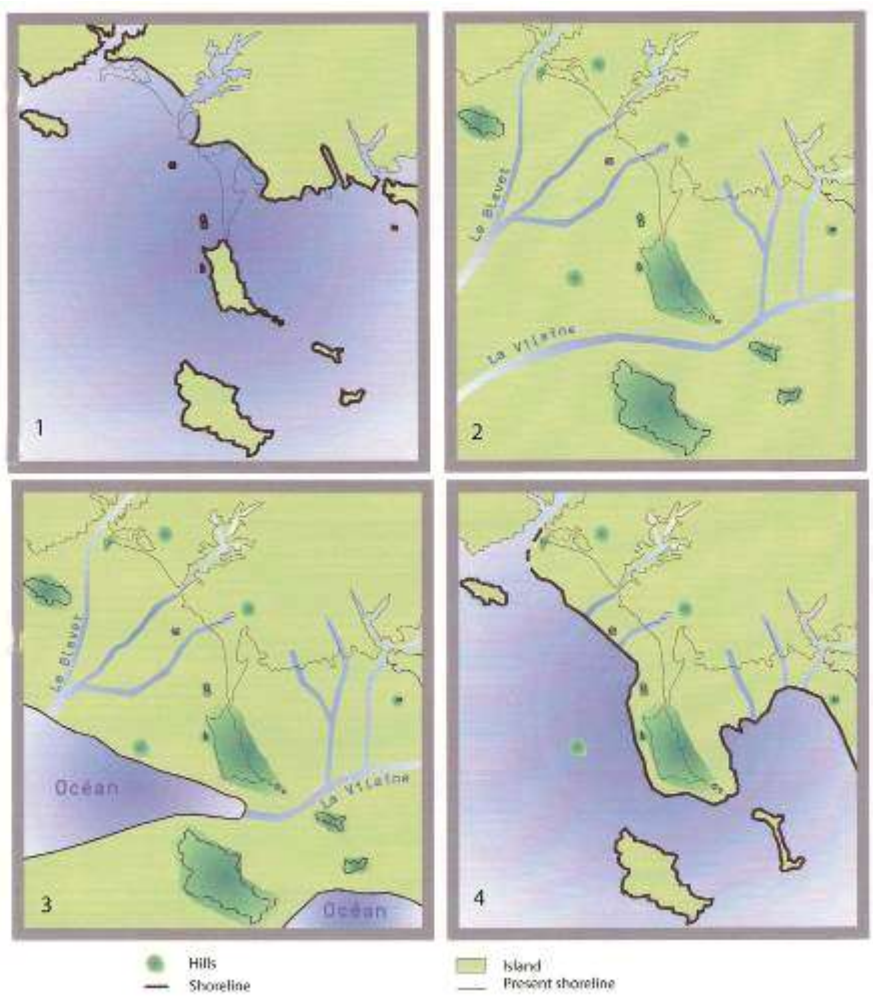

Figure 3K4. Palaeo reconstruction of the Morbihan and Quiberon peninsula environment (map by D. Allaire, after Le Pessec, 2011). (1) From 135.000 to 115.000, (2) From 115.000 to 18.000, (3) c. 9.000 BC, (4) c. 6.000 BC.

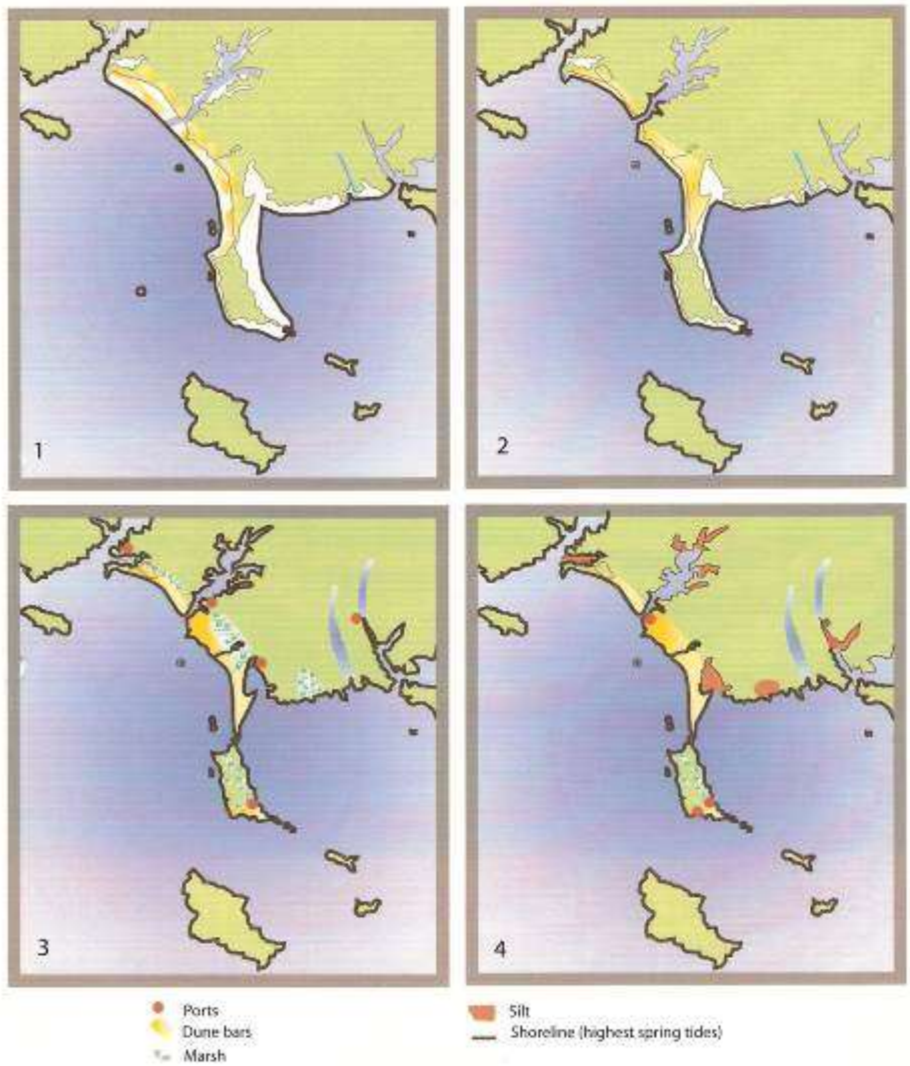

Figure 3K5. Palaeo reconstruction of the Morbihan and Quiberon peninsula environment (map by D. Allaire, after Le Pessec, 2011). (1) From 4.500 to 1.500 BC, (2) from 400 BC to 300 AD, (3) from 1.200 to 1.600 AD, (4) from 1850 AD to present.

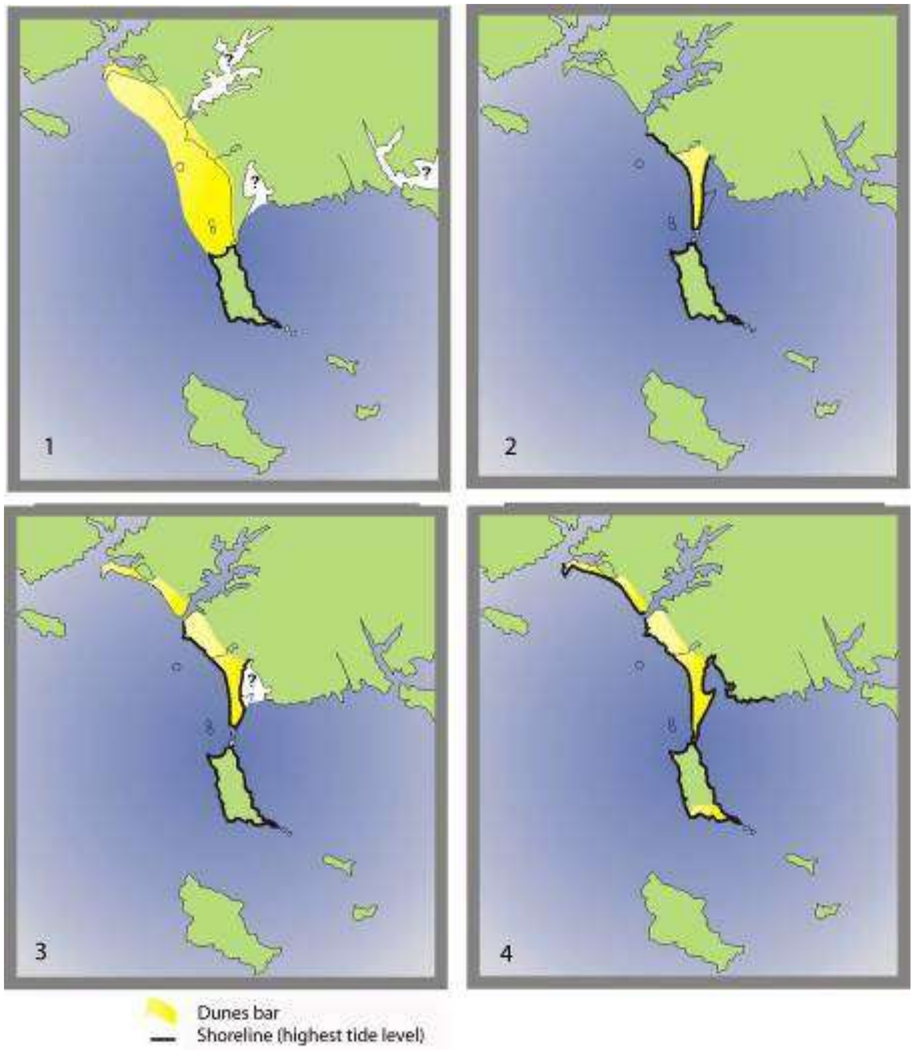

Figure 3K6. Hypothesis on the island vs continental evolution of the Quiberon peninsula/island (map by D. Allaire, after Le Pessec 2011). (1) 5th-4th millennium BC, (2) 3rd millennium BC, (3) Roman time (1st-4th century AD), (4) Modern times.

3K.1.2 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for Project

The archaeological and palaeoenvironmental data has been obtained from the *AMARAI* Database, the *Atlas des Patrimoines* and the *Splashcos* Database. One important source has been the unpublished documents from M. Le Pessec (2011 and 2013), compiling all the available published documentation, completed by unpublished personal observation.

Several books were also used, either general on the prehistory and archaeology of Brittany (Giot *et al.,* 1995, 1998), thematic and focussed on one specific period (Monnier 1981), or diachronic but limited to one geographic area, such as the Morbihan department (Galliou, 2009) or the Gulfe of Morbihan (Lecornec, 2001).

Several archaeological projects have been carried out in this area over the last twenty years. The longest research project and excavation is on the Beg er Vil Mesolithic site which will be detailed further below (Marchand & Dupont, 2012, 2013). Another archaeological project was the study of fish traps from the Mesolithic to modern period along the Brittany coast coordinated by Loïc Langouët and Marie-Yvane Daire, since 2006 (Daire & Langouët 2008, 2010). Over 750 fish traps were identified in Brittany, but the Quiberon ones were chosen for the Arch-Manche project because of the opportunity to carry out some underwater surveys on these prehistoric installations. The description of the works carried out in 2013 will be detailed below.

We also mention below, the results obtained by S. Cassen and his team on the partly submerged standing stone alignments, the study of which has provided additional evidence and new data on Holocene sea level rise. In addition, a database on submerged prehistoric sites has recently been constituted, as the French contribution to the international Splascos Atlas (in progress); it was a main resource for prehistoric sites in addition to archaeological inventories of the *Atlas des Patrimoines* (http://atlas.patrimoines.culture.fr/atlas/trunk/) and especially the AMARAI Database, which provided the most detailed and updated information about archaeological sites in Brittany, especially island and coastal ones.

3K.1.3 Summary of the archaeology and history of the Quiberon peninsula study area

Some sites of the Quiberon area belong to the most famous prehistoric sites in Europe, especially the Mesolthic cemeteries of the Téviec and Hoedic islands (Large 2002, Collective 2007). However, during the last decades, our knowledge concerning the prehistory and more widely on the archaeology of the Quiberon peninsula (Figure 3K7a&b) has been deeply improved, thanks to fieldwork programs on several sites including: Beg-er-Vil (excavated under the direction of Grégor Marchand & Catherine Dupont; Marchand & Dupont, 2012 & 2013), and Groh-Collé on the Kervihan cape (excavated by Jean-Noël Guyodo 2006-2008) (Guyodo, 2008). Interdisciplinary approaches have considered both terrestrial and underwater remains, leading to a real renewal of the data, particularly on the Kerbougnec and petit Rohu standing stone alignments (Cassen *et al.,* 2010).

The heritage of the Quiberon peninsula is clearly very rich and diverse, with sites and finds from the Palaeolithic through to the Middle Ages and modern times, this will be demonstrated below. The survival of these sites is primarily down to the sandy environment which has preserved not only the monuments but also the artefacts and organic remains (including wooden coffins, tools, skeletons etc). Even where the main part of the monuments has disappeared, a wide range of megalithic monuments are still visible in the peninsula and contribute to its tourist appeal. As well as this, the study of peat layers behind the Rohu beach allowed us to propose an environmental reconstruction of the peninsular landscape from 11000 BP to modern times (Gaudin, 2004).

Early Prehistory (Palaeolithic and Mesolithic)

Studies on the stratigraphy of Pleistocene deposits from the south coast of the Armorican Massif (Morbihan) are not as advanced as in the north of Brittany. Geological features are extremely different and the absence of loess, as the lesser slope deposits (lower cliffs), implies weakness of sediment. The fossil beach of Saint-Colomban connects deposits to the west, with an occupation platform at 6m. The geological study of the deposit in its general context, therefore suggests that human occupation dates back beyond the last interglacial, perhaps at the end of isotope stage 11 or 13, (Monnier, 1981). On the Quiberon peninsula, evidence for Palaeolithic occupation is minimal, one layer has been reported on Téviec Island (acheuléo-levalloisien facies).

The best-known Mesolithic sites from Brittany are the cemeteries on the islands of Hoëdic (10 graves) and Téviec (9 graves) in Morbihan (Ghesquière & Marchand 2010; Marchand, 2014). The collective graves are placed in shell middens without any particular order. Some graves show evidence of *post mortem* manipulations of the bones. There are also single burials and empty graves (cenotaphs). The graves are covered with stones, a hearth or antlers forming a sort of dome. Rich funeral gifts, flint tools, engraved bones, shell ornaments and ochre demonstrate the affluence of these hunter-gatherers, or rather fisher-gatherers. Certain shells are sex-specific.

In Teviec there are stone cist graves. The bones of an infant have been ornamented with striations. The radiocarbon date measured in 2005 for the Téviec site indicates an occupation c. 5300/5000 calibrated BC, i.e. 6514 +/- 45 years B.P. The corresponding settlements consist of shell middens. A radiocarbon date of 4625 (uncal.) for Hoëdic places it in the 6th Millennium BC, rather late in the Mesolithic sequence, and indeed there are some indications of contact with agricultural societies to the east. Their economy was based on marine resources. Recently, a number of accelerator dates have been published for Hoedic.

Dating back to the Mesolithic period, and 80 years after its discovery, the Téviec cemetery and its 23 skeletons are still objects of attention (recent analyses and exhibition in progress, Figure 3K8).

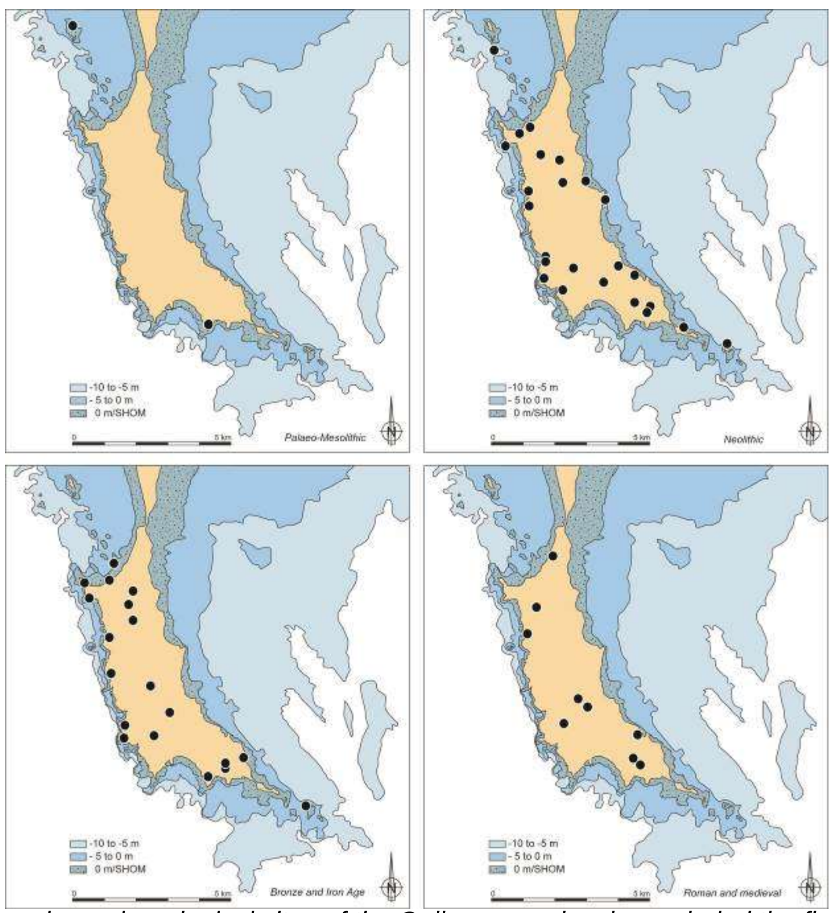

Figure 3K7a. The major archaeological sites of the Quiberon peninsula, excluded the fish weirs presented in a separate figure (map by L. Quesnel and M.Y. Daire).

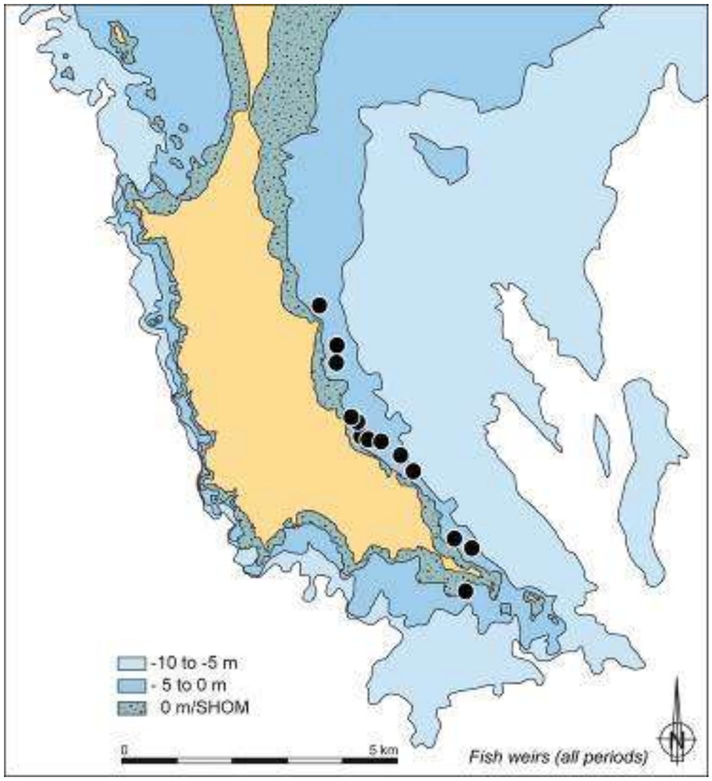

Figure 3K7b. The ancient fish weirs of the Quiberon peninsula (map by L. Quesnel and L. Langouet).

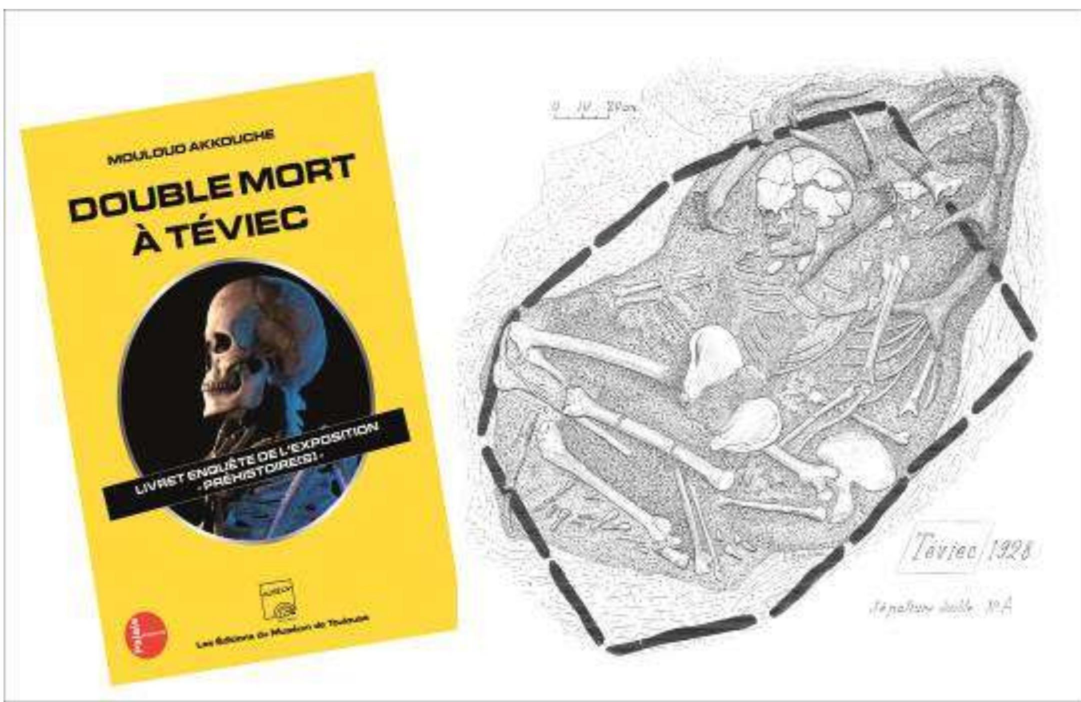

Figure 3K8. Téviec Mesolithic cemetery. (Left): exhibition document, http://www.palais-decouverte.fr/, (right): drawing of the A burial by F. Bouillon.

Section 3K.5 below will present in detail the Beg er Vil Mesolithic settlement, which is one of the main sites of our case study area; it consists of a prehistoric layer dating back to 6100 BC, located above a hanging beach, and composed of a shell midden where prehistoric tools were preserved (Marchand & Dupont 2013).

Later Prehistory (Neolithic),

The cultures which occupied the area between 5500 and 1800 BC left a lot of megalithic monuments in the Quiberon peninsula. A lot of them disappeared during later periods, where they were reused for modern construction, destroyed by erosion or hidden under the sandy dunes. The main categories of megalithic monuments present on the peninsula are standing stones, sometimes grouped in alignments and funeral structures (passage graves).

In spite of the frequent destruction of standing stones, several 'menhirs' still exist in the peninsula (Figure 3K9); as in other regions of Brittany, their precise dating remains difficult as this tradition stems from the Neolithic up to the Bronze Age. The most famous monuments still visible are Manémeur, Er Palouenneù (road to the Vivier), Er Limouzen, Guerguerit cape, Beg er Vil, Goulvars (2 or 3 standing stones), Keridenvel and Er Ruguied.

Figure 3K9. Quiberon standing stones in Conguel (left) and Manémeur (doc. Le Pessec).

Megalithic burials are also numerous on the peninsula, mainly represented by passage graves, however, many have been destroyed by erosion or modern constructions: including Manémeur , Kerné, Roch Priol, Toul Braz islet, Roch an Aud, Percho, Beg-Portivy, Mané Beg-er-Noz. One of the most famous is the 'Conguel' passage grave, nowadays partly destroyed, it has long served as a reference for the ceramic typo-chronology. Famous for the skeletons and the ceramic set found during the excavation (by Z. Le Rouzic in 1925), this monument dates back to the late Neolithic, (2800/2500 BC) (L'Helgouac'h 1962). It was been "restored" in the early 20th century (Figure 3K10).

The Neolithic site of Groh Collé is another regional reference for the cultural assessment in Brittany. Located on a cape, it has been recently excavated by J. N. Guyodo (2006-2008). Its occupation dates back to the late Neolithic (4 000 to 2 000 BC) (Guyodo 2008).

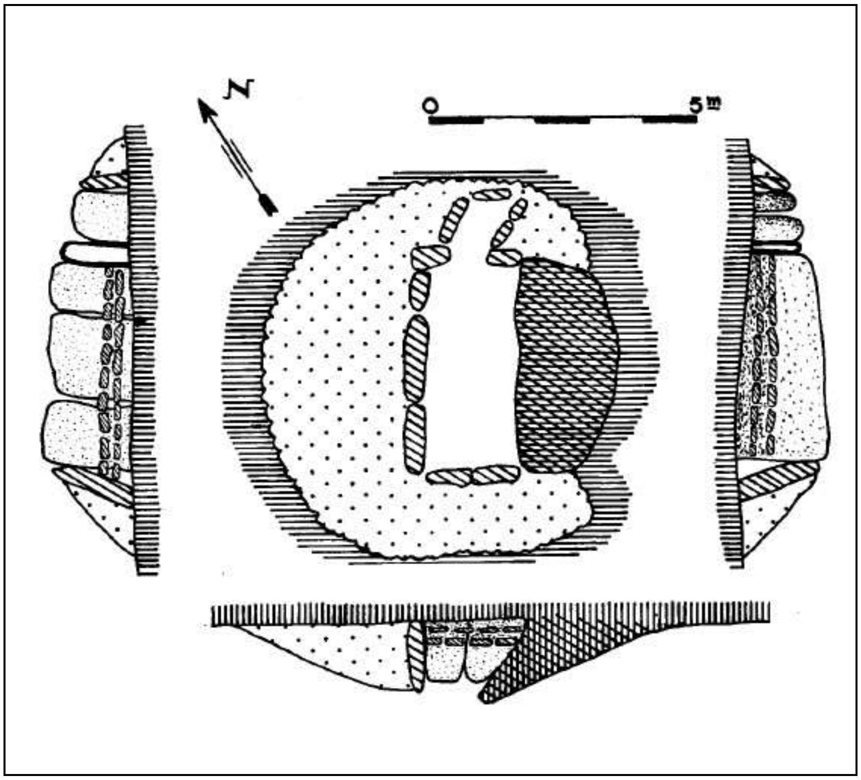

Figure 3K10. Plan of the Conguel passage grave (doc. Le Rouzic, 1930, after L'Helgouac'h, 1962).

Figure 3K11. The Neolithic Groh-Collé site during the excavation by J.N. Guyodo (source Le Pessec 2013).

The most important Megalithic site on the Quiberon peninsula is without a doubt the Kerbourgnec alignments situated in Saint-Pierre-Quiberon. Until the recent works by Cassen *et al.,* it was said to be made up of 25 sometimes oddly-shaped menhirs aligned in a sequence of five rows. Only a little further from this site, there is a "Cromlec'h" with a total of 27 menhirs placed in a circle - it is the third largest in the whole of Morbihan. Recent research has led to the discovery of the tidal and submerged part of the alignments. The menhir lines travel further down and out into the sea, remains of which can be seen at very low tide. They draw several very clear lines of rocks stretching out into the sea in parallel rows. The sediment has been washed away from around the rocks, and they now just sit on the rocky seabed, but it is possible to clearly see the lines. At least seven rows of rocks are visible but the end of the alignments remain permanently submerged, even during the lowest spring tides, providing evidence of the effects of sea level rise (Figure 3K12).

The site of the Moulin or Kerbougnec alignments has recently provided a revised vision of western France megalithism as well as for environmental studies combining terrestrial and underwater approaches (Cassen *et al.,* 2010).

On the Petit Rohu site, after the discovery of several stone axes in 2007, fieldwork carried out produced evidence for at least one submerged stone alignment located to the south-east of the axe head find spot and several dozen metres away (Cassen *et al*., 2008). The structure is readily distinguishable from a more recent stone structure, related to fishing, located 800m away. Peaty soils have been intermittently observed over several years, buried beneath marine sand; these are being progressively eroded away by the force of the sea, as their sand cover becomes thinner. These soils preserve marks, criss-crossing each other in places, which relate either to cultivation or to salt extraction; and there are also hoof-prints of ungulates (cattle and pigs). This palaeoenvironmental context allows us to argue that the axe heads had been deposited in a marshy environment that had developed behind a dune system, at the foot of a remarkable granite outcrop. Sea level rise since the mid-fifth millennium BC - the likely date at which the axe heads were deposited - means that the shore has advanced by some 500m since then.

Bronze Age and Iron Age

Evidence of Bronze Age human occupation is scarcely represented in the Quiberon peninsula, one of the best records being the Vivier settlement, excavated by J. Briard (Briard *et al.* 1990). Several burials in stone cists or under tumulus are also recorded. The palaeoenvironmental study, carried out in parallel with the most recent excavations, has shown that this region had been severely cleared by Neolithic people who built the numerous megalithic monuments during the former period.

The Iron Age is better documented by a large range of sites: fortified settlements (Beg an Aud), cemeteries and burials (Thinic islet), sometimes associated with villages (Kerhihuel/Kergallo, Kernavest, Port-Bara, Goulvars, Runaron, Kerné), and salt production workshops (Toul-Bras islet). As an illustration of the good preservation conditions of sandy dunes, during the excavations on the Thinic island (by F. Gaillard in 1883), 27 stone cists each of them containing one or several skeletons, stone tools, antlers etc. were found (Figure 3K13).

In the regional tradition, the Quiberon peninsula and, more widely, the 'Mor Braz' area is said to have been the setting of the naval battle between Caesar’s flotilla and the Vénète's flotilla in 56 BC.

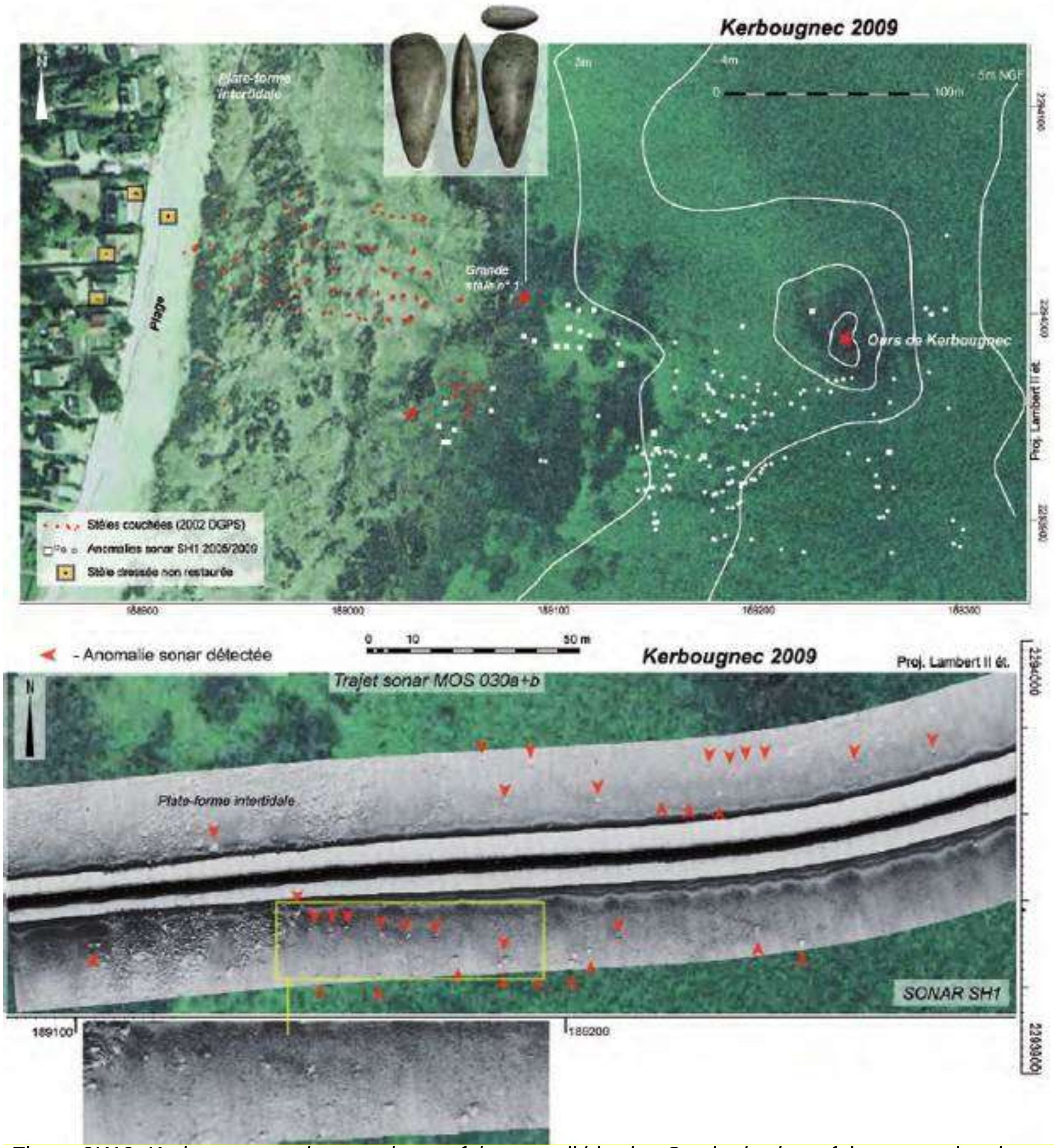

Figure 3K12. Kerbougnec, submerged part of the megalithic site. Synthetic view of the sonar signals and jadeite axe found on the site (after Cassen et al. 2010).

Figure 3K13. Thinic islet, Portivy-Quiberon (while low and high tide) (cl. Le Pessec).

Roman Period

Roman *villas* are not uncommon in the study area and remains are reported, notably in Keriaker (Figure 3K14), excavated in 1966 by G. Bernier, where a small building with two rooms was accompanied by a domestic kiln used for cooking. The walls were decorated with paintings and shells stuck on the coating. However, the Roman period is mainly represented in the Quiberon peninsula by the numerous finds of Roman coins and artefacts, in addition to isolated finds of objects. The Port Haliguen 1 treasure was composed of 450 coins and the second one contained 105 Roman coins (Goulpeau, 1985).

Medieval Period (500AD – 1485AD)

Several chapels and the Saint-Clément cemetery (excavated during the late 19th century) (Figure 3K15) appear in the Medieval period. Most of the churches of the peninsula had their foundation back in the Middle Ages. A document (chart) from the 11th century mentions the ancient name of the Quiberon peninsula which is "*Insula Keberoën*" (in 1037).

In the Bay of Quiberon, we have little documentation on navigation in the late Middle Ages. Nevertheless, this high sea level and low siltation Bay allowed from 1450, the use of many "ports" Port Haliguen as natural, perhaps also Port Orange.

Figure 3K14. The Kermarker site, the roman remains are currently buried under the dune (cl. Le Pessec).

Figure 3K15. The ancient cemetery in Saint-Clément, sarcophagus probably from the Carolingian period (751 à 987) (cl. Le Pessec).

Post-Medieval Period (1485AD – 1901AD)

To the north of the peninsula, the Plouharnel landing ports seem to have been used until around 1826, before siltation. In this area, the tide mill of Bego operated from 1774 until its destruction in 1850, due to the construction of the Auray/Quiberon road. Cabotage on the Atlantic coast grew strongly from that time, for various reasons, but the rise in sea level could also play a role in the development of ports at the river bottom such as Auray, Vannes, etc.

A significant element of the Post-Medieval period is the construction of coastal military defences, demonstrated here by the Fort Penthièvre (Figure 3K16). Built in 1746 in the framework of the military coastal defences, it was reused by the royalists after the French revolution of 1789. It was then reconstructed and reused several times (see below).

Modern

The majority of sites from the 20th Century comprise WWI and WWII defence systems. As mentioned above, the Fort Penthèvre (Figure 3K16) was reused, especially by the German army during WWII. Nowadays, the fort belongs to the Army and is still in use by the Marine Infantry Regiment of Vannes, for training.

Figure 3K16. The Fort Penthièvre, view from the north (cl. Le Pessec).

3K.1.4 Art History of the Area

This section presents the background to artistic representations within the area including key schools and individual artists. This provides the background to the broader consideration of individual artworks within the study area, the two main painters considered here being Maxime Maufra and Jules Noël (see below). The coastal region of the Quiberon peninsula, and more widely the coast of the continental shelf of Morbihan was quite well depicted, but probably lesser than the tourist zone of Cote d'Emeraude (see case study 3H) which was a major source of inspiration for artists from all over the world and is where the Pont-Aven School of painters was created in the 19th Century. We didn't deal here with the extremely rich set of paintings representing the Belle-Île-en-Mer island landscapes and rocky coasts (with the dominant character of Monet) as it is located outside of our case study area.

Several pioneers of photographic techniques captured numerous parts of this area; mainly due to the development of tourism and the creation of some seaside resorts, photographic postcards produce a lot of visual records of coastal tourist areas.

Figure 3K17. The Quiberon seafront and beach (early 20th century) (postcard, cl. Lannelongue).

Introduction

The study area focuses on the Quiberon peninsula, especially for the archaeological and palaeoenvironmental approaches; however, the area considered for artistic resources has been enlarged and covers a wider area of about 100 km wide, this is in order to gather a sufficient set of illustrations, and includes some very accurate case study sites.

As in the other case study areas, the approach for the coastal study sites will, therefore, aim to:

- demonstrate the role that historical works of art (oil paintings, watercolours and prints) and especially photographs can provide in terms of supporting understanding of long-term coastal change;
- assist understanding of the chronology of coastal change in southern Brittany, especially in the Quiberon area;

- provide examples of those artists' works which form reliable records of coastal conditions at the time they were painted.

Art Resource

Regarding the main sources used for paintings of the area, some illustrated books provided a wealth of paintings and watercolor drawings (Delouche, 2011). But the main source was the *Joconde* online database. The Culture ministry database *"Joconde"* is the gate of museums and public galleries collections in France. The catalog contains nearly 500,000 records including archeology, fine arts, ethnology, history, science and technology, it is enhanced by thematic options and virtual exhibitions. Joconde is the result of an ongoing partnership between the office of the digital broadcasting service collections of museums in France and the participating museums.

For the Gulf of Morbihan area, an interesting resource with a full list of all the artists (painters, photographs, postcard editors etc.) having depicted the area can be found on: http://dictionnairedugolfedumorbihan.over-blog.com/article-les-artistes-du-golfe-du-morbihan-73045992.html, some examples are also published in the paper version of the *Dictionnaire du Golfe du Morbihan* (De Beaulieu, 2011).

One of the most prominent figures for this area is Maxime Maufra (1861-1918) (Collective 1998, Ramade 1988) (Figure 3K18). He was introduced to painting with Charles Leduc and his brother Alfred Leduc in Nantes, reproducing landscapes of the Loire river banks. His father decided to make him a business man; this explains why he undertook a language course in England (Liverpool).There he discovered what painting really was, including the work of Turner. He visited Wales and Scotland, whose landscapes are his inspiration. He returned to France in 1884, where he tried to manage both his business and pictorial work.

Very quickly he established his own technique and approached landscape painting with a preference for maritime landscapes of Brittany. He moved around Quiberon, the Pointe du Raz, in the peninsula of Crozon and many other places. He settled in 1903 in a small farm at Kerhostin (Quiberon) which he then bought in 1910. He tried unsuccessfully to restore a small painting group in these places and he was appointed "Peintre de la Marine" (painter of the Navy) in 1916. Attached to the Breton regional culture, Maxime Maufra was one of the leaders of the "fine arts" in the Breton Regionalist Union section.

Landscapes, harbours and urban views of Britain have largely inspired the painter Jules Noël (1810-1881) (Figure 3K19). His style, comparable to the one of Eugène Isabey, varies between a wise and realistic effect of light, sometimes close to Impressionists. He spent is youth in Brest and started to teach drawing in Brittany, in Saint-Pol-de-Léon, Lorient and Nantes. From 1847 until his retirement in 1879, he taught at Paris and enjoyed holidaying in Normandy and especially in Britain (Rodrigue & Cariou 2005).

Figure 3K18. 'Plage de Portivy", by Maxime Maufra (1907) (private col. Source of the document: http://fr.wahooart.com/).

Figure 3K19. 'Port de Larmor', by Jules Noël (1868) (Private collection,source: http://enflanant.hautetfort.com/).

3K.1.5 Art Resources Consulted for the Project

In order to establish the resources available for this study it was necessary to review the existing artworks. The main source of artists has been the database of the Ministry of Culture of France, called "Joconde" (see above). For the Morbihan case study area, the art approach partly benefited from the academic work (Masters) led in the Rennes 2 University by Edwige Motte (Motte 2013). The theme of the dissertation was: "*Representation and Evolution of the Shoreline: What do regional paintings teach us about the Breton coastal environment*?". It was also necessary to review the topographical paintings, drawings and prints held by the principal national, region and local collections covering the case study area.

The photographic postcards consulted for the project belong either to private collections, or to public ones (Biet & Bouze 2007), particularly the Regional ancient postcard conservatory which is an important resource (http://www.cartolis.org/), and primarily the documentary collection available in the Archéosciences Laboratory (University of Rennes) (ICARE, http://ntarcheo2.univ-rennes1.fr/icare/). Several books have recently demonstrated the importance of photographic pioneers in the region and provided a commentated documentation to our research.

Concerning the maps and charts used for the case study, one of the most informative resources for this area is the "*Carte des Ingénieurs géographes du Roy*" (18th century), which provides very accurate details especially along the coast. At a local scale, the "Cadastre Napoléonien" (19th century) is very detailed and provides a view of the extent of the private and public properties, buildings and fields, sometimes with additional textual information.

3K.2 Current Environmental Impacts/Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the coastline and reviews the current coastal management issues and approaches (Collective, 2009).

Figure 3K20. Excavations on the megalithic monument of Port-Blanc, Quiberon (Doc. Félix Gaillard, Société Polymathique du Morbihan).

3K.2.1 Review of Key Contributors to Coastal Change

It has been explained for the different case study areas that coastal erosion over the centuries is evidenced through the loss of a number of communities including places of interest regarding the natural and cultural coastal heritage (Figure 3K21). We underlined above that the two coasts of the Quiberon peninsula are very different regarding natural threats, the western one is most exposed to waves and wind erosion, especially during storms, while the eastern coast is more protected. Nevertheless, if we take into account the various kinds of geomorphological features (see above), the sandy dunes are one of the most vulnerable components of this landscape (Cavalie, 2001).

Concerning the dunes vulnerability, the document presented in Figure 3K22 is particularly interesting, since 1907 the vast majority of dunes were transformed, it is therefore difficult for us today to realize the state of the landscape during the 18th and 19th centuries, and before the great works beginning around 1850. We can list some important changes: the construction of bunkers in 1939/45, the numerous sand quarries used for building during the 19th and 20th centuries (archives of the City Council), the numerous archaeological excavations carried out from 1850 to 1939 (sites buried under the dunes), and of course, the winds continuous work, especially where the vegetation is sparse. The situation of coastal areas of the Morbihan department regarding natural threats is summarized in Figure 3K23.

3K.2.2 Summary of Current Coastal Management Approach

Coastal risk management is a responsibility of coastal local authorities in partnership with national and regional ones. Aware of the great tourist potential of their coastal towns which were dominated by agriculture there was an increase in tourism development. The area has been largely developed with new roads and parking areas in order to improve access to the coastline alongside the construction of coastal defences including sea walls. Updated in February 2014, the presentation of the Integrated Coastal Zone Management (ICZM) approach in the Gâvres-Quiberon area underlines the changes to coastal management in this area http://www.labretagneetlamer.fr/?q=node/226.

The expected results are to develop new synergies to promote the understanding and management of the marine and coastal entity, Watershed Etel and the Gâvres –Quiberon dunes and initiate cooperation between the two union structures and their partners to jointly optimize the technical means and scope of the actions.

Figure 3K21. Natural threats on the Quiberon coasts, (top): damages on the Penthièvre dyke after a storm, (bottom): damaged Neolithic site of Kerné (cl. Le Pessec 2011).

Figure 3K22. The Quiberon dunes and beach, late 19th century (archives of the City Council).

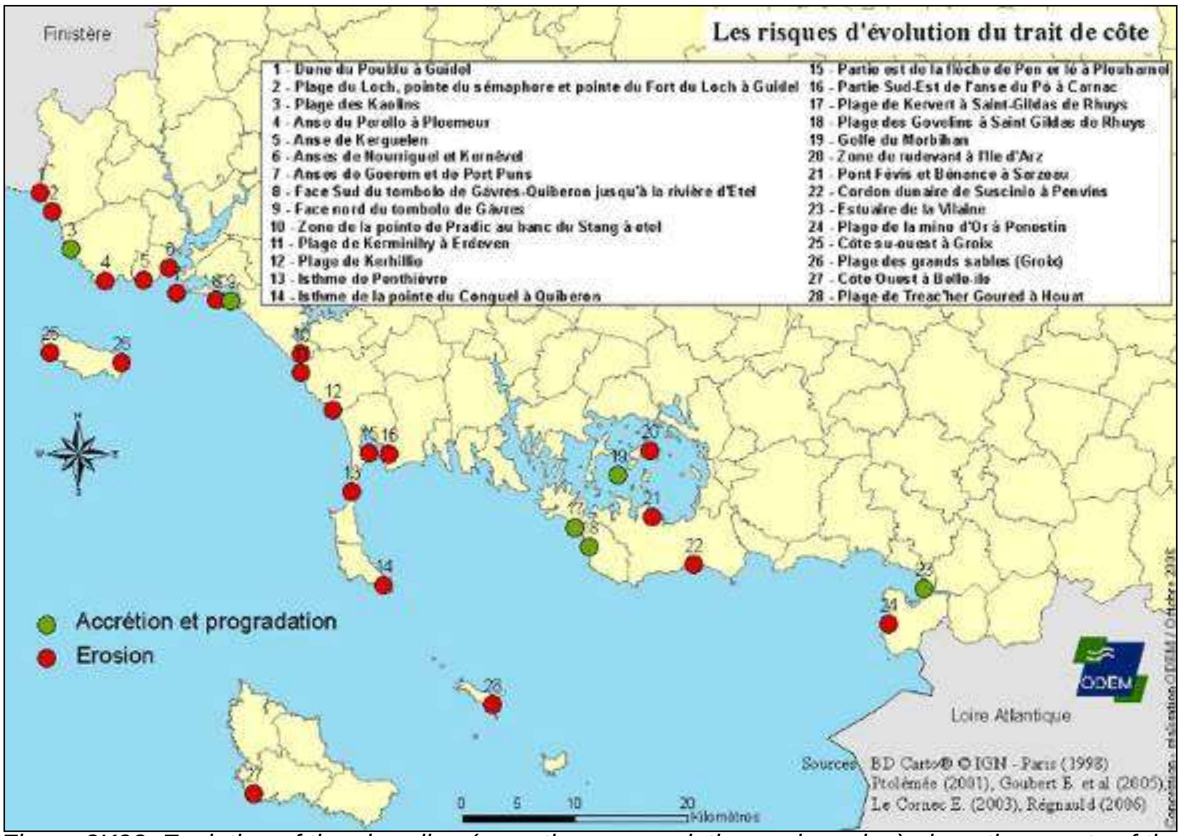

Figure 3K23. Evolution of the shoreline (accretion, progradation and erosion) along the coasts of the Morbihan department. Amongst the 28 sites, 22 are retreating due to erosion (source: http://www.bretagne-environnement.org/).

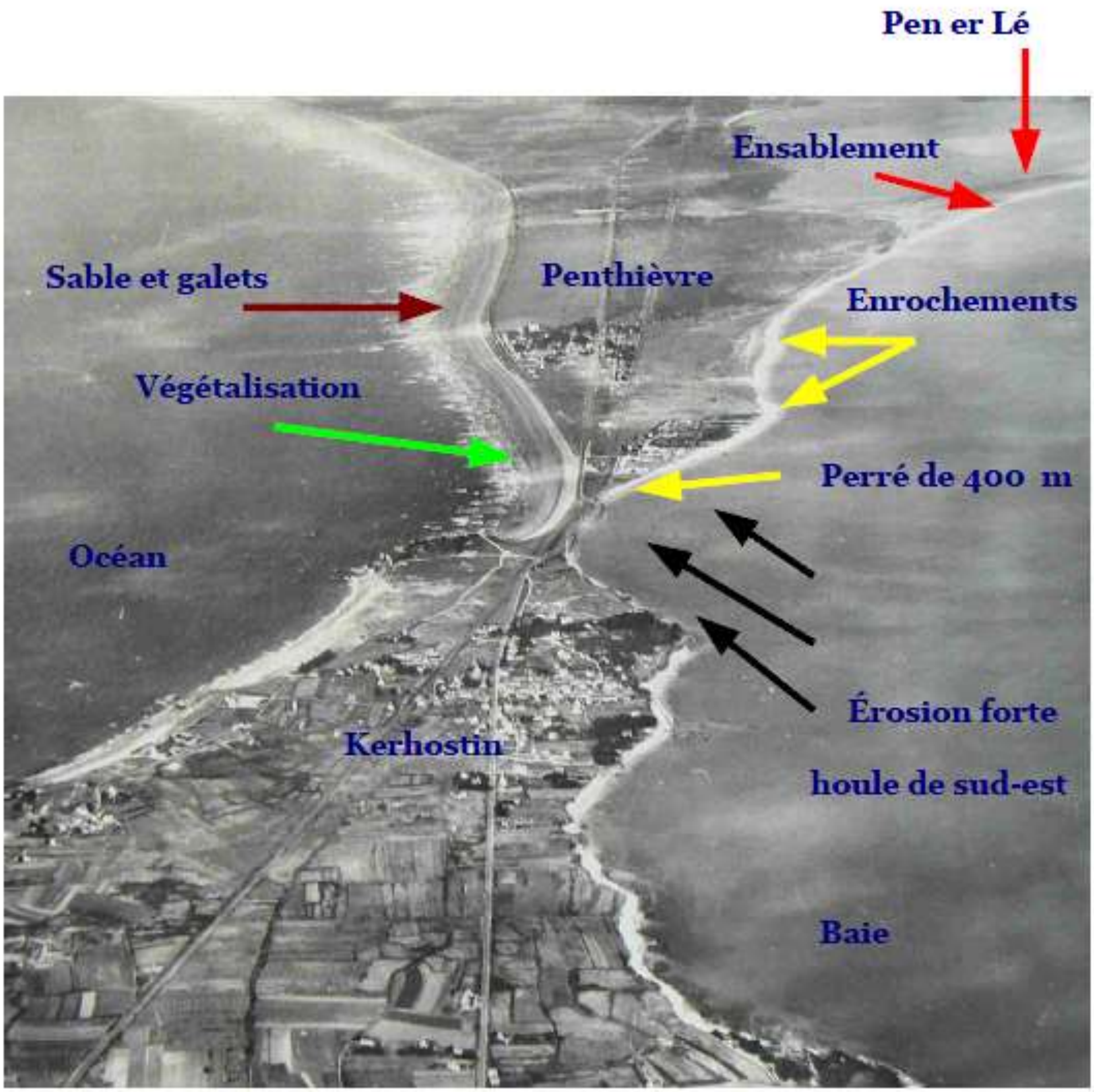

Figure 3K24 Evolution of the Penthièvre isthmus and coastal management (protections on 1 km length) (after Le Pessec 2011).

3K.3 Archaeological and Palaeoenvironmental Ranking

This section outlines the results of the archaeological and palaeoenvironmental ranking from the Quiberon and Morbihan study area, followed by a discussion of the results. The ranking methodology applied is detailed in Section 2.

The discipline of archaeology has a long history, much of the prehistoric element of the discipline developed from work in the Morbihan area (Collective 2007) where some of the most important European sites are located. This explains the richness of the available data, among which we had to choose some of the most representative illustrations of coastal change through the millenniums. Our interest turned then mainly to recent works and new approaches, and sometimes leaving out some emblematic monuments or major heritage records, which appear less informative for the issue of coastal evolution.

The environmental evolution of the Quiberon peninsula has been deeply studied and subject to field and desk based analyses carried out by P. Stéphan (in Marchand and Dupont 2013) especially in the framework of the Beg er Vil project. Complementary data has been obtained thanks to the underwater surveys by ADRAMAR (Le Ru 2013) in combination with the study of the submerged fish traps (Daire & Langouet 2010). These studies mainly concerned the southern part of the Quiberon peninsula, as the Penthièvre isthmus has long been the subject of a morphodynamic study, due to the importance of the dunes cover.

3K.3.1 Results of the Archaeological and Palaeoenvironmental Ranking

The table of highest ranking sites is dominated by prehistoric sites, more specifically Mesolithic settlements and Neolithic monuments (Table 3K1). It is clear that this area contains a concentration of Mesolithic sites showing an exceptional dataset and reference for Western Europe (Téviec and Hoedic cemeteries and Beg er Vil occupation).

The Quiberon peninsula is dominated by megalithic monuments (passage graves and standing stones), and at a lesser level, some Iron Age occupation sites of interest. The systematic surveys carried out by J.M. Large (Large, 2002) on the islands (Houat and especially Hoedic) have recently totally renewed our knowledge of the human occupation of the archipelago. There, major sites (standing stones alignments, settlements) provided resources for environmental analysis. The recent development of fish traps studies in Brittany (Daire & Langouët 2010) have taken benefit of new kinds of field investigations (underwater surveys), which were undertaken off the Quiberon peninsula. All these studies help us to reconstruct the environment of the Morbihan coast and its geomorphological changes from prehistoric times.

The presence of Neolithic monuments, burial graves and standing stones, is a constant in the Morbihan area, famous for major prehistoric stone monuments (Carnac, Locmariaquer etc.). One peculiar phenomenon, densely represented in this case study area is the one of standing stone alignments. Beyond the ones of Carnac, the standing stones of Hoedic (Large 2014) and the alignments of Kerbougnec and Petit Rohu, partly submerged, have recently drawn attention to a new vision of megalithism in Western Europe (Cassen *et al.* 2010).

Through the archaeological ranking analysis, we will consider the Mesolithic site of Beg er Vil and the fish traps of the south eastern coast of Quiberon as providing accurate data on sea level rise since the Mesolithic and, more generally, coastal change (see below).

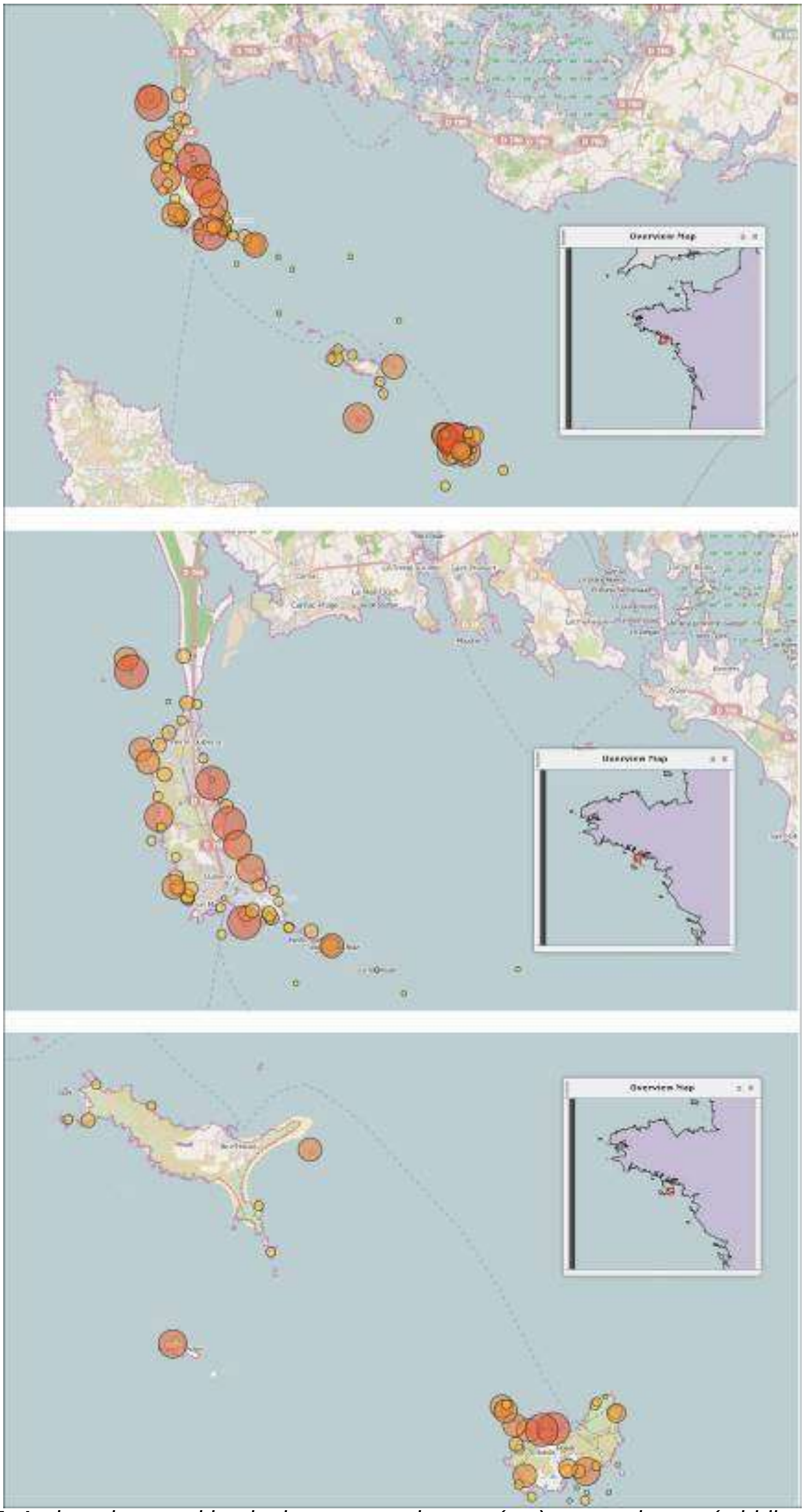

Figure 3K25 Archaeology ranking in the case study area (top): general map, (middle and bottom): detailed maps.

APE uid	Site Name	Site Type	Period	Score – Sea Level	Score – Environ mental	Score – Temporal Continuity	Total Score	Coastal Context
1074	SAINT-PIERRE-QUIBERON - Ile Guernic	Other find spot	Neolithic	High	High	High	100	Coastal
1163	SAINT-PIERRE-QUIBERON - Kerbourgnec	Monument	Neolithic	High	High	High	100	Inter tidal
1166	SAINT-PIERRE-QUIBERON - Petit Rohu	Monument	Neolithic	High	High	High	100	Inter tidal
1213	QUIBERON - Beg er Vil	Other find spot	Mesolithic	High	High	High	100	Coastal
1297	HOEDIC - Douet alignement	Monument	Neolithic	High	High	High	100	Above HW
1298	HOEDIC - Groah Denn alignement	Monument	Neolithic	High	High	High	100	Above HW
1083	SAINT-PIERRE-QUIBERON - Groh-Collé	Other find spot	Neolithic	High	Medium	High	88	Coastal
1162	QUIBERON - Saint Julien fishtraps	Marine Installation	Bronze Age	Medium	High	High	88	Inter tidal
1161	QUIBERON - Port Haliguen fishtraps	Marine Installation	Bronze Age	Medium	High	High	88	Inter tidal
1285	ILE D'HOUAT - Ile aux chevaux	Other find spot	Iron Age	High	Medium	High	88	High Cliff
1491	HOEDIC - Sterflant	Other find spot	Iron Age	High	Medium	High	88	Dunes
1076	SAINT-PIERRE-QUIBERON - Ile Teviec habitat	Other find spot	Mesolithic	Medium	Medium	High	77	Above HW
1070	SAINT-PIERRE-QUIBERON - Beg-en-Aud	Monument	Iron Age	Medium	Medium	High	77	Above HW
1082	SAINT-PIERRE-QUIBERON - Porz Guen dolmen	Monument	Neolithic	High	Medium	Medium	77	High Cliff
1201	QUIBERON - Beg er Goalennec	Other find spot	Bronze Age	Medium	High	Medium	77	High Cliff
1204	QUIBERON - Ile Toul Bras	Other find spot	Iron Age	High	Medium	Medium	77	Above HW
1263	ILE D'HOUAT - Er Yoc'h	Other find spot	Neolithic	High	Medium	Medium	77	Coastal
1306	HOEDIC - En Inizen	Other find spot	Neolithic	High	Medium	Medium	77	Sandy foreshore
1296	HOEDIC - Koh Kastel alignement	Monument	Neolithic	High	Medium	Medium	77	Soft Cliff
1295	HOEDIC - Le Télégraphe dolmen	Monument	Neolithic	High	Medium	Medium	77	Soft Cliff
1293	HOEDIC - Port neuf necropolis	Other find spot	Mesolithic	High	Medium	Medium	77	Dunes
1289	HOEDIC - Port Louit dolmen	Monument	Neolithic	Medium	Medium	High	77	Above HW

Table 3K1. Top archaeology/palaeoenvironement ranking results.

Ranks for sea level change

	High	Medium	Low
Number of sites	18	53	27

Ranks for environmental change

	High	Medium	Low
Number of sites	9	29	60

Ranks for temporal continuity

	High	Medium	Low
Number of sites	13	35	50

Table 3K2. Analysis of the top archaeology/palaeoenvironment ranking results.

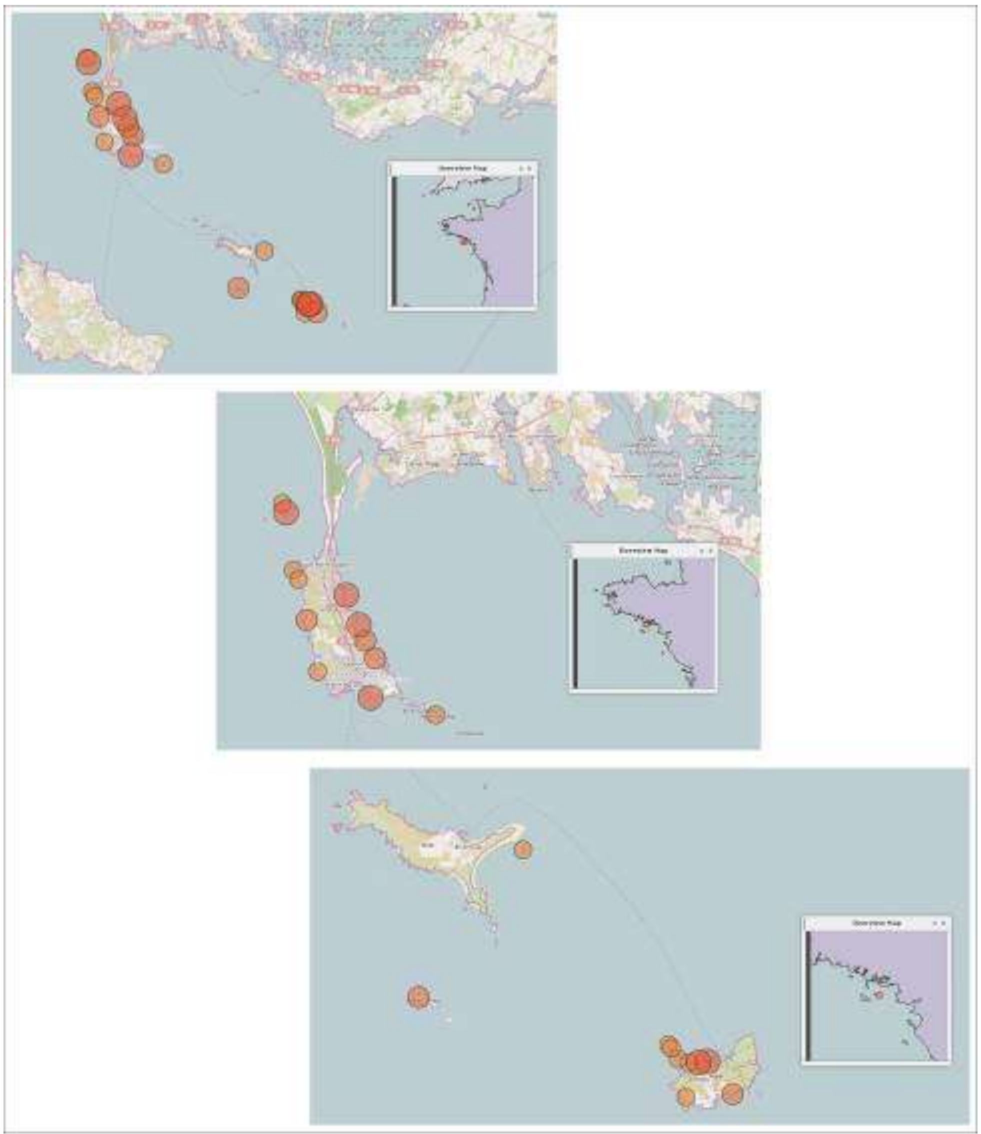

Figure 3K26. Map showing the distribution of the highest scores sites within the case study area

3K.3.2 Discussion of the Ranking Results

The table of highest ranking sites (Table 3K1) is dominated by Neolithic monuments, mainly standing stone alignments, then passage graves and settlements. Among these sites, those located either buried under dunes or currently located in the intertidal/marine area appear to be the most informative regarding coastal change. Alongside the megalithic monuments other top ranking sites include Mesolithic sites which contain environmental evidence.

The fish traps located off Saint-Julien bay and Port Haliguen harbour, in Quiberon, also provide new data thanks to a program of underwater survey. This data can provide information which will enable the modelling of past coastal change.

Some other sites which have ranked lower still have the potential to provide information on coastal change, such as Iron age settlements located next to the shore (Hoedic) or on the top of rocky cliffs (beg an Aud).

3K.4 Ranking Artistic Depictions

The ranking systems developed for artworks, historic photographs, maps and sea charts were applied to each of the selected depictions, the results are described in more detail below.

3K.4.1 Art Ranking

The research has identified two main exhibiting artists, Maxime Maufra (1861-1918) (Ramade, 1988) and Jules Noël (1810-1881). The development of the ranking system is described in Section 2. For this case study area, 10 pantings have been selected, which represent various kinds of lanscapes, most of them concerning the Quiberon peninsula area.

The majority of these artworks represent wild landscapes, especially before urbanisation and tourist buildings. The oil painting from Maufra depicts the Larmor port allowing us to consider the evolution of the structure, with a former small fishing port which turned into a sailing harbour in the middle of the 20th century. Maxime Maufra (1861-1918), landscape painter (Ecole de Pont-Aven) gives a synthetic view of the landscape, eliminating the details and sometimes exagerating some features, this must be considered when using the artworks to understand coastal change.

Jules Noël's style, comparable to the one of Eugène Isabey, varies between wise and realistic effects of light, sometimes close to Impressionists (Rodrigue & Cariou 2005).

Case Study Number	Location	Artist	Date	Score type	Score style	Score enviro	Total Score
101	La crique côté Quiberon	Maxime Maufra	1903	Oil	Picturesque	General view	37
102	La plage et le port de Portivy	Maxime Maufra	1907	Oil	Topographical	General view	59
103	Les dunes de Port Blanc à Quiberon	Maxime Maufra	1908	Oil	Picturesque	General view	37
104	L'Arche de Port Blanc, presqu'île de Quiberon	Maxime Maufra	1880-1920	Oil	Picturesque	General view	44
105	Pointe de Ker Bihan	Maxime Maufra	1885	Oil	Topographical	General view	59
112	Le port de Larmor	Jules Noël	1868	Oil	Picturesque	General view	40
134	Falaises de Quiberon	Jules Noël	1863	Oil	Topographical	General view	40
261	Pêcheurs ramassant leur senne près de l'isthme de Penthièvre	Elodie La Villette	1880	Oil	Picturesque	Detailed	48
262	La crique de Port Bara	Elodie La Villette	c1880	Oil	Picturesque	Detailed	48
263	Quiberon, cavernes de la côte sauvage	Christophe Paul de Robien	1753-1756	Oil	Picturesque	General	51

Table 3K3. Top art ranking results for the Quiberon-Morbihan area.

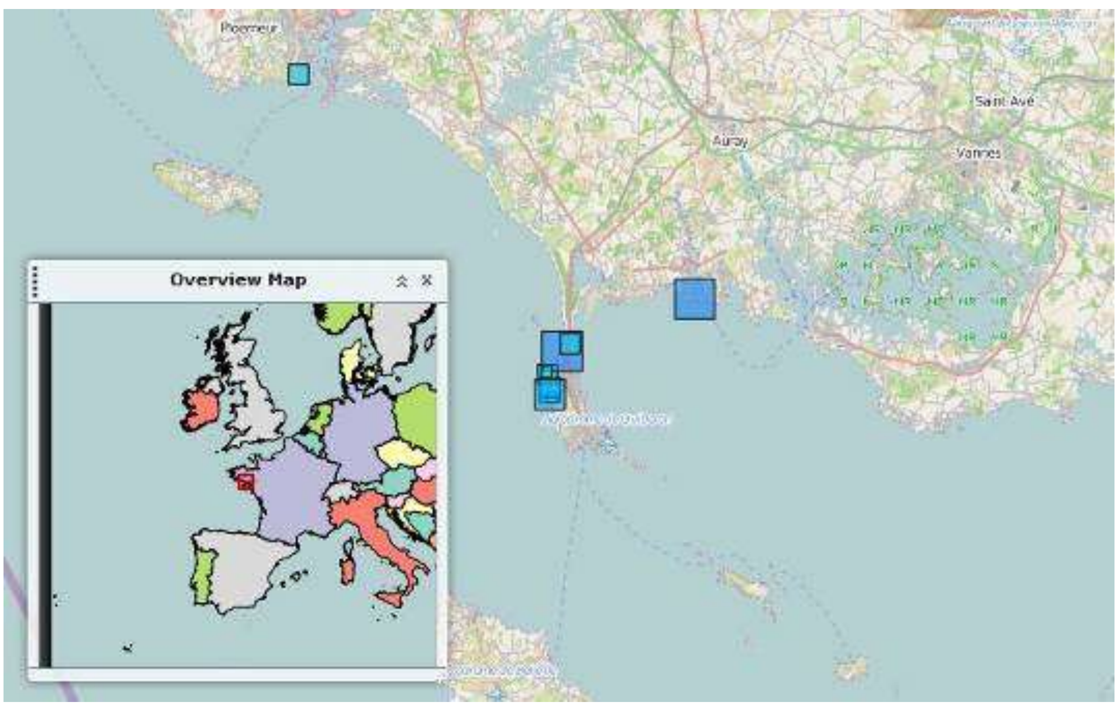

Figure 3K27. Location of art images within the Quiberon and Morbihan case study area.

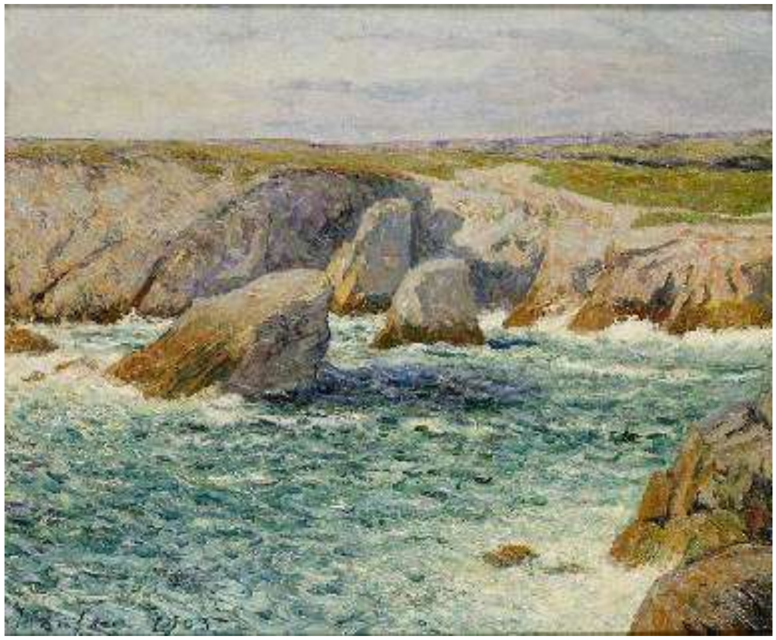

Figure 3K28. La crique côté Quiberon by Maxime Maufra (1903) (Musée du Havre, doc. source: http://www.quizz.biz/).

3K.4.2 Historic Photograph Ranking

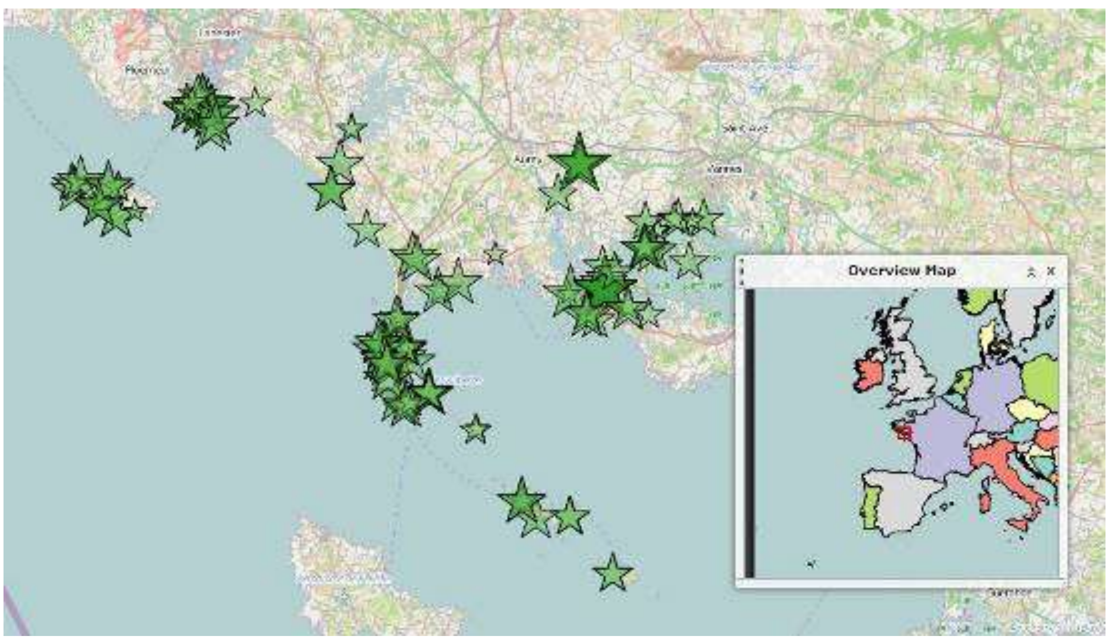

Figure 3K29 Location of historic photos in the Quiberon and Morbihan case study area.

A total of 177 historic photos and postcards were assessed as part of the project for this case study area; images were primarily chosen from locations along the coastline where historic paintings and archaeological sites were also known. The photographs were collected and then ranked. Hundreds of historic images exist for this stretch of coastline, it should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic photos to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums and galleries, as well as private collections has the potential to provide many more.

Table 3K4 below outlines the results of the ranking and presents the highest ranking images, note that photographs were ranked as either a heritage view or a non heritage view.The majority of photos assessed were of heritage views, containing features which can be identified today, the oldest photo assessed was taken in the late 19th century.

In addition, pictures showing parts of the landscape before the construction of modern infrastructures were included. Most of the photos with a score close to 100 correspond to monuments "multi pictured" (e.g. the Er Lannic standing stones circles, with 30 photos or the Pont sal site with 6 photos).

This tourist area along the coast of Morbihan is covered by a set of 177 photos and postcards; however, some zones of the case study area are not represented. Tourism was often a result of the megalithic monuments, particlularly Carnac and these monuments are therefore regularly depicted. After 1936 as mass tourism developed we begin to see photographs and poscards of more general coastal scenes.

Img_ uid	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
125	Dolmen dans le marais de Pont Sal (Plougoumelen)	1908	High		Good	77
248	Er Lannic (Arzon)	1900-1930	High		Good	77
329	Rocher isolé à Port Blanc (Saint-Pierre-Quiberon)	1911		Medium	Good	100
316	Er Lannic (Arzon)	1923-1926	Medium		Good	100
412	Menhir de Mané er Hroueg (Locmariaquer)	1907	Good		Fair	88
415	Coffres de Mané Beker Noz (Saint-Pierre-Quiberon)	1913	High		Good	100
443	Port Melin (Groix)	1900-1925	High		Good	77
464	Entrée de la Citadelle (Port-Louis)	1900-1925	High		Good	100
468	Fontaine Sainte Radegonde (Riantec)	1950-1970	Medium		Good	55
541	Fouilles à Port Neuf (Hoedic)	1934	Medium		Fair	66
543	Fouilles à Er Yoc'h (Houat)	1926	Medium		Fair	66

Table 3K4.Top photos ranking results for the Quiberon-Morbihan area.

Figure 3K30. The tidal megalithic monument of Pont Sal (Plougoumelen) (cl. D'ault Du Mesnil/Z. Le Rouzic, (© Labo Archéosciences UMR 6566 CReAAH).

Many of the historic photographs assessed were taken by pioneers in scientific disciplines, many of which represent archaeological sites (including Megalithic monuments), and can tell us about coastal change and sea level rise (López-Romero & Daire, 2013). This is the case for the dolmen of Pont Sal (Plougoumelen), currently located in a swamp (river Bono) and regularly submerged (Figure 3K30). This is also the case from archaeological excavations carried out by M. and St.-J. Péquart in cooperation with Z. Le Rouzic on the Er Lannic island (Arzon), which allows you to see the restoration of the monument (documentary set of the Laboratory Archéosciences UMR 6566 CReAAH). Er Lannic is a symbolic and very early site illustrating sea level rise.

The Hoedic island (Mor Braz) remained relatively isolated (despite the presence of a permament population of several hundred people) untill 1930 as it was not a tourist location at this time. The pictures taken by the Péquart family, during their excavations of the Mesolithic cemetery in the 1930s are at the same time of archaeological interest and "ethnographic" (these photos have a "semi-private" status © Melvan and Institute of Paleontology).

These scientists sometimes took pictures of the landscape which can tell us about changes in the shoreline, particularly with infrastructure that will appear a few years later. The shoreline changes are noticeable in several places. Firstly the Etel bar (sandbar at the mouth of the estuary), which is visible at low tide but has a variable location (depending on winds and tides) and historic photos allow us to track this. Secondly, Port Melin on Groix Island, photographed before the construction of a dam in 1965, and finally the St. Radegund fountain, it was built in 1869 and was flooded at high tide, today, a new floor has led to the formation of a pond, where the tides no longer penetrate.

3K.4.3 Maps/Charts Ranking

Several historical maps exist of the coastline, with some dating back to the 17th century. It should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic maps and charts to provide information on coastal change, through a selection of 15 documents. A brief search of resources available online was carried out, although further research online, in museums, libraries and galleries, as well as private collections has the potential to provide many more.

The focus of the maps/charts study was on the Quiberon peninsula and the Gulfe of Morbihan but some of the maps consulted depicted the whole of the Morbihan region (Figure 3K31). The maps were assessed and digitised to create map regressions of the coastline, this was later combined with all other data sources.

Figure 3K31. Location of the maps assessed in the Quiberon-Morbihan case study area.

Most of the older charts assessed relate to trade and military defences. They often provide detailed information on harbours, shelters, watering places, as well as anchorages, rocks and major landmarks for navigation (e.g. coastal shipping). Defensive points along the coast are highlighted on the maps during the wars (e.g. 17th and 18th centuries with Port-Louis and its citadel). While further offshore the charts often depict currents and tides. Finally, with the establishment of the Napoleonic cadastre (19th century), the plots are shown in more accurate maps.

We also have an archaeological map by A. Devoir (Figure 3K33). This is not accurate at the coast, but we see details of megalithic monuments. This allows us to consider the older studies highlighting the evolution of the coastline with the representation of the "channel of Morbihan."

Finally, some of these monuments have been destroyed (or missing), which tells us about their archaeological condition.

MAP_uid	Title	Year	Score Chronometric Accuracy	Score Topographic Accuracy	Score Detail in non-coastal area	Score Geometric Accuracy
58	Orientations mégalithiques aux environs de Locmariaker	1890-1926	13.33	50	66.66	66.66
82	Ile Hédic	1746	13.33	16.66	33.33	33.33
83	Ile Hoedic	1886	6.66	16.66	33.33	50
84	Ile d'Houat	1886	6.66	16.66	33.33	50
85	Quiberon et ses îlots	1889	6.66	16.66	33.33	33.33
86	Belle-Ile, Houat et Hoedic	1857	6.66	16.66	33.33	50
87	Carte particulière des côtes de Bretagne : Depuis l'île de Groix jusqu'au Croisic, contenant Port-Louis, Belle-Isle et le Morbihan	1756	73.33	25	66.66	83.33
97	Carte du Morbihan et la presqu'île de Quiberon	1764	73.33	33.33	33.33	66.66
98	Carte hydrographique, topographique et archéologique du golfe du Morbihan et de son littoral	1869	66.66	66.66	66.66	100
99	Plan du Havre de Morbian	1680	20	38.88	33.33	66.66
110	Plan de l'isle d'Hedic	1693	73.33	33.33	33.33	66.66
111	Plan de l'isle d'Houat	1693	73.33	25	33.33	66.66
112	Plan du Port-Louis	1693	73.33	27.77	66.66	83.33
116	Carte Générale de l'Orient, le port Louis, l'isle de Grois et leurs Environs	1737	73.33	38.88	100	83.33
117	Carte des côtes de Bretagne, Quimperlé	1750	66.66	38.88	66.66	83.33

Table 3K5. Top ranking maps within the Quiberon-Morbihan case study area.

Figure 3K32. Section of the Cassini map (late 17th century) where the dunes are very well represented as well as the sand bar coming from the narrow part of the isthmus and the swamp which was filled in during the 18th and 19th centuries (source: Geoportail).

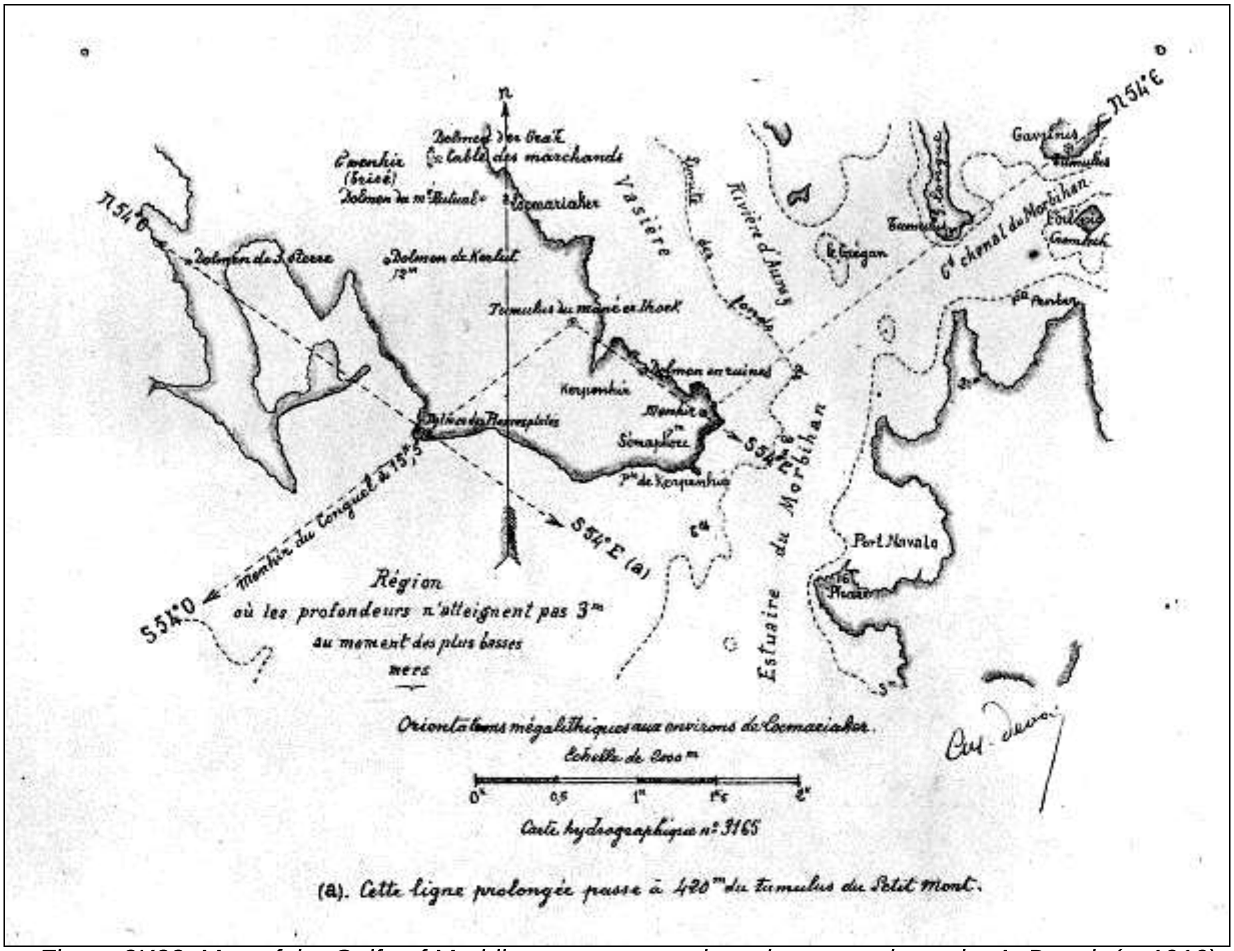

Figure 3K33. Map of the Gulfe of Morbihan entrance and southern part drawn by A. Devoir (c. 1910) (© Labo Archéosciences UMR 6566 CReAAH).

3K.5 Archaeological Fieldwork

Archaeological and palaeoenvironmental fieldwork was carried out on the Quiberon peninsula, this section outlines the field studies undertaken and the main results.

3K.5.1 Key Research Questions

The aim of the research was to determine the potential of archaeological and environmental data to inform on long term coastal change in the Quiberon area. The regional coastal changes were to be addressed on a long-term scale, with a very specific chronology for some periods, especially the Mesolithic and Neolithic.

3K.5.2 Approach to information gathering and fieldwork

The program dedicated to the Quiberon peninsula study area comprised detailed fieldwork (2011, 2012 and 2013) combined with desk based studies and analysis (radiocarbon dating combines with environmental). Various kinds of documentation have been used, as well aerial photos, ancient maps and charts and historic documentation, in order to retrace the environmental and human occupation history of this site. The fieldwork was comprised of several excavation campaigns on the Beg er Vil Mesolithic site (under the direction of Grégor Marchand and Catherine Dupont) and underwater surveys on the submerged structures and fish weirs off the Saint-Julien bay and Port-Haliguen harbour (by ADRAMAR in cooperation with L. Langouët).

3K.5.3 Archaeology Field Data Gathering Results

The selected sites in the case study area have provided detailed information illustrating coastal evolution around the Quiberon peninsula, with a special focus on the southern part, and a very detailed study of the Beg er Vil Mesolithic site (Marchand & Dupont, 2012 and 2013).

Concerning the archaeological sources, as mentioned above, data has been obtained from both terrestrial and submerged sites. The main results of the fieldwork are presented below within two sub-sections, the first summarizing the results gathered on the Beg er Vil Mesolithic site, the second one showing the contribution of the underwater surveys on the submerged fish traps located off Saint-Julien bay and Port Haliguen harbour (Le Ru, 2013).

3K.5.3.1 Beg er Vil, Quiberon

Location

At the southern end of the peninsula of Quiberon in the commune of the same name, the tip of the Beg-er-Vil site is open to the south bay, which is home to Port Maria and the main pier to the Mor Bras islands. The prehistoric site is located at the bottom of a small cove on the western flank of the rocky point at a height of only 5m NGF.

Figure 3K34. Location map of the Beg er Vil site (by L. Quesnel, after Manchand et al., 2013).

Why was the study site selected?

The Mesolithic site at Beg er Vil in Quiberon (Morbihan) is characterized by a remarkably well preserved shell midden, visible in the palaeo-cliff on the south coast of the peninsula. The site was occupied at the end of the 7th millennium BC and is very homogeneous and has not been affected by subsequent disturbance. The site contains unique evidence of the lifestyle of hunter-fisher-gatherers of Atlantic France, particularly during major climatic events of the Holocene. Rapid deterioration of the site caused by marine and anthropogenic erosion resulted in the establishment of a planned research program from 2012, held in collaboration with several research partners: CNRS, University of Rennes 1, Regional Service of Archaeology of Brittany, General Council of Morbihan, Arch-Manche Programme (Interreg IVA "2 Seas"), Mairie of Quiberon and Maison des Sciences de l'Homme in Brittany (MSHB).

Figure 3K35. View of the Beg er Vil site in 2013, from the south (after Manchand et al., 2013).

Marine resources have been exploited extensively, as evidenced by a layer of about 0.6m thick. This diversity reflects an opportunistic behavior of the Mesolithic population, who did not hesitate to exploit the diversity of the coastal environment. Beg er Vil is considered as a unique framework for study into the Mesolithic of the European Atlantic coast. Faunal remains from the site also provide very precise paleoenvironmental indicators.

This site is older than the well-known Téviec habitats and Hoedic-burial, but their inhabitants obviously shared the same techniques, traditions and the same symbolic thought.

Figure 3K36. Stratigraphy of the archaeological layer of the Beg er Vil site along the coast (after Manchand et al., 2013).

Geomorphological setting

Around the site, it is difficult to see the original layout, due to the dune cover and recent urban developments, but there seems to be a slight slope of the granite surface to the west and the ocean. In a network of geological fractures of south-west/north-east orientation that have been affected by marine erosion and the creation of the creek, a large flaw is significant, bordering the northwest Mesolithic habitat and may have once been a brook, now hidden by the dunes. This dune cover is thick (almost two meters at the site) and serves to support the current urban development. The site is located to the western part of a fossil beach dating to a previous interglacial stage (Figure 3K37).

What was the position of the Mesolithic settlement at the end of the 7th millennium BC in relation to the coastline of the time? Many geomorphologic studies are needed to answer this question; marine erosion, sand inputs and human developments have combined their effects to alter our perceptions. However, it is possible to offer a first glimpse from the bathymetric contours chart (SHOM - No. 7141S - Baie de Quiberon). For the record, the level 0 of Hydrographic and Oceanographic Service of the Navy (SHOM) corresponds to lower levels of spring tides, 5 m below the current level of the highest tides, in the light of the local value of tidal range. It is clear that this parameter is the most important for human occupancy. With a lower sea level of 12-15 m below the current level (Stephan, in Marchand, 2013), we must then consider the bathymetric curves -7m to 14m.

At this sea level it is possible there was an old cove between the basse Treac'h An and the existing rocks of Four. It is probable that the extensive Mesolithic habitat was at about 500 meters from the shore, maybe more if soft rocks or dunes grew in front of the coast. The slurred facing west or southwest slope should be significant. Even if the image can be surprising as the current coasts seem low, the Mesolithic habitat was placed in a dominant position in a radius of 2 km, or about 20 minutes walking. The west coast of the peninsula would have been beaten by swell and the more peaceful east coast were more easily exploitable. For the record, the Mesolithic site at the Téviec necropolis is located 10 km as the crow flies to the N/NW. The Hoedic necropolis, also famous, is 22 km to the southeast, but you must take a boat to reach this island camp today.

From 8200-8100 cal BP, all coastal floors therefore stood at a position between -14 m and 12.5 m compared to the current one. To achieve a first recovery of the intertidal zone, it is therefore necessary to reduce current levels of tide by 10 m. Thus, the low-water level of spring tides (LLW), currently set by SHOM at the 0.75 m level (SHOM, 2013), should be at the current depth between -13.25 m and -11 75 m. The highest water-level of spring tides was, meanwhile, at a depth that can be estimated between -7.15 m and -8.75 m.

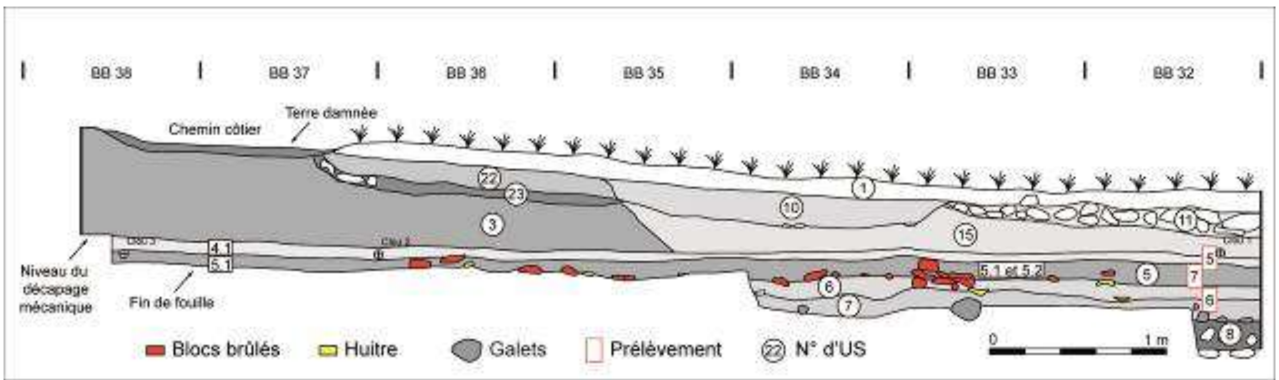

Figure 3K37. Stratigraphy of the archaeological layer of the Beg er Vil site (after Manchand et al., 2013).

Key coastal risk management issues for the frontage

A study of aerial photographs available (from 1932 to present) clearly shows the dynamic erosion of this part of the point of Beg er Vil (Figures 3K38 & 39). On its north side, the site would have declined by 6.4 m ± 0.86 m; but much less on the rockier south. A digital land survey has established the position of the site in its immediate environment. A total of 6000 measurement points corresponding to geographical and altitudinal dimensions (X, Y, Z) were obtained over an area of about 1.4 ha. A first reconstruction of paleo-coastal landscapes is then proposed, taking into account the most recent work that put the sea level between -15.5 and -11 m below the present (ie a tide of white water depth contour - 7.15 and -14.02 m).

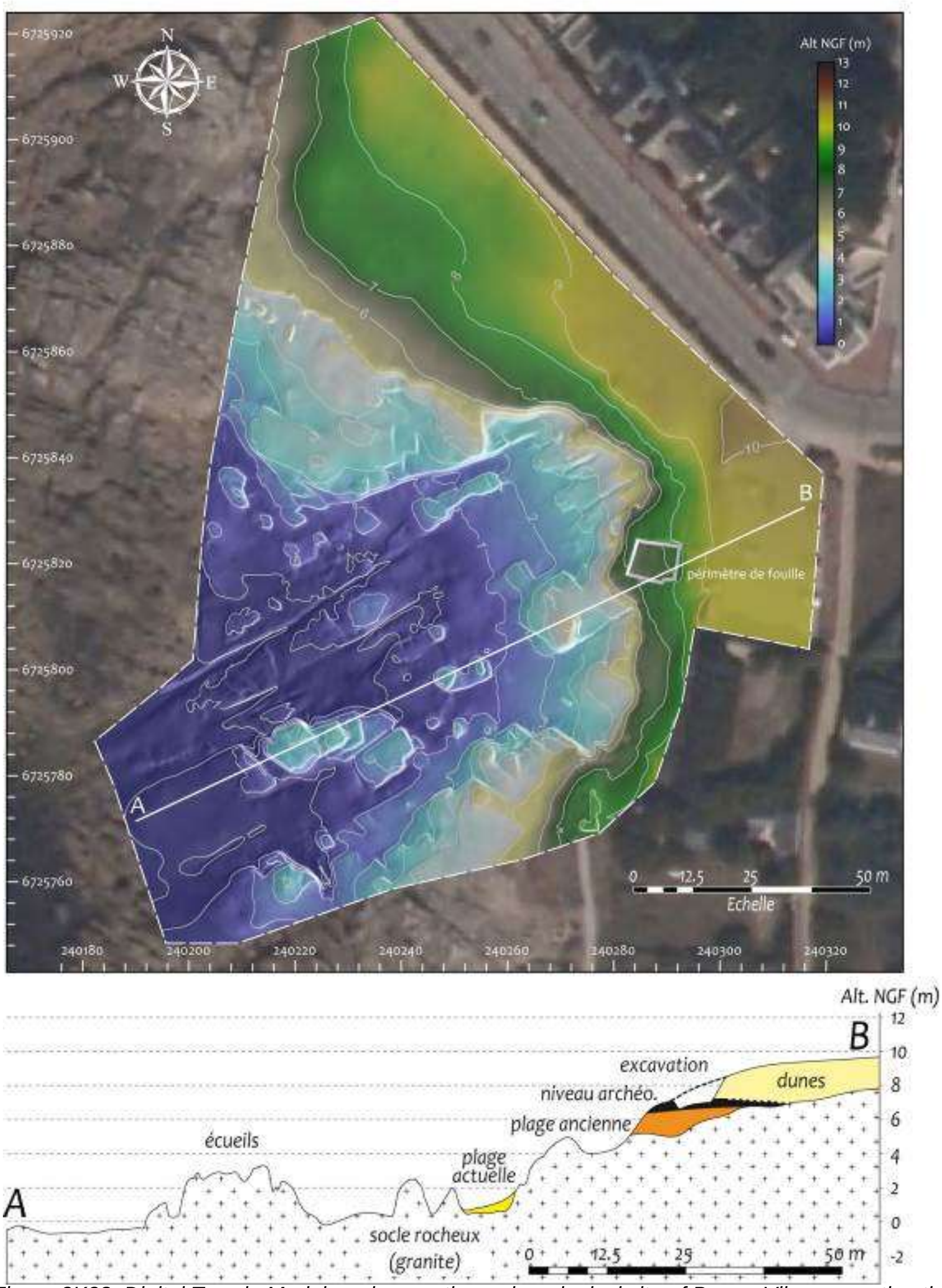

Figure 3K38. Digital Terrain Model made near the archaeological site of Beg er Vil representing the topographic modeling of the foreshore. Here, the terrain is superimposed on the coastal orthophoto taken September 28, 2011 at 10:40 (UTM) (Source: © Ortho Littorale V2 - MEDDE). A topographic profile was extracted from the DTM between points A and B (doc. P. Stéphan, after Manchand et al., 2013).

Figure 3K39. The Beg er Vil site in march 2011. Since 2007, the cliff coatal retreat is estimated to 1 m (cl. G. Marchand, after Manchand et al., 2013).

How the site can inform coastal risk management

Measures of the changes in the coastline were made from the DSAS (Digital Shoreline Analysis System) module in ArcGIS along 55 transects perpendicular to the shoreline and equidistant from 5 m.

By 1932, some private houses are present north of the site (Figure 3K38). One can observe further phases of construction as seen in 1964 and continuing to the present state (Figure 3K39 to 3K42). In the south, several buildings were constructed on the tip of Beg er Vil. In 1932, the houses north of the site are served by an unpaved road. In 1964, one can observe the paving and widening of the road. The construction of the roads is clearly visible (lots of materials on roadsides and land crossing to the east of the site). Since the general shape of the road has not evolved (adding a lane parallel to the pedestrian road), between 1964 and 2008, a car park adjacent to the site of Beg er Vil and probably covering parts of it was constructed (Figure 3K41).

From a general point of view, the coastline around the site of Beg er Vil has changed little apart from some very localized areas. Erosion seems more active in the bottom of the bay where the decline of the coastline locally reached 6.4 m ± 0.86 m. Thus, the values are very high between transects 25 and 40 and between 40 and 45 transects (Figures 3K47 & 48). However, the most advanced points were only slightly subject to erosion (Figures 3K44 to 46). These dynamics are likely explained by the micro topography of the foreshore.

The archaeological site of Beg er Vil is installed on a rocky massif. It was therefore relatively protected from marine erosion during the past eight decades. However, it has recently been affected on the northern edge (with erosion reaching this place 6.4 m ± 0.86 m) and to a lesser extent on its southern flank (Fig 3K47).

Beg er Vil Mesolithic site - Ranking score achieved: 100

Figure 3K40. Evolution of the coastline in the background with the image of Géolittoral 2011 (source Ministry of Ecology, Sustainable Development and Energy) The site of Beg er Vil is indicated by a red star (after Manchand et al., 2013).

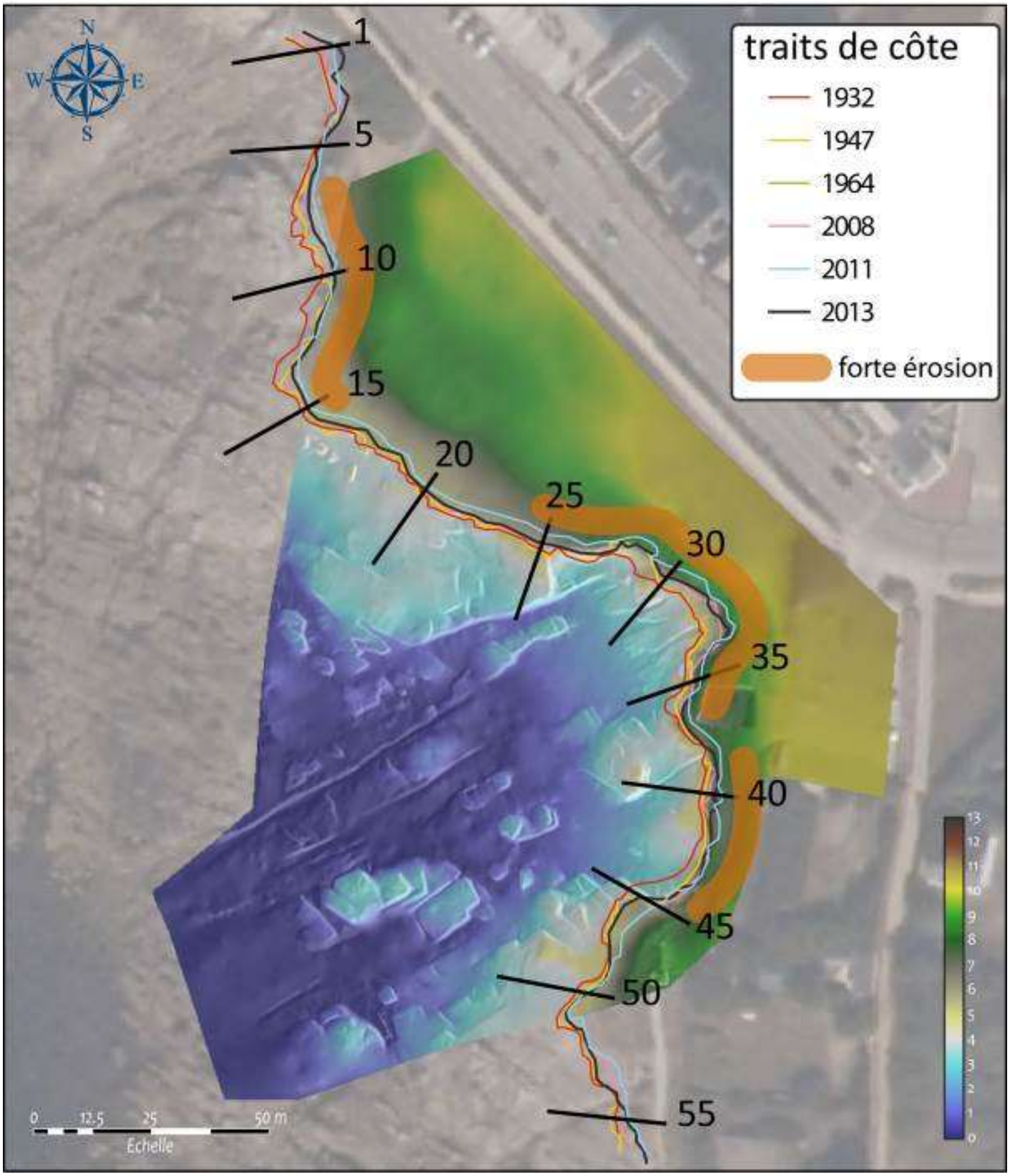

Figure 3K41. Kinematics of coastline around the site of Beg-er-Vil (doc. P. Stéphan, after Manchand et al., 2013).

Figure 3K42. Panoramic view of the Beg er Vil site from thevwestern bay (cl. Marchand, after Manchand et al., 2013).

Figure 3K43. The Beg er Vil site dunring the 2013 excavations, panoramic view from the North (cl. Marchand, after Marchand et al., 2013).

3K.5.3.2. Fish weirs of the Quiberon Peninsula

Location

All the fish weirs discovered along the coasts of the Quiberon peninsula are located on the eastern and south-eastern façade (Figure 3K44). The two fish traps of Port- Haliguen are situated to the north of the harbour of the same name and opposite the hamlet of Kermorvan. The four alignments at Saint-Julien lie opposite the hamlet of the same name and are of various types. Note, the tidal range in Quiberon Bay is about 4 m.

Why was the study site selected?

The purpose of the operation was to resolve two distinct issues. The first of these related to methodology because we wanted to see if underwater geophysical surveys are a pertinent method for studying fish- weirs that no longer dry out at low tide and add to the information already available, notably information collected during aerial surveys, archives and ancient texts.

The second was scientific because the fish weirs of Port-Haliguen and Saint-Julien are 4 of the 83 known fish traps that are permanently submerged and therefore their study requires the use of underwater archaeology techniques (Langouët and Daire, 2009). The intention was to supply the facts that would allow us to document these structures, to study their architecture and organization, and to determine their archaeological levels for the purpose of dating them. Giving that their location in a current submerged area, i.e. no longer reachable by dry foot, is by itself an indication of sea level rise since the time of their construction.

By virtue of their position, the zones of Port-Haliguen and Saint- Julien are subject to considerable environmental pressure and Port-Haliguen is also a site of intense anthropic activity. It is therefore probable that only the sturdiest of structures have survived.

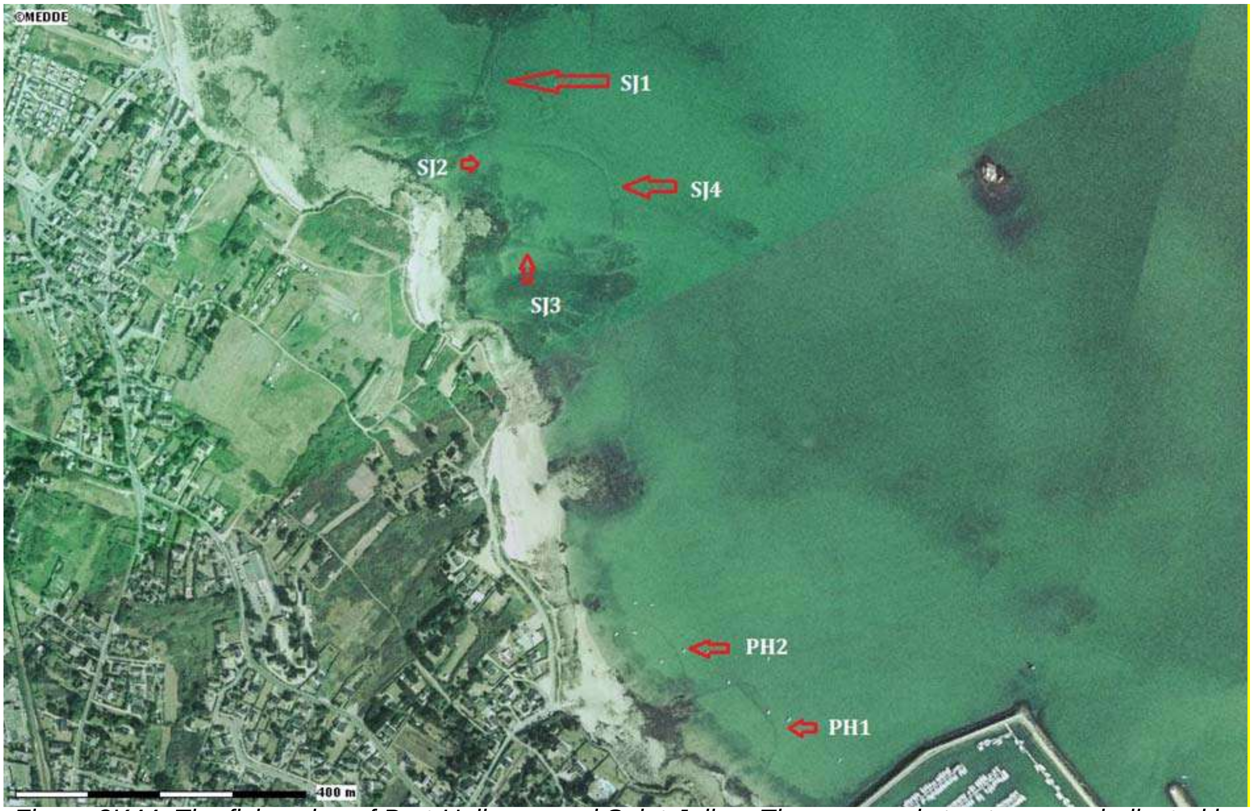

Figure 3K44. The fish weirs of Port-Haliguen and Saint-Julien. The surveyed structures are indicated by the red arrows and their names are written in white. View provided by Ortho Littorale 2000.

Methodology

Operations were timed to coincide with suitable tide levels. For the first part of the survey, the highest tides ensured we had sufficient water depth for our operations and allowed us to sail as closely as possible to the rip- rap and the coast without endangering the survey equipment and the boat. For the second part, the lowest tides were chosen for diving operations.

The location of the fish traps, which are obviously close to the coast, required us to take an unusual approach. In addition, the area in front of the Port-Haliguen fish traps is a roadstead. Maneuvering in the zone was, as a result, laborious. In terms of methodological approach, geophysical survey could be complemented with direct observation through diver survey, however, poor weather conditions meant that only limited dive operations were carried out.

Operations carried out by ADRAMAR (Le Ru, 2013) on these fish traps are able to provide new information on geomorphologic context and risks of the underwater and coastal area of the Bay of Quiberon. In this aim, several nautical and scientific mediums were involved during the 2013 campaign. Here is the main data and results of the 2013 field campaign.

Hermine-Bretagne is Adramar's support ship. Eighteen meters long, she is a research vessel specializing in underwater archaeology. Her shallow draught (1 m) allowed us to sail extremely close to the rocks during the survey. The vessel's role in the operation was to deploy and maneuver the geophysical devices (side- scan sonar, sub-bottom profiler). She was also used as a platform for the survey dives.

The objective of the survey was to:
- acquire a wide sonar mosaic of the zone;
- corroborate by GPS the precise location of the fish traps;
- generate geophysical data;
- determine the existence or absence of features near the fish weirs that are not visible from the air.

In the area of Saint-Julien surveys focused on two alignments, Saint-Julien 1 and Saint-Julien 4 because of the inability to sail above the alignments Saint-Julien 2 and 3. The erratic sailing routes resulting from the environmental conditions and the shallowness of the waters, which limits the useful range of the profiles but was offset by the satisfactory coverage, greatly affected the surveys. Nevertheless these problems did not prevent the identification of the alignments.

The side- scan sonar lived up to expectations in the sense that it allowed us to delimit the study zone by accurately locating and highlighting the characteristics of the fish traps. For example the duality of Port-Haliguen 1 is clearly visible. Acquisition through the side- scan sonar also allows for the remains to be studied in terms of height, length and breadth2. Thus, once the surveys were complete, the six rocky alignments at Port-Haliguen and Saint-Julien were identified and mapped.

Fish trap PH1 extends from 3°06.47' W – 47°29.39' N to 3°6.39' W – 47°29.34' N3. The doubling of the feature occurs at 3°06.42' W – 47°29.41' N and is about 15 meters long. We intended to observe this dual feature in greater detail but poor diving conditions prevented us from doing so. This alignment is between 1.5 and 4 meters wide with a length of 208.2 meters for the main alignment and 65.2 meters for secondary alignment.

Port-Haliguen 2 extends from 3°06.48' – 47°29.42' N to 3°06.55' W – 47°29.55' N and and measure between 1.2 and 2.6 meters wide and 135.3 meters long. The coordinates of Saint-Julien 1 are: 3°06.76' – 47°29.88' N to 3°06.76' W –47°29.82' N. The alignment has a width between 1.6 and 2.8 meters and a length of 105.4 meters.

Saint-Julien 2 is larger: between 1.4 and 4.1 meters and a length of 59 meters. Its coordinates are 3°06.74' – 47°29.80' N to 3°06.73' W – 47°29.77' N. Saint-Julien 3 has the same width as SJ2 and a length of 53.1 meters. Its coordinates are 3°06.71' – 47°29.73' N to 3°06.64' W – 47°29.72' N.

Saint-Julien 4 from 3°06.59' – 47°29.74' N to 3°06.66' W – 47°29.80' N with a width from 1.8 to 3.2 meters and a length of 144.4 meters. However for Saint-Julien 4, after taking into account the data acquired through sonar and the faintness of the trace, we extrapolated the final coordinate to be 3°06.72' – 47°29.79' N.

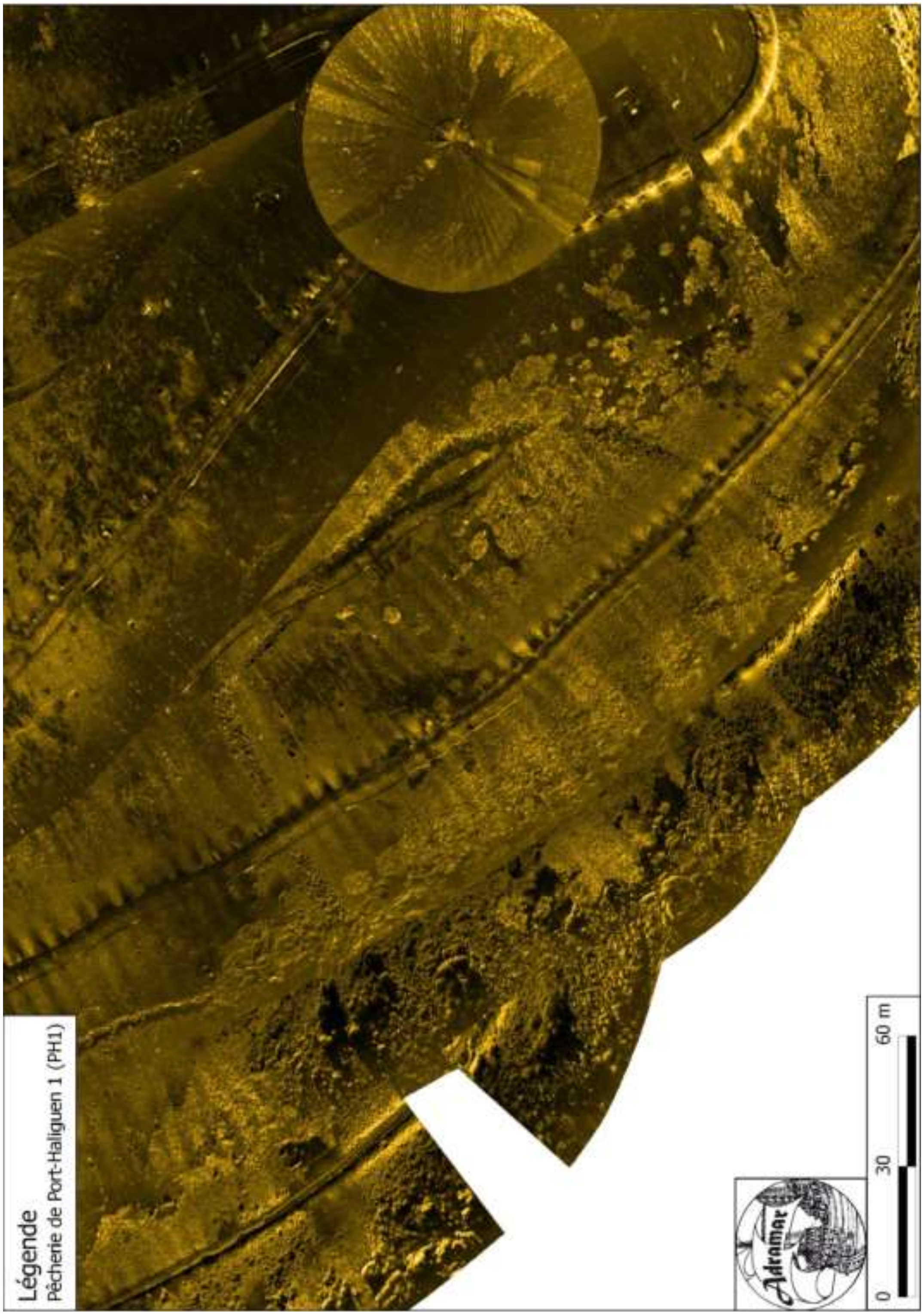

Figure 3K45. Sonar image of the fish trap Port-Haliguen 1 © ADRAMAR (after Le Ru 2013).

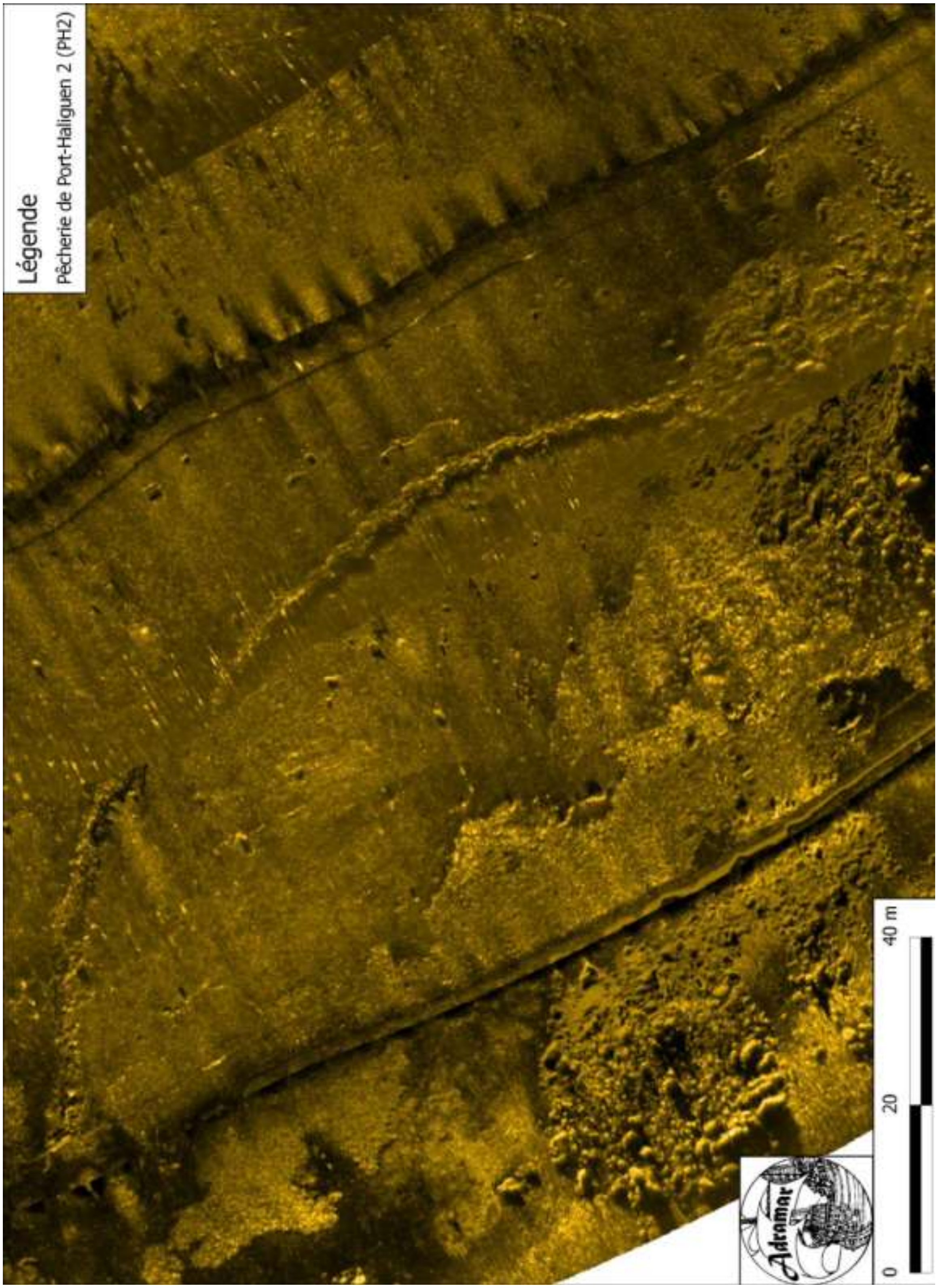

Figure 3K46. Sonar image of the fish trap Port-Haliguen 2 © ADRAMAR (after Le Ru 2013).

The failure to observe the remains directly prevents us from gaining accurate information about the architecture alignments but does not prevent us to learn the depth at the lowest dam point, which is critical to the understanding of the development period and implementation of the structure. Sonar surveys allow us to target and to bring information about areas more precisely because we know the date, time, water depth between tow fish sonar and its target, the height of the target and the depth of immersion of the tow fish. This allows us to determine the height of water above the point then apply a correction in relation to the value of the atmospheric pressure taken where necessary.

Thus, for Port-Haliguen 2 April 2, 2013 between 10:28 and 10:35 a.m. we can average a height of 4.7 meters of water. In Saint-Julien, same date, on the alignment of SJ1 between 9:46 and 9:48 a.m., can be determined by averaging all three targets, a water height of 4,6 meters. In Saint-Julien 2, at 11:35 a.m., the water depth is about 4.4 meters. Saint-Julien 3, there is an average of 4.5 meters between 11:35 and 11:40 a.m. However, Saint-Julien 4, on the same date at 9:46 a.m., the water depth is 4.1 meters.

We have to note also the considerable anthropic activity shown by the observation of lockers, berths and other debris on the sonar. There are 60 unidentified remains, excellent markers of the intensity of human activity on the study area and the potential risks it poses to the archaeological remains in the area.

Because of the uncertainty of the route taken during the sub-bottom profiler surveys, the sailing conditions mentioned above rendered the interpretation of the data and the identification of the features complex.

Contacts were classified as follows:
- Reliable contacts: these contacts that correspond to abnormalities in the structure of the rock alignment or nearby and are of particular interest.
- Unreliable contacts: these contacts are anomalies in the data but the data does not allow us to be certain of their nature (acoustic artifact, buried element etc.)

Rock alignments are sometimes visible in the data sediment penetrator. The detection of these rock alignments is evident when these alignments are located in sandy areas, as soon as you approach the rocky areas the differentiation between naturally occurring rock and alignments of fish traps is very complex or even impossible.

Four contacts have nevertheless been identified over the area of Port-Haliguen. These contacts do not appear to be an extension of the observed side- scan sonar structures. On the area of Port-Haliguen 1 there are 2 contacts. One is classified as reliable, the other as unreliable. Reliable contact (CF-2) is located ten meters from the rocky alignment Port-Haliguen 1. The latter indicates an abrupt change in the nature of the sediment at that location and was not observed anywhere else on the study area.

The unreliable contact (CPF-7) is located directly in the structure of the fish trap between 0.4 and 0.5 meters of trenching. This contact could correspond to a structural element in the fish trap with its intensity but could also correspond to an acoustic artifact as observed in the rest of the profile; this is why it classified as unreliable.

It also counts two contacts for Port-Haliguen 2. One classified as reliable, the other as unreliable (Figure 3K48). The unreliable contact (CPF-6) may correspond to a slight increase of the underlying sedimentary layer but is much more intense than the surrounding reflectors. It is also situated close to the alignment. The reliable contact (CF-1) is composed of two distinct but related segments. They both correspond to contacts that appear to delineate the fish trap in height and contacts of higher intensity. They can therefore be either buried fish trap structures or the boundary between the sedimentary layer and the underlying rock mass.

For the area of Saint-Julien, five contacts have been identified. They are all located on the alignment Saint-Julien 4. On SJ1, the quality of the data allowed us only to detect rock alignments on some profiles. It should be noted that these contacts do not appear to be an extension of the observed side- scan sonar structures. On the five detected contacts on the alignment SJ4, three are reliable contacts and two are unreliable contacts.

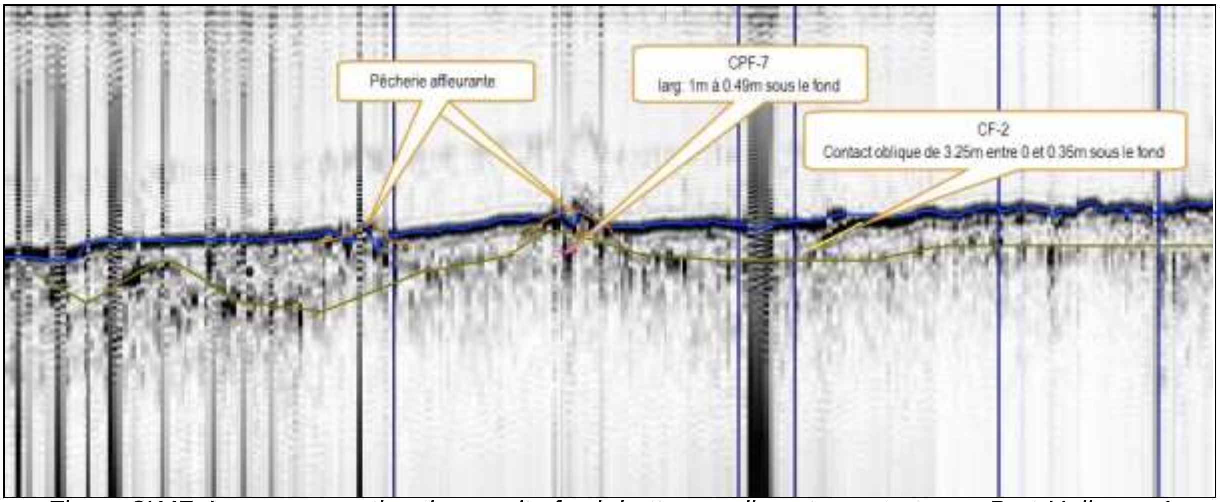

Figure 3K47. Image presenting the result of sub bottom sediment penetrator on Port-Haliguen 1 © ADRAMAR (after Le Ru 2013).

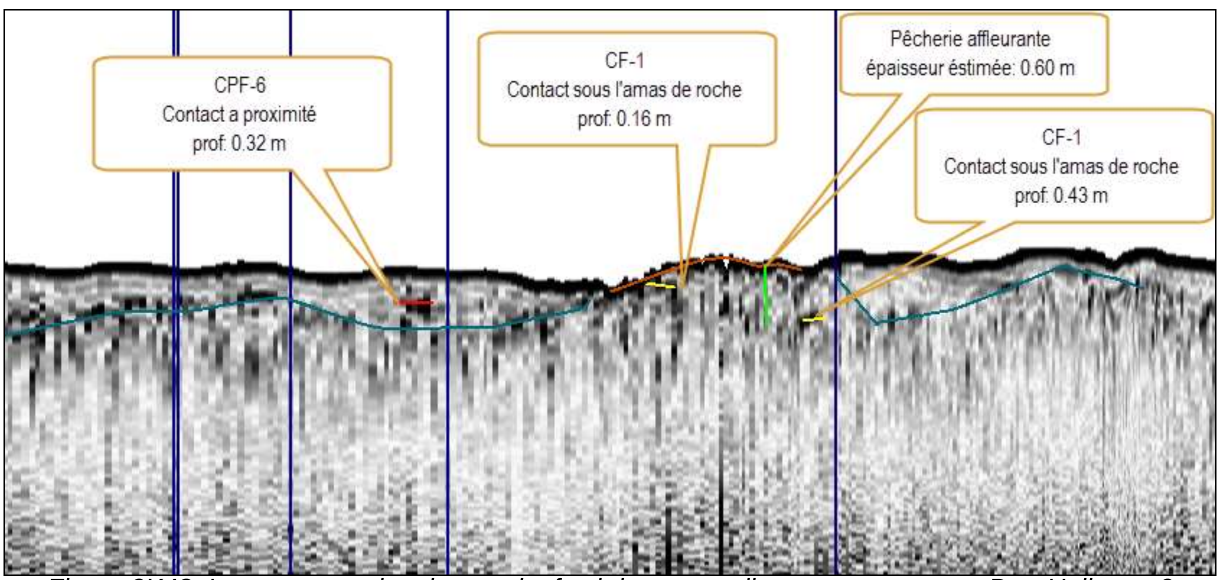

Figure 3K48. Image presenting the result of sub bottom sediment penetrator on Port-Haliguen 2 © ADRAMAR (after Le Ru 2013).

The contact CF-1 (Figure 3K49) is a frank limit at 0.56 m under the heap of rock forming the alignment. This limit could be either the limit of the mass of rock forming the fish trap or a fish trap component structure.

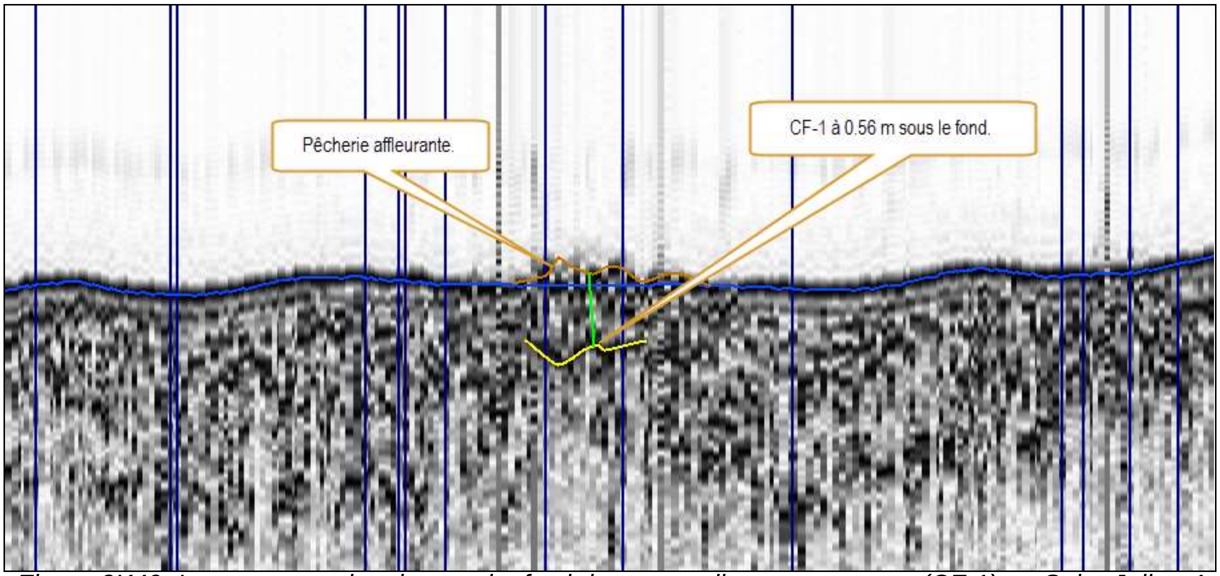

Figure 3K49. Image presenting the result of sub bottom sediment penetrator (CF-1) on Saint-Julien 4 © ADRAMAR (after Le Ru 2013).

Contact CF-4 (Figure 3K50) is composed of two linked contacts. Both contacts correspond to very sharp boundaries in the sedimentary layer and are very straight which does not seem to be of natural origin. These two contacts being located near the alignment, it is possible to correspond to a previous structure that is now buried. Their width is between 2 and 5 meters which correspond to the widths observed on the other surface alignments.

Contact CF-5 highlights a frank boundary with suspicious form. It is possible that this corresponds to a sedimentary layer but, inclination and intensity make a remarkable anomaly that could correspond to a structure or buried object. This contact is approximately 4 meters in length.

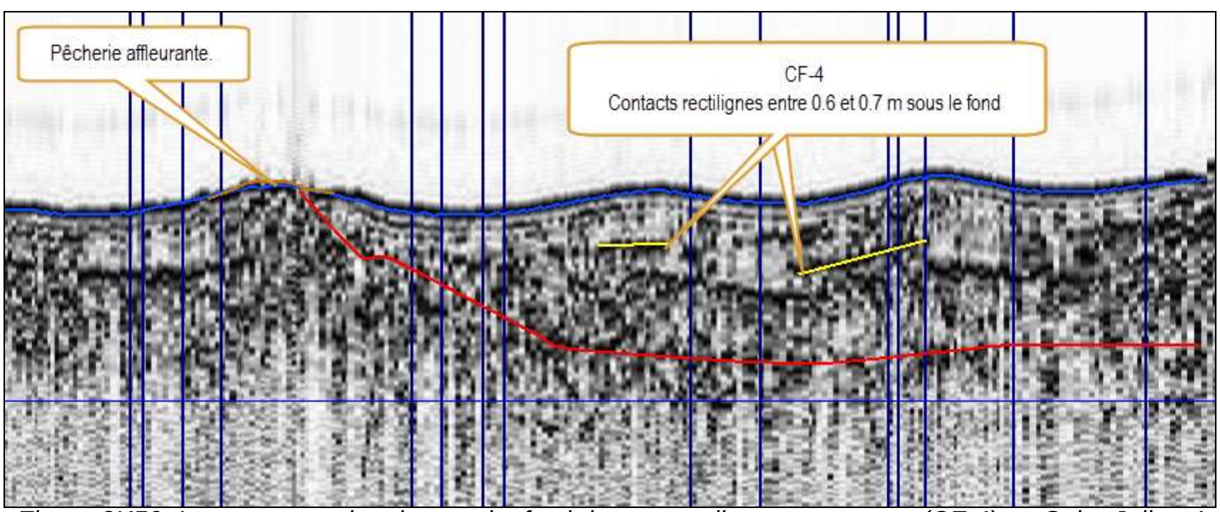

Figure 3K50. Image presenting the result of sub bottom sediment penetrator (CF-4) on Saint-Julien 4 © ADRAMAR (after Le Ru 2013).

Contacts CPF-8 and CPF-9 (Figure 3K51) correspond to two small contacts in the sedimentary layer surface. They are too small to match rows of rocks as observed previously but may be the subject of signing at least 2 metres and very different nature of their environment.

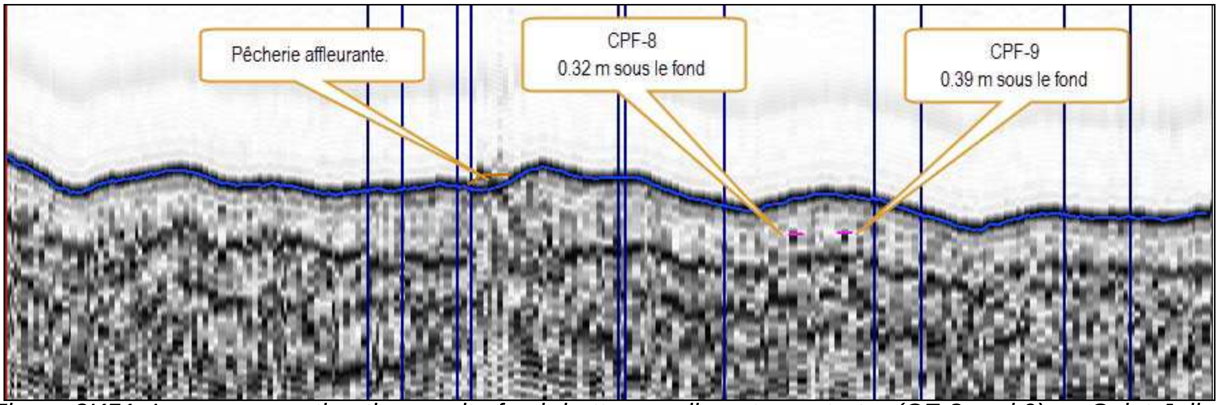

Figure 3K51: Image presenting the result of sub bottom sediment penetrator (CF-8 and 9) on Saint-Julien 4 © ADRAMAR (after Le Ru 2013).

Data from the sediment penetrator provides valuable information that should be explored further. Note that if on PH2 contact CF-1 corresponds to the base of the fish trap (Figure 3K48), as well as the CF-1 contact for SJ4, and the thickness of PH2 is estimated at 0.60 metres then information for a more precise dating of structures is available. Indeed, by adding these burial depths to depth measured at the base of fish traps and recorded during dives or measure the level of water which is available through sonar surveys, then we can more accurately determine the height of water above the point.

The six alignments were to be the subject of survey dives. To do this, several dive points were determined for each alignment; the purpose being to collect, at various places, the height of the feature and information relating to the stone structure. Unfortunately poor weather conditions prevented us from carrying out the dives which would have involved visual observation and measurements. Several buoys were installed but only two of them were used as starting points for dives and, because of the poor weather, underwater visibility was extremely limited.

The first dive was made on 3 April 2013 and lasted 3 min. because visibility was nil. On 6 April another dive was made despite a considerable quantity of suspended matter. An hour long dive in water at 6°C was made on part of the Port-Haliguen 1 fish trap, starting from the peak and heading towards the doubling. The dive began at 11 a.m. and, taking place during the rising tide, it was the depth closest to the end of the dive which was recorded. Thus at 12.15 p.m. at the base of the fish trap the depth was 3.6 metres. This dive was the only opportunity for us to take photographs.

After that, dives were made on 15 and 16 April but visibility was very poor, at best 20 cm, and this prevented us from making any useful observations. On 15 April the dive at 9.25 a.m. indicated a depth of 4.8 metres on the same section as that of the April 6 dive. The first part of the second section of Port-Haliguen 4 underwent visual survey during two dives on 16 April. The aim was to collect additional information on the dual part of the fish trap. Water depth at 9.39 a.m. was 4 m and 4.9 m at 9.40 p.m.

The dives that took place were therefore limited to the fish trap Port-Haliguen 1 and concentrated on two areas, both situated on the first section of the alignment: ALPH1_P01 and ALPH1_P028. The poor weather conditions prevented us from gaining an overview of the features and the very limited visibility prevented us from carrying out a satisfactory study of their architecture. However it was possible to observe a relatively well preserved structure. To the diver, the fish trap is legible and can be followed underwater. It is especially the case for the first part of the first section of the Port-Haliguen fish trap. Indeed the dives made on the last part of this section established that the feature was less dense and the blocks were somewhat scattered. Nevertheless the feature remained legible, visibility permitting.

In some places we noticed a difference in size and shape between the blocks on the edge of the feature and the infilling. Some of the outer bonding blocks were 80 to 120 cm long, were embedded in the substratum width wise and were inclined approximately 20°. The filling comprised blocks of either 20 or 50 cm long. The alignment was up to 5 m wide. The substratum seems to be very thin because our staking came up against a layer of rock, especially in the first part of the section. Was it the underlying rock or ballasting buried in the sediment? Staking on the last part of the section showed that the sediment layer was thicker.

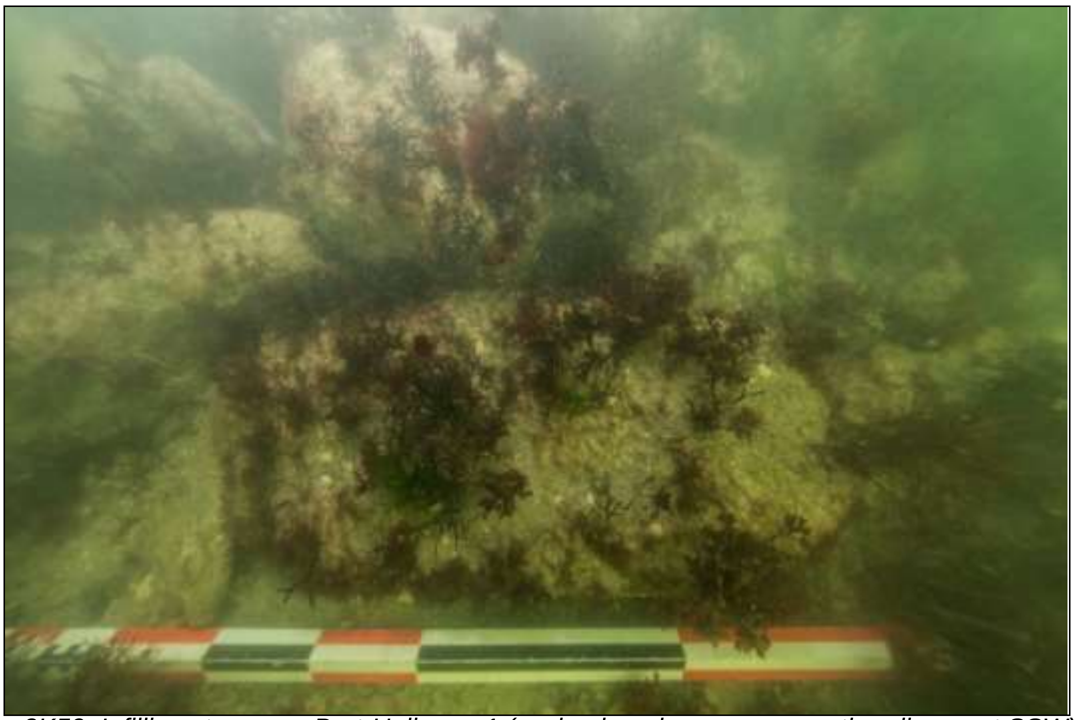

Figure 3K52. Infilling stones on Port-Haliguen 1 (scale placed crossways on the alignment SSW) © T. Seguin /ADRAMAR (after le Ru 2013).

Quiberon fish weirs - Ranking score achieved: 88

3K.6 Art Field and Research Studies

As mentioned above, this area has been depicted through various media including; paintings, photos, maps and charts. For each kind of data source, field studies helped us in the analysis of the informative value of the pictures as illustrations of coastal change in the Quiberon peninsula case study area. The main results are presented below.

The art approach partly took profit from the academic work led by E. Motte (Motte, 2013) in the Rennes 2 university. This work was completed by consultation of several art books and online resources (e.g. Joconde database). Ancient postcards used for the project were available either in private collections or though online resources; the main part of the ancient photos illustrating this coastal area belongs to the Archéosciences laboratory collection (university of Rennes, ICARE project; López-Romero and Daire, 2013).

3K.6.1 Key Research Questions

The aim of the research was to understand what kind of information the selected datasets can provide and how informative they are regarding past coastal change.

3K.6.2 Approach to information gathering and fieldwork

Concerning art, the academic work of E. Motte partly consisted of a comparison of the paintings or artistic representation with the real current landscape, based on a geomorphologic approach, with detailed measurements and depictions (Motte 2013).

Sites represented on ancient photos were also subject to a field approach, comparing the current situation with the one pictured in the late 19th century and the early 20th century images; in this approach, when possible, several photos of various dates taken from different angles have generally been compared; we will present below a synthetic result.

Historical maps in this area have been compared with present and with historical satellite images in order to assess the conditions of the coastline and changes that may have taken place over time. The IGN Database provides a huge collection of aerial views of Brittany from 1947, which have been compared with the aerial views of Brittany provided by GeoBretagne.

3K.6.3 Art Field Data Gathering Results

The selected sites in the Quiberon peninsula and southern Morbihan case study area were chosen to reflect various geomorphological features and to understand the coastline changes and human impacts.

For the various artworks the fieldwork element has been largely visual in terms of identifying the location of the paintings and making judgments, on site, of the role that art can fulfill as a qualitative or quantitative tool to support coastal risk management.

The main focus for the maps and charts has been the examination of one particular map and to make an assessment of what it tells us about changes over time from field observation. However, for some of the study sites it has been found that the area is depicted in several maps. This helps us to establish a chronology of coastal change through the eighteenth and twentieth centuries. The results for each case study location are described below.

K1. Pêcheurs ramassant leur senne près de l'isthme de Penthièvre, by Elodie La Vilette, 1880 (Figure 3K53).

Location
The painting represents a section of the Penthièvre isthmus, which is located in the Northern part of the Quiberon peninsula (Figure 3K53).

Why was the study site selected?
The painting has been selected because it is one of the rare artworks showing a settled area, as more often painters of the Quiberon peninsula have shown the wild rocky coast (see below).

Geomorphological setting
The isthmus is composed of sandy dunes which is the main visible feature (see above).

Key coastal risk management issues for the location
The issues for the coastal risk management combine here the pressure of erosion on the soft rocks and dunes and the urbanization and construction linked to human activities.

How the artwork can inform coastal risk management
The painting shows a quay and port constructions, linked to fishing and seaweed gathering activities and depict the anthropic pressure on this landscape. The comparison with the current view indicates that vegetation is growing in this area (Figure 3K53); this may be a positive things as plants can contribute to the stabilization of dunes.

Where can the original artwork be viewed?
Département des Arts graphiques du Louvre

Pêcheurs… près de Penthièvre - Ranking score achieved: 48

K2. Quiberon, cavernes de la côte sauvage, by Christophe Paul de Robien, 1753-56 (Figure 3K54).

Location
The painting represents the rocky wild coast of the Quiberon peninsula, located on the western façade facing the ocean.

Why was the study site selected?
This picture has been selected as it one of the most ancient paintings depicting this area.

Geomorphological setting
The main geomorphological setting is the natural grottos, cut into the granite cliffs, and visible on the painting.

Key coastal risk management issues for the location
The main coastal risk management in this area is linked to the natural coastal erosion, even if it is less active on the rocky cliffs than on the sandy dunes.

How the artwork can inform coastal risk management
As it was drawn by E. Motte in her analysis of the painting (Motte 2013), the artist has exaggerated the size and visual importance of the grottos, compared to the current reality

(Figure 3K54) However, the existence of the grottos is itself an indicator of the erosive tendency of the cliff body, along this wild coast which is very exposed.

Where can the original artwork be viewed?
Département des Arts graphiques du Louvre

Quiberon, caverns de la côte sauvage - Ranking score achieved: 51

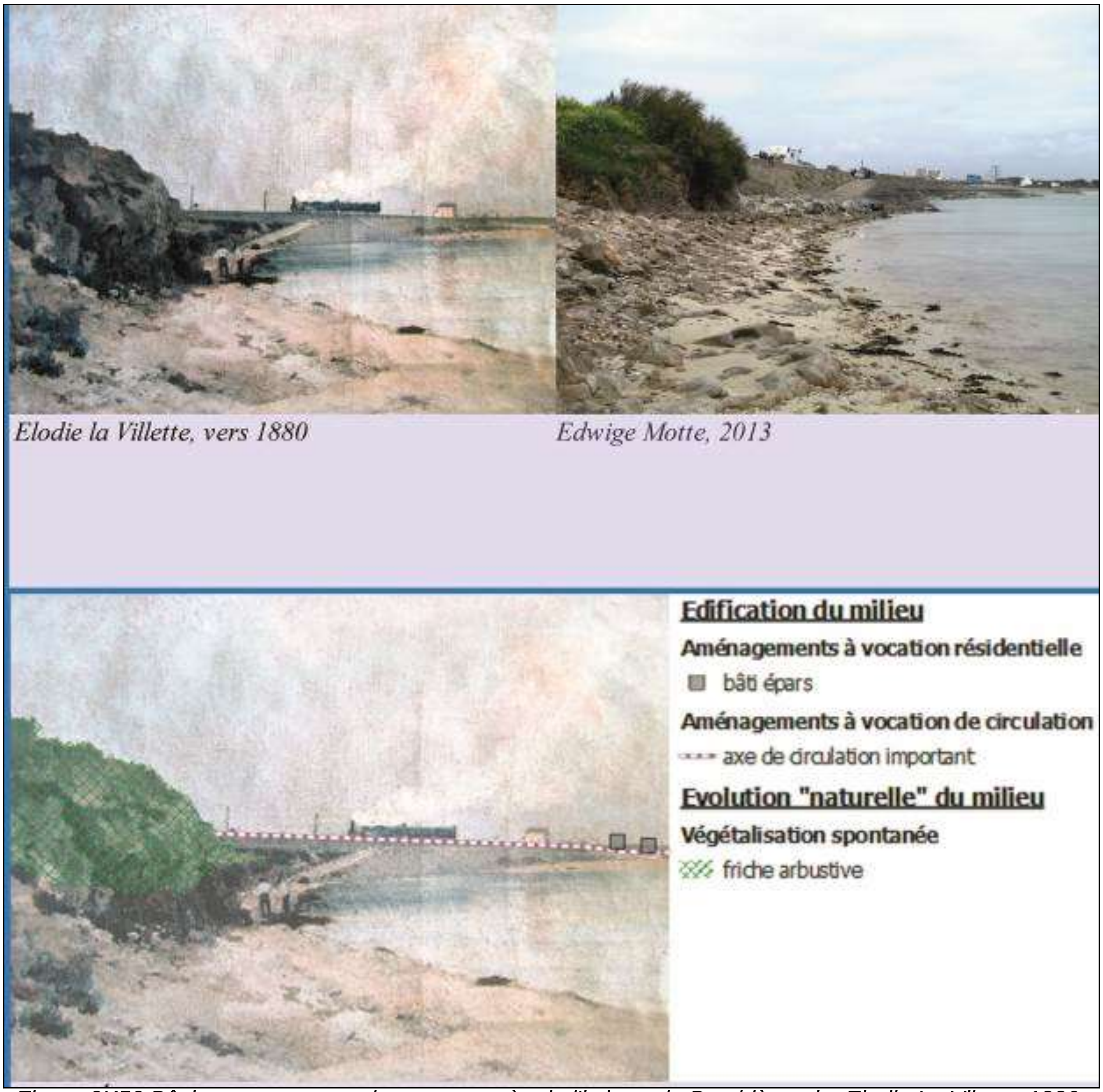

Figure 3K53 Pêcheurs ramassant leur senne près de l'isthme de Penthièvre, by Elodie La Vilette, 1880, analysis of the painting by E. Motte (after Motte 2013).

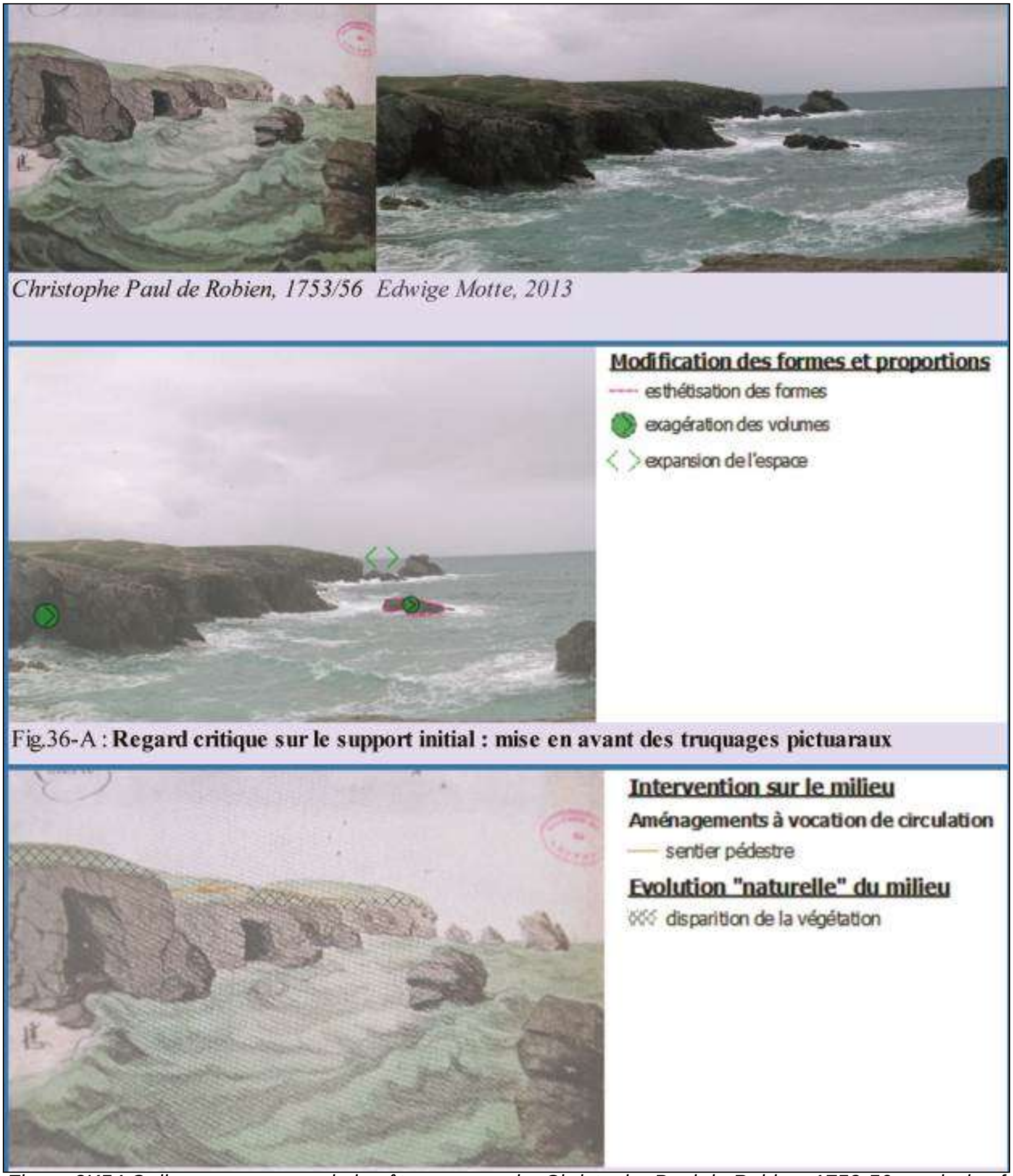

Figure 3K54 Quiberon, cavernes de la côte sauvage, by Christophe Paul de Robien, 1753-56, analysis of the painting by E. Motte (after Motte 2013).

K3. La crique de Port-Bara, by Elodie La Vilette, c. 1880 (Figure 3K55).

Location
Port Bara is one of the scarce beaches located on the western coast of the Quiberon peninsula.

Why was the study site selected?
The painting has been selected as it provides a detailed view of the rocky cliff, with a tendency to certain realism (Figure 3K55).

Geomorphological setting
The painting represents a sandy beach the Port-Bara which is located at the foot of a rocky (granite) cliff.

Key coastal risk management issues for the location
The main coastal risk management in this area is linked to natural coastal erosion, even if it is less active on the rocky cliffs than on the sandy dunes.

How the artwork can inform coastal risk management
Only slight cliff erosion but no major change can be visible along this part of the rocky coast of the peninsula, which is more resistant to erosion than the sandy dunes. The changing aspects of the beach are due to the annual movements of sand, the quantity of which generally diminishes during winter and comes back in spring.

Where can the original artwork be viewed?
Département des Arts graphiques du Louvre.

La crique de Port-Bara - Ranking Score achieved: 48

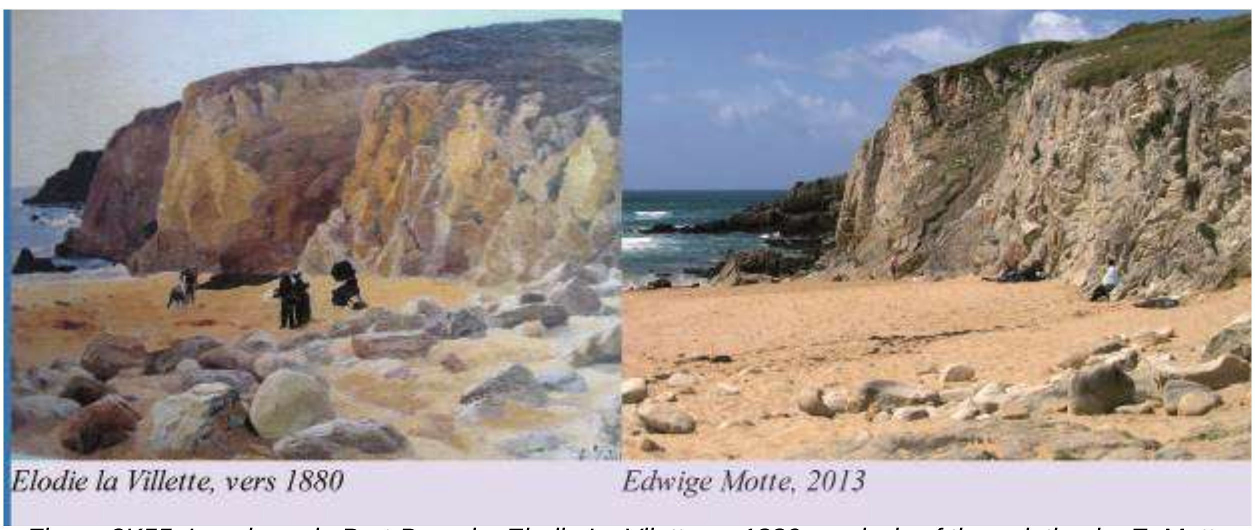

Figure 3K55. La crique de Port-Bara, by Elodie La Vilette, c. 1880, analysis of the painting by E. Motte (after Motte 2013).

K4. L'arche de Port Blanc, presqu'île de Quiberon, by Maxime Maufra, c. 1880 (Figure 3K56).

Location
Port Blanc is located on the western coast of the Quiberon peninsula.

Why was the study site selected?
The site has been selected as it shows one of the typical erosive features of the western rocky cliff of the wild coast of Quiberon peninsula, i.e. the famous "arch" of Port-Blanc.

Geomorphological setting
The geomorphologic setting is the granite rocky cliff of Quiberon, along its western coast.

Key coastal risk management issues for the location
The main risk in this area is erosion of the granite cliffs.

How the artwork can inform coastal risk management
The artwork represents a rocky arch, formed in the granite cliffs by the waves and the swell. The current view (photo on Figure 3K56) shows a wooden barrier, the presence of which corresponds to a risk management measure, designed to protect visitors as well as the natural site.

Where can the original artwork be viewed?
Private collection.

L'arche de Port-Blanc - Ranking Score achieved: 44

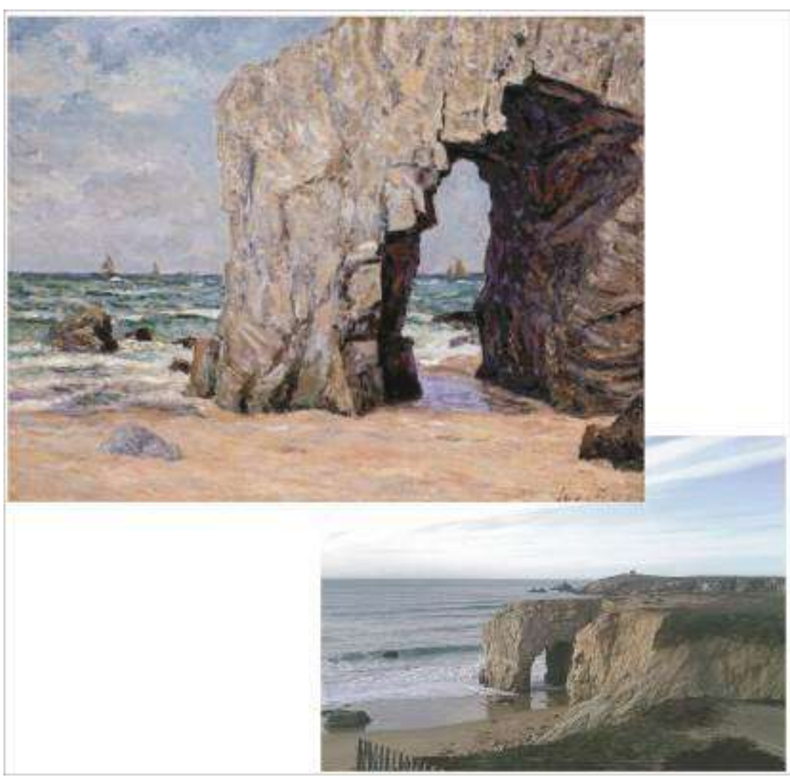

Figure 3K56. L'arche de Port Blanc, by Maxime Maufra, c. 1880, and the current view of the site (source: Wikipedia).

3K.7 Analysis

The Quiberon peninsula study has combined the use of archaeological and palaeoenvironmental data, paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve our understanding of coastal change in the long and short term.

3K.7.1 Archaeology and Heritage Features

Many studies are still needed before we can have all the information necessary for the reconstruction of past landscapes and environments of the Quiberon Peninsula. Topographic surveys conducted at the archaeological site of Beg -er- Vil cover only a very small area and are particularly difficult to obtain due to a very chaotic morphology. Also, Lidar data promised on the French coast in the Litto3D program are eagerly awaited as they will read, both fine and large tracts of coastal landforms. This topographic data should be extended seawards by bathymetric surveys at high resolution using multi beam. This information will then satisfy the needs of specific morphological data in sub- tidal areas. As such, we can already welcome the measurement campaign carried out by Adramar which will clarify the nature of the seabed in the area.

In the Quiberon Bay, in depths ranging between -5 and -15 m below low water spring tides, the sedimentary cover contains valuable information on coastal environments and their evolution since 10,000 years ago. Coring conducted by Marion Dufresne confirms: 5000 years of environmental history are preserved (from 9700 to 4300 cal BP), in about 9 m of marine sediments. Pollen and foraminifera contained in this core are under study and should help to refine the paleogeography. To extend this approach, new cores would be necessary, at lower depths. Indeed, coverage of between 0 and -5 m deep sediment was never truly investigated, due to the difficulty of whether coring shallow depths. However, we assume that it contains organic deposits that would more accurately reconstruct ancient shorelines.

Geomorphological setting

Sub-seabed immediately south of the peninsula of Quiberon presents the two main morphological sets that characterize the Breton Précontinent.

1. The rocky spine 'prélittorale' in the Peninsula and its offshore extensions in the direction of Houat and Hoedic islands (Teignousse and Béniguet paths). Shoals are limited to the south by an escarpment fault oriented N120 morphological barrier. This barrier is cut in four places by tidal passes orientation at N30 passages Teignouse (51 m) of Béniguet (20 m) , Sisters (15 m) and between Hoedic and Basse Guérin (30 m). The transition from Teignouse forms the deepest notch and corresponds to a fossil valley. It is marked by particularly strong submarine slopes (between 5 and 10%), reflecting a deep incision of an ancient river organization in the bedrock. Menier (2004) showed that during phases of low sea level of the Pleistocene, the Vilaine and its tributaries then flowed through this narrow valley (whose width does not exceed 1 km) and would extend to the sea more to the west.

2. The pre-coastal depressions are located on either side of the Quiberon Peninsula and are marked by gentle slopes, between 0 and 0.25%. On the west side of the peninsula, the finds are mainly rocky since the wave action limit the sedimentation and reveal the base on a large area (plateau Birvideaux). On the east side, however, low hydrodynamics inside the bay of Quiberon resulting in muddy, rocky flats belted near the coast.

The outline of the palaeoenvironmental history of the region is now well known thanks to recent work by marine geologists in the Mor Bras (Proust *et al.* , 2001; Menier, 2004 ; Sorrel *et al.* , 2010). During the phase of low sea level of the last glacial maximum (about 20,000 - 18,000 BP) , the whole " Précontinent Breton " was part of a continental system , traversed by a network of valleys incised into the bedrock. As we said earlier, the Vilaine flowed offshore to the west of the peninsula of Quiberon in the current pass through the Teignouse. It received the waters of many tributaries that now drain the Gulf of Morbihan and the small estuaries of Crac'h St Philibert, Auray. In the main valleys and interfluves, coastal rivers deposited sand and silt before the sea began its ascent.

At the beginning of the Holocene, the fluvial system gradually gave way to a river-estuary system. The sea flooded the valleys and at the interface between the river and the sea, where fluvial currents lose their jurisdiction and where the sea penetrates daily, muddy material rich in marine shells was deposited in thicknesses of 5 to 10 m. This estuarine phase is likely staggered between 10 000 and 7000 cal. BP, gradually winning the upstream portion of the valleys as the sea level rose. It is in this time range that is the occupation phase of the Mesolithic site of Beg er Vil, at a time when the rate of sea level rise is still high (about 0.8 cm / year to globally) and where, throughout the Mor Bras, valley bottoms rapidly transformed.

Thereafter, the rates of sea level rise slowed (around 6500 cal BP) and without the shoreline gradually stabilized. Marine silt continued to accumulate in the shallows, while in the upper part of the foreshore area Neolithic bog existed which is today located just below the LLW, as evidenced by peat deposits discovered at the bottom of the foreshore of the small Rohu (Gaudin, 2004; Cassen *et al.*, 2010), to Kerpenhir (Visset *et al.*, 1996) to Kerbougnec (Marsille, 1930).

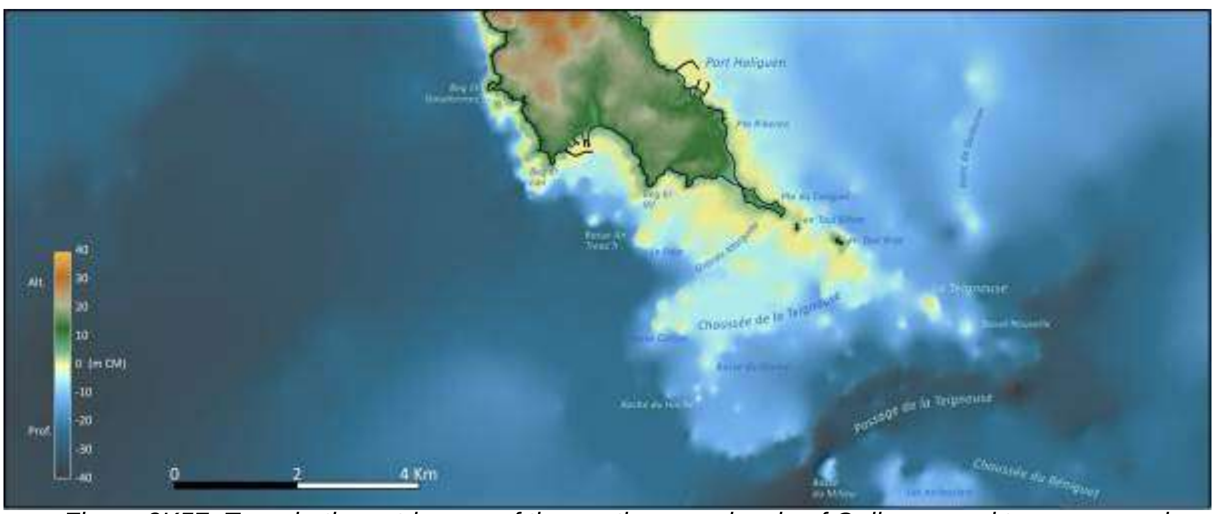

Figure 3K57. Topo-bathymetric map of the southern peninsula of Quiberon and toponymy major seamounts (doc. P. Stéphan, after Manchand et al., 2013).

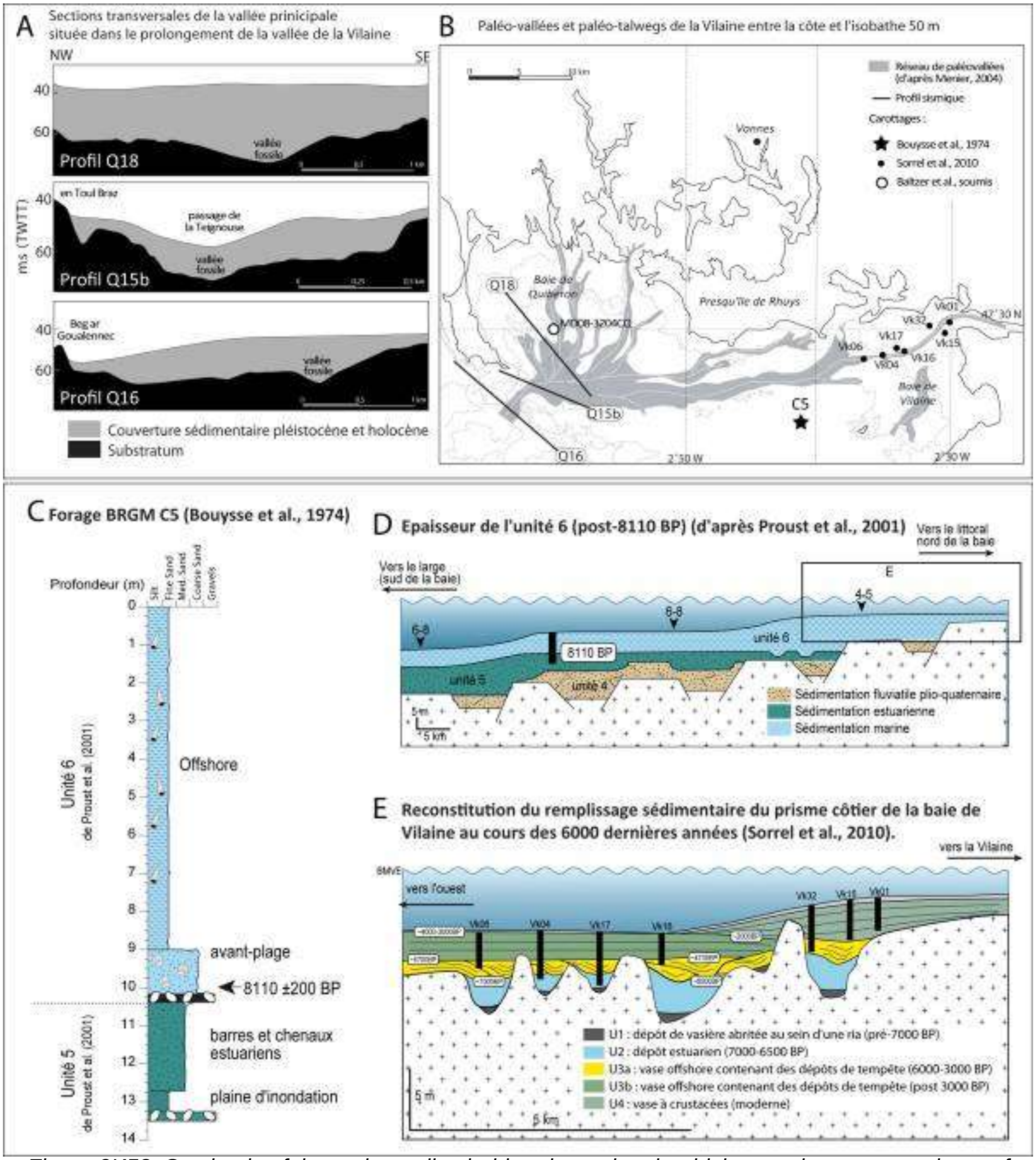

Figure 3K58. Synthesis of the main studies held to determine the thickness, the nature and age of submarine sediments between the Quiberon Peninsula and the Bay of Vilaine (A and B: modified Menier, 2004. C: modified Bouysse et al, 1974; modified. D: Proust et al, 2001. E: amended Sorrel et al, 2010) (doc. P. Stéphan, after Manchand et al., 2013).

3K.7.2 Artistic Depictions

Following the research and location of a quite small number of artistic images of the coastline along the Quiberon study area we have underlined their relative importance in terms of their value in informing on long and short term coastal change. The art case study area only provided some focuses on specific areas, especially the wild coast on the western façade of Quiberon peninsula.

Although not a comprehensive study, several historic photographs and maps were also assessed. In addition, some modern postcards dating from the tourism development during the early 20th century (Figure 3K60) have promoted the natural landscapes of Morbihan and especially the Quiberon peninsula.

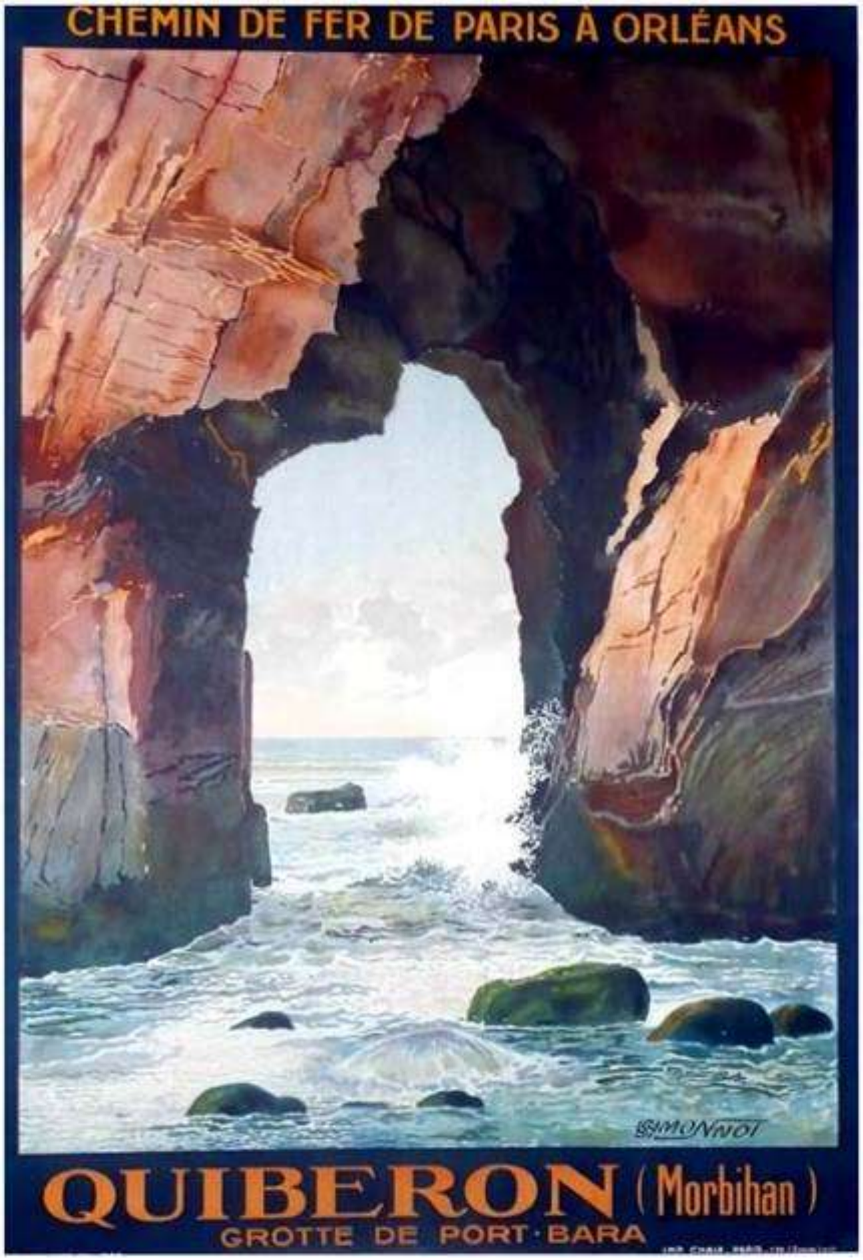

Figure 3K59. Quiberon, grotto of Port-Bara" by L. Symonnot - 1929 (source vintage-posters-gallery.com).

3K.7.3 Combined Resources

The Er Lannic megalithic monument, Gulf of Morbihan.

Located on the Atlantic Armorican facade, the gulf of Morbihan means “small sea” in Breton. It is a small inland sea, closed by the peninsula of Rhuys, which covers 12.000 hectares. Among the hundreds of islands and islets which the gulf counts, about thirty are inhabited.

The gulf is a highly touristic area, well known for its megalithic monuments: standing stones, passage graves, monumental burials and cairns make up the richness of the prehistoric heritage. Several of these monuments, e.g. the 60 m wide cairn of the Gavrinis Island became gradually isolated from the mainland because of sea level rise. Another example is the twin standing stone circles on the Er Lannic islet, which now appear partially submerged.

The 2 main islands, “’île d’Arz” and the “’île aux Moines”, are charming by the diversity of their landscapes and natural environments. The gulf of Morbihan is home to thousands of hectares of rocks, beaches, herbaria, salt-springs and also more than 100,000 birds: stilts, egret, goosander, gulls, seagulls, etc. These unusual landscapes move according to the rhythm of the tides. The gulf is also a place for fishing (fish and shells); it features a famous oyster center with an orientation towards the production of oyster spats. The images (Figure 3K60) show various aspects of the landscape, as well as its evolution during the past millennium, especially the importance of sea level rise for this flat where former palaeovalleys were progressively invaded by sea water and isolated the hills that then became islands and islets.

On the islet of Er Lannic, 500m (0.3mi) south of Gavrinis, there are two stone circles, both made of some 60 stones (Figure 3K61). They are now half submerged by the waters of the Gulf of Morbihan, but in prehistoric times they stood on the mainland. Only the northern circle can be seen, the southern one being entirely submerged. Er Lannic is now a Bird Reserve and cannot be visited, so the northern stone circle is visible only from the air or by boat. This circle, half submerged, is 65m (213ft) in diameter and its stones are 2 to 5.4m (6.5 to 17.7ft) high.

The site was excavated in the 1920s by Zacharie Le Rouzic, who calculated that Er Lannic had been erected about 5000 years ago. He found around each stone a cist containing charcoal, animal bones, worked flints, pottery, and a lot of polished axes. Two stones are carved with axes and a yoke, and one of the uprights' packing stones has nine cupmarks (according to Le Rouzic, arranged to form the outline of the constellation Ursa Major). The southern submerged stone circle is horseshoe-shaped open to the east, 61m (200ft) in diameter.

Two outlying stones, now fallen and below the water, lie east and west 50m (164ft) and 90m (295ft) from the circle, on a line tangent to the visible ring's northern corner, marked by the highest stone of the circle (5.4m - 17.7ft). At the southern tip of the submerged horseshoe there was a great pillar called *the blacksmith's stone* by fishermen (Gouezin & Le Gall 1992). These lines to cardinal points had probably some astronomical connections, presumably to the moonsets (sources: http://www.stonepages.com/france/erlannic.html and Labo Archéosciences UMR 6566 CReAAH).

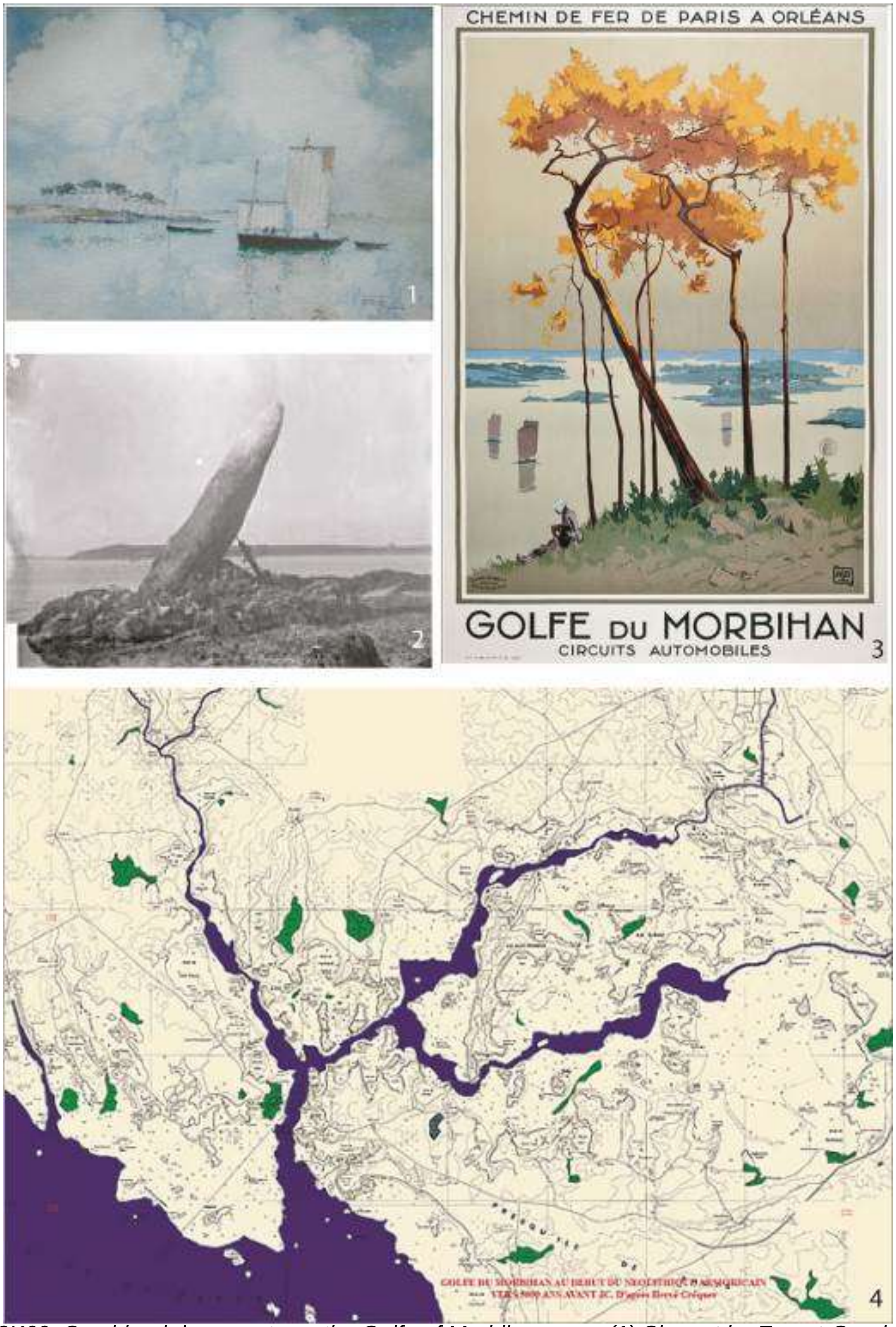

Figure 3K60. Combined documents on the Gulfe of Morbihan area. (1) Sinagot by Ernest-Guerin (1887-1952), (2) The Er Lannic megalithic site during the restoration by Z. Le Rouzic (c. 1920), (3) Golfe du Morbihan, porter 1927 (source http://www.vintage-posters-gallery.com/fr/affiches-de-la-bretagne-htm), (4) Schematic map produced by shifting the bathymetry of 10 meters and incorporating qualitative sedimentation phenomena and deepening (source: http://www.ileauxmoines.fr/articles.php?id=25).

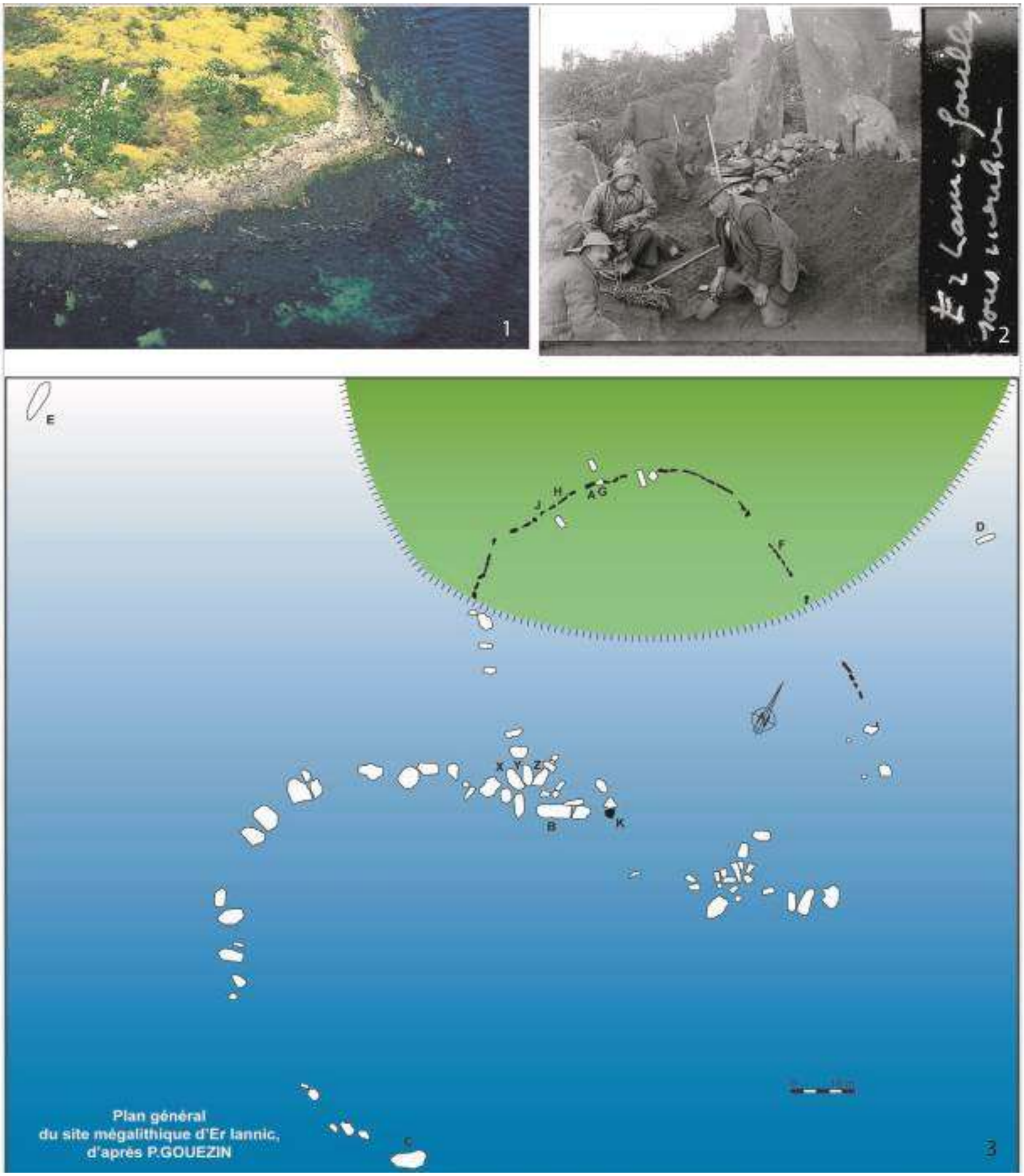

Figure 3K61. Combined documents on the Er Lannic megalithic site. (1): A view from the air of the half submerged stone circle on the islet of Er Lannic, in the Gulf of Morbihan (Cl. Reynaud, source futura-sciences.com), (2) Zacharie Le Rouzic, Marthe and Saint-Just Péquart, during the restoration of the Er Lannic monument (c. 1920). © Labo Archéosciences UMR 6566 CReAAH.), (3) Map of the Er Lannic stone circles (doc. P. Gouézin, after Gouézin & Le Gall 1992).

3K.8 Conclusions and Recommendations

One of the main natural features in this case study area is represented by dunes and sandy bars, which are vulnerable to coastal change. If we assess the risks on the dunes environment, it appears that the period from 1965-1985 corresponds to a "let happen" phase, parallel with the mass tourism development with various consequences: multiplication of wild paths on the dunes surface, shuffling along and erosion that striped down important surfaces etc. The vegetation disappearance and its consequences on fauna led the authorities to react. In 1985, various settlements were set up in order to limit the touristic flow and to forbid the access of vehicles on the dunes. Access paths to the beaches were created as well as structured car parks (Cavalie, 2001).

In conclusion, we can notice that the various coastal management decisions or actions are not always coordinated and those irreversible destruction processes are going on, damaging the natural environment and the landscapes. Each partner or manager makes their own decisions, all having the same target but without agreement. This situation leads to divide up the territory. In addition, the existing protection settlements are not numerous enough and sometimes inefficient facing the growing tourist development. These gaps are especially sensitive in the protection of natural environments (free circulation and walking, lack of control etc.) and in the tourist equipment (insufficient car parks, lack of sanitary and sport equipments etc.).

Specialists recommend setting up an agreement between the various management policies, in order to define priorities within a global landscape strategy, and to federate the policies on this territory the complexity of which being due to its extent and diversity (Cavalie, 2001).

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For further information on the project and to access the full Technical Report please go to www.archmanche.hwtma.org.uk/downloads

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3K.8 Case Study References

Audren C., Jegouzo P., Belloncle JL. et Daniel F., 2003. *Système d'Information sur la Géologie du Morbihan (SIGM) : élaboration d'un ensemble de bases de données et de cartes numériques dédié au socle géologique* - Rapport final. ODEM, Géosciences Rennes. 71 p.

Biet M.C., Bouze O., 2007, *Bretagne d'antan, la Bretagne à travers la carte postale ancienne*, HC ed., Rennes.

Briard J., Gebhardt A., Marguerie D., Nicolardot J.-P., Robino P. 1990. Habitats et environnement de l'âge du Bronze en Bretagne, in M.-J. Roulière-Lambert et M. Oberkampf (dir.), *Un monde villageois. Habitats et milieu naturel en Europe de 2000 à 500 av. J.-C.,* Girardot, Lons-le-Saunier: 37-44.

Cassen S., Baltzer A., Lorin A., Sellier D., Boujot C., Menier D., Rousset J.M. 2010. Prospections archéologiques et géophysiques de stèles néolithiques submergées en baie de Quiberon (Morbihan), *Cahiers d'Archéologie Subaquatiques*, XVIII: 5-32.

CassenS. , Boujot C., Errera M., Marguerie D., Menier D., Pailler Y., Petrequin P., Poirier S., Veyrat E., Vigier E. 2008 . Discovery of an underwater deposit of Neolithic polished axeheads and a submerged stone alignment at Petit Rohu near Saint-Pierre-Quiberon (Morbihan, France). *Antiquity* Vol 82 Issue 316 June 2008. http://antiquity.ac.uk/projgall/cassen316/

Cavalie B. 2001. *Opération Grand site Gâvres-Quiberon*. Atelier de l'Ile, Quiberon, n.p.

Collective 2007 – *Marthe et Saint-Just Péquart, archéologues des îles. De Houat à Hoedic, 1923-1934.* Melvan, La revue des deux Îles, n°4, p. 173-212.

Collectif, 2008. *Dictionnaire d'histoire de Bretagne*, Skol Vreizh, Morlaix.

Collective 2009. *La gestion du trait de côte*. MEEDM (Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer). Editions QUAE, 352 p.

Daire M.Y., Langouët L. (dir.), 2008. *Les pêcheries de Bretagne Archéologie et Histoire des pêcheries d'estran*. AMARAI & Centre Régional d'Archéologie d'Alet éd., 144 p.

Daire M.Y., Langouët M.Y. 2010. *Les anciens pièges à poissons des côtes de Bretagne, un patrimoine au rythme des marées*. Co-édition CeRAA-AMARAI, Les Dossiers du Centre Régional d'Archéologie d'Alet, n°AG, 165 p.

De Beaulieu F., 2011. *Dictionnaire du Golfe du Morbihan*. Ed. le Télégramme, 332 p.
Galliou P., 2009. *Le Morbihan*, Carte archéologique de la Gaule. Académie des Inscriptions et Belles Lettres, Paris, 445 p.

Delouche D., 2011. *Les peintres en Bretagne*. ed. Palantines, Qimper, 362 p.

Galliou P., 2009. *Le Morbihan,* Coll. Carte Archéologique de la Gaule, éd. Acad. Inscriptions et Belles Lettres, Paris, (2nde éd.), 456 p.

Gaudin L., 2004. *Transformations spatio-temporelles de la végétation du nord-ouest de la France depuis la fin de la dernière glaciation. Reconstitutions paléo-paysagères*. Thèse de doctorat, Mention : Archéologie et Archéométrie, Université de Rennes 1, UFR Structure et Propriétés de la Matière.

Ghesquière E., Marchand G. 2010. *Le Mésolithique en France*. Archéologie des derniers chasseurs-cueilleurs. La Découverte / INRAP, Paris, 180 p.

Giot P.-R., Briard J., Pape L., 1995. *Protohitoire de la Bretagne,* Ouest France éd., Rennes, 423 p.

Giot P.R., Monnier J.L., L'Helgouac'h 1998. *Préhistoire de la Bretagne*, Ouest France éd., Rennes, 452 p.

Gouezin P., Le Gall E. 1992. *Le site mégalithique d'Er Lannic*, Association Archeo Douar Mor.

Goulpeau L. 1985. Un second trésor d'époque augustéenne découvert à Port-Haliguen (Quiberon, Morbihan). *Revue archéologique de l'Ouest* (RAO), 2: 83-93.

Guyodo J.-N. (dir.) 2008. *L'habitat néolithique de Groh-Collé à Saint-Pierre-Quiberon (Morbihan*). Document Final de Synthèse de fouille programmée. SRA de Bretagne. Rennes, 2008

Langouët L., Daire M.Y., 2009. Ancient maritime fish-traps of Brittany (France): A reappraisal of the relationship between human and coastal environment during the Holocene. *Journal of Maritime Archaeology*, vol. 4, n°2, p.131-148.

Large J.M. 2002. Une archéologie de l'île d'Hoedic (Morbihan) – Inventaire des sites pré et protohistoriques. *Bulletin de l'A.M.A.R.A.I.*, n° 15, p. 5-46.

Large J.M. 2014 (dir.). *La file de pierres dressées du Douet, Hoedic (Morbihan, France)*. Melvan, 240 p.

Lecornec J. 2001. Le golfe du Morbihan. Occupations humaines du Néolithique à l'époque romaine. In L'Helgouac'h J. and Briard J. - *Systèmes fluviaux, estuaires et implantations humaines de la Préhistoire aux grandes invasions.* CTHS: 219-228.

Le Pessec, 2011. *Quiberon, île ou presqu'île* ? Unpublished document, Quiberon.

Le Pessec, 2013. *Le patrimoine archéologique, témoin de 7 000 ans d'histoire dans la presqu'île de Quiberon*. Unpublished, Unpublished document, Quiberon.

Le Ru L. 2013. G*eophysical prospection and survey dives on the fish- traps of Port- Haliguen and Saint- Julien (56).* Unpublished report, ADRAMAR, 39 p. + annexes.

L'Helgouac'h J., 1962 - Le dolmen de Conguel en Quiberon (Morbhan). *Bulletin de la Société préhistorique française*, 59: 371-381.

López-Romero E., Daire M.Y., 2013 - The ICARE project: an insight into the formation and consolidation of archaeology in western France (ca. 1850-1990). *Bulletin of the History of Archaeology* 23(1):3, 1-11. DOI: http://dx.doi.org/10.5334/bha.2313

Marchand G., 2014. *Préhistoire atlantique. Fonctionnement et évolution des sociétés du Paléolithique au Néolithique*. Ed. Errance, 528 p.

Marchand, G., Dupond, C. (2012). *Le site mésolithique de Beg-er-Vil (Quiberon, Morbihan), sondages archéologiques programmés*. Service Régional d'Archéologie de Bretagne, Rapport n°2012-228. 126 p.

Marchand G., Dupont C. 2013. *Beg-er-Vil à Quiberon, Un habitat du Mésolithique sur le littoral du Morbihan.* Première année de fouille triennale. Unpublished report, 250 p.

Marsille L., 1930. La Variation des lignes des rivages armoricains. La formation du Morbihan, *Bull. Soc. Polym. Morbihan*, 2-26.

Menier D., 2004. *Morphologie et remplissage des vallées fossiles sud-armoricaine : apport de la stratigraphie sismique*. Doctorat de l'Université de Rennes I, Mémoire de Géosciences Rennes, n°110. 202 p.

Monnier J.L. 1981. *Le Paléolithique de la Bretagne dans son cadre géologique*. Travaux du Laboratoire d'Anthropologie, université de Rennes1, 350 p.

Motte, E. 2013. *Représentations et évolutions du littoral en Bretagne.* Mémoire de Master 2, Université Rennes 2, département de Géographie, 23 p.

Proust J.-N., Menier D., Guillocheau F., Guennoc P., Bonnets S., Rouby D., Le Corre C., 2001. Les vallées fossiles de la baie de la Vilaine : nature et évolution du prisme sédimentaire côtier du Pléistocène armoricain. *Bull. Soc. Géol. France*, 172, 737-749.

Ramade P. 1988, *Maxime Maufra, un ami de Gauguin en Bretagne* - Le Chasse-Marée, éditions de l'Estran à Douarnenez.

Rodrigue M., Cariou A. 2005. *Jules Noël*. Catalogue de l'exposition, Editions Palantines, 192 p.

Sorrel, P., Tessier, B., Demory, F., Baltzer, A., Bouaouina, F., Proust, J.-N., Menier, D., Traini, C., 2010. Sedimentary archives of the French Atlantic coast (inner Bay of Vilaine, south Brittany): Depositional history and late Holocene climatic and environmental signals. Continental Shelf Research 30, 1250–1266.

Visset L., L'Helgouac'h J., Bernard J. (1996). La Tourbière submergée de la pointe de Kerpenhir à Locmariaquer (Morbihan), étude environnementale et mise en évidence de déforestations et de pratiques agricoles néolithiques. *Revue archéologique de l'Ouest*, 13, 1996, 79-87.

CASE STUDY 3L – OSTEND RAVERSIJDE, BELGIUM.

Case Study Area: Ostend/Raversijde

Main geomorphological types: Beaches, Dunes

Main coastal change processes: Natural erosion, Human induced

Primary Resources used: Archaeological/Palaeoenvironmental Data

Summary: The Ostend-Raversijde study area, located on the central Belgian coast, is known for its numerous archeological traces and remnants, often found in the intertidal zone but all buried now due to sand accretion. The technological challenges posed by the land-sea transition zone made this an excellent test-case.

Recommendations: The results of this case study demonstrate that a clever combination of marine and terrestrial geophysical and geotechnical techniques forms a valuable tool for the evaluation of archaeological remnants and the reconstruction of buried palaeo-landscapes. This opens important perspectives for long-scale coastal change studies, especially in view of the current and future coastal defense plans

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the technical report on the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

Ostend/Raversijde is one of two Belgium case study areas for the Arch-Manche project. This case study report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented. The analysis of these results and the potential for demonstrating the scale and rate of coastal change are then presented. For further details about the project methodology see Section 2.

Within the study area the archaeological and palaeoenvironmental resource has been researched, ranked and analysed along with a small number of historical maps. The extents of the detailed study areas are shown in Figure 3L1 below.

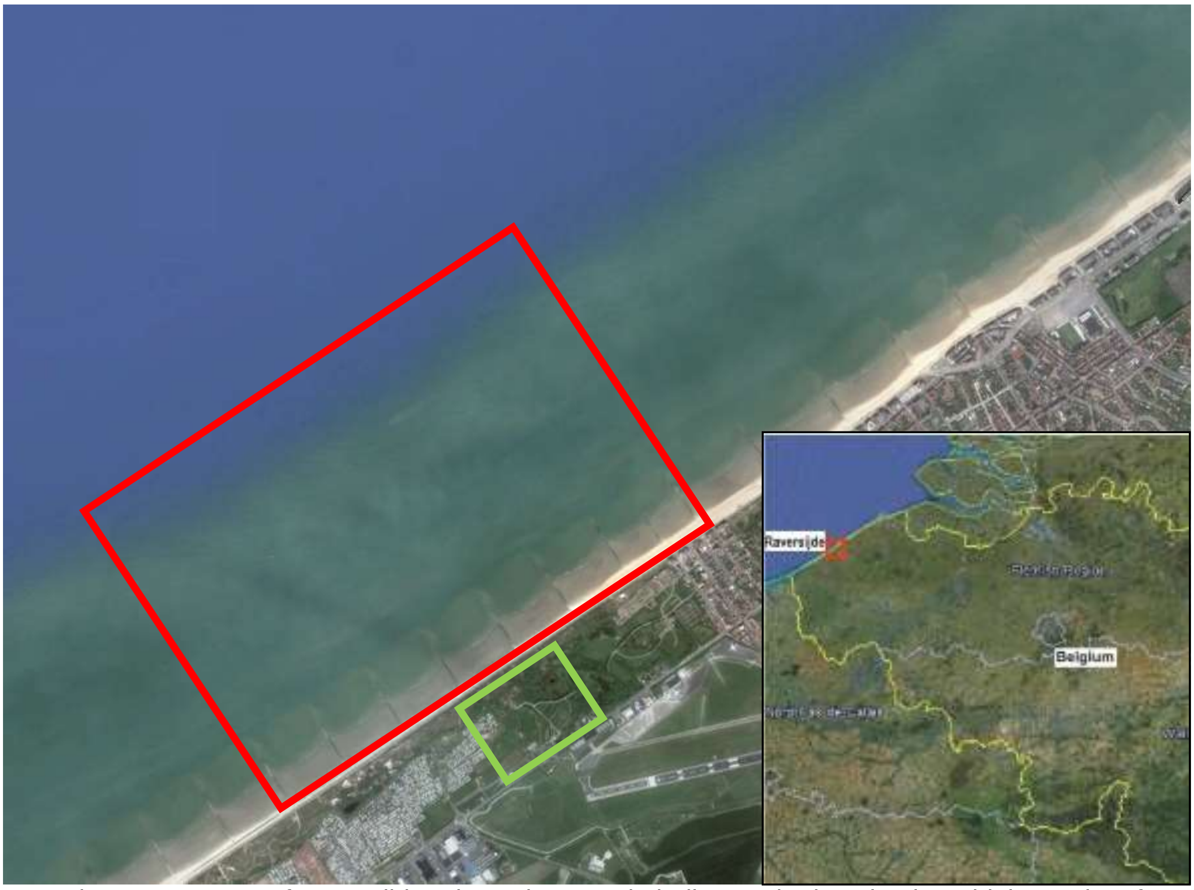

Figure 3L1: Area of Raversijde. The red rectangle indicates the location intertidal test site of Raversijde (red rectangle). The green rectangle marks the archaeological site inland, where many investigations have carried out since 90's (Google Earth).

3L.1 Introduction to the Ostend/Raversijde Study Area

The Ostend-Raversijde study area is located in the central Belgian coastal region, between Ostend and Middelkerke (Figure 3L1). The Belgian coast is largely marked by a rigid coastline, consisting of a small strip of beaches, directly bordered by human reinforcements, sometimes intersected by dune sections. This rigid coastline only came into existence after the Early Middle Ages, due to human embankment activities. In the Holocene pre-medieval period, the coastline was characterized by barrier beaches with tidal flats extending landward. The present beach of Raversijde is a low lying, slightly seaward sloping intertidal area. Since the 19th century, many archeological traces and structures have been found, almost all being located in the intertidal zone (Demerre et al., 2013). This archaeological importance, and the fact that such an intertidal zone poses major technological challenges (combining both marine and land survey techniques), makes this an excellent test-case for the evaluation of these techniques for efficient palaeogeographical landscape reconstructions in the Belgian coastal area.

3L.1.1 Geomorphological evolution

This section outlines the key geological and geomorphological features and processes of the study area. These factors have a significant impact on the on-going changes to the coastline and associated sites, deposits and features preserved related to the archaeological and heritage resource.

Pre-Holocene evolution of the Ostend Valley

The pre-Holocene evolution of the Belgian coastal plain is highly intertwined with 4 major palaeovalleys: the IJzer, Ostend, Coastal and Flemish valley. An overview map of these valley systems and the surrounding top-Pleistocene (i.e pre-Quaternary or top-Paleogene) surface of the Belgian continental shelf and coastal area is shown in Figure 3L2. The Ostend-Raversijde site is located at the edge of the Ostend Valley, which was connected to the Flemish Valley through the Coastal valley (Mathys, 2009; De Clercq et al., 2013). The Ostend valley itself was formed during the Saale ice age (ca. 352.000 - 130.000 yrs BP). At that time the North Sea was dry land and large rivers incised the landscape. Gradually, river sediments were deposited in the valley. When temperatures started to rise at the end of the Saale ice age, the permafrost melted and the river started to incise even further. During the warmer Eem period (ca. 130,000 - 116,000 yrs BP) sea level rose again and the Ostend valley transformed into a tidally influenced estuarine area. It is then that it obtained its typical funnel shape (Figure 3L2).

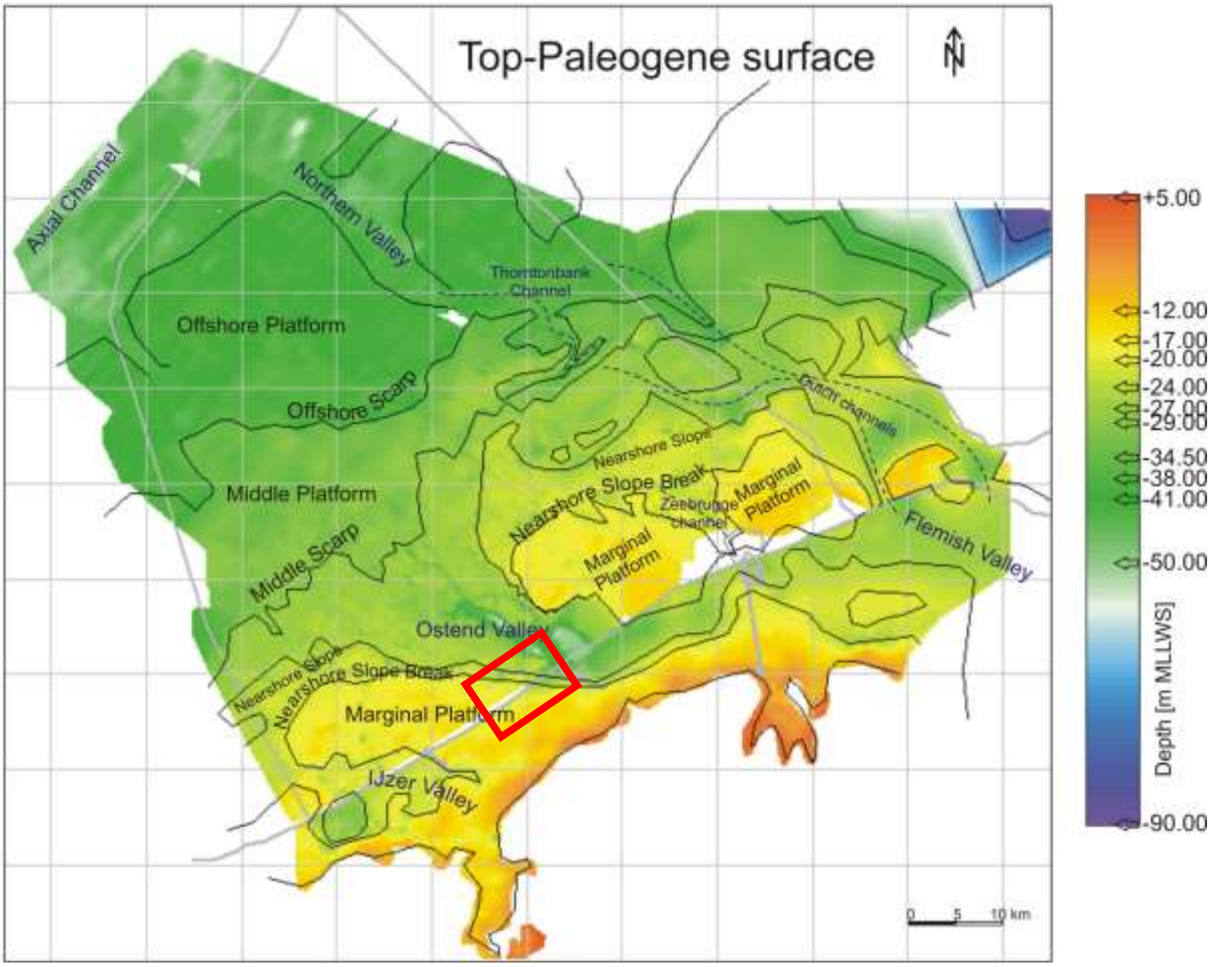

Figure 3L2: Pre-Quaternary (top-Paleogene) topography of the Belgian continental shelf and coastal plain, and its four valley systems (Ostend, IJzer, Coastal and Flemish valley). The Ostend Valley has a typical funnel-shape (De Clercq et al., 2013; Mathys, 2009).

During the following ice age, the Weichsel (116.000 – 11.700 yrs BP), sea level dropped and the North Sea became dry land again, and the Ostend valley was transformed into a river valley again. Incision, however, was less profound than in the Saale period. Due to the dry conditions, large dune complexes were formed. One of these dune complexes (*Maldegem-Stekene*) separated the Ostend valley from the Flemish valley, causing the end of river activity in the Ostend valley (Mathys, 2009).

Holocene evolution of the study area

The shallow sediments of the study area are made up of a highly variable (laterally and vertically) sequence of sand, peat, silt and clay layers that reflect the complex history of the Holocene during which marsh-like environments, sandy dunes, and intertidal mud- and sandflats alternated.

During the Early Holocene sea level rose very fast and a large part of the Belgian continental shelf was already inundated (red line in Figure 3L3). A large coastal plain came into existence, roughly 20-30 km offshore from the present coastline. Because of the increasing wave action a large dune barrier system developed in front of the coastal plain (Figure 3L4). Behind the dune barrier, the coastal plain most likely consisted of a large (inter)tidal flat environment marked by constantly changing tidal channels, tidal flats and marshes. The landward part was most likely cut by numerous rivers that flowed towards the sea. Together with sea level rise also the groundwater level started to rise, and coastal peatland started to develop for the first time (so-called 'basal peat') (Baeteman, 2007).

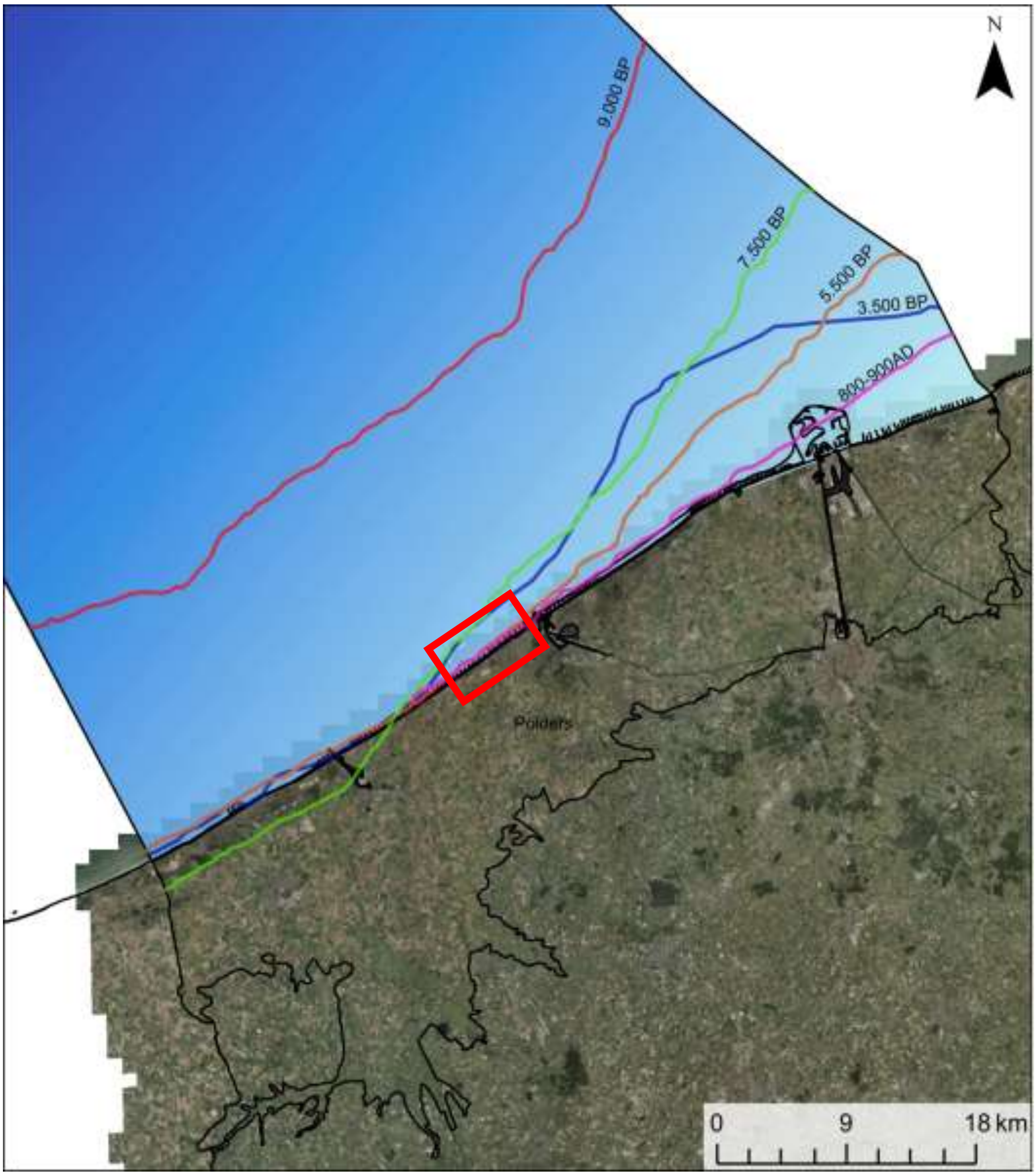

Figure 3L3: Schematic evolution of the Belgian coastline during the Holocene (De Clercq, 2013, after: Mathys, 2009). The red rectangle marks the Ostend-Raversijde site. The black line on land marks the edge of the current coastal plain.

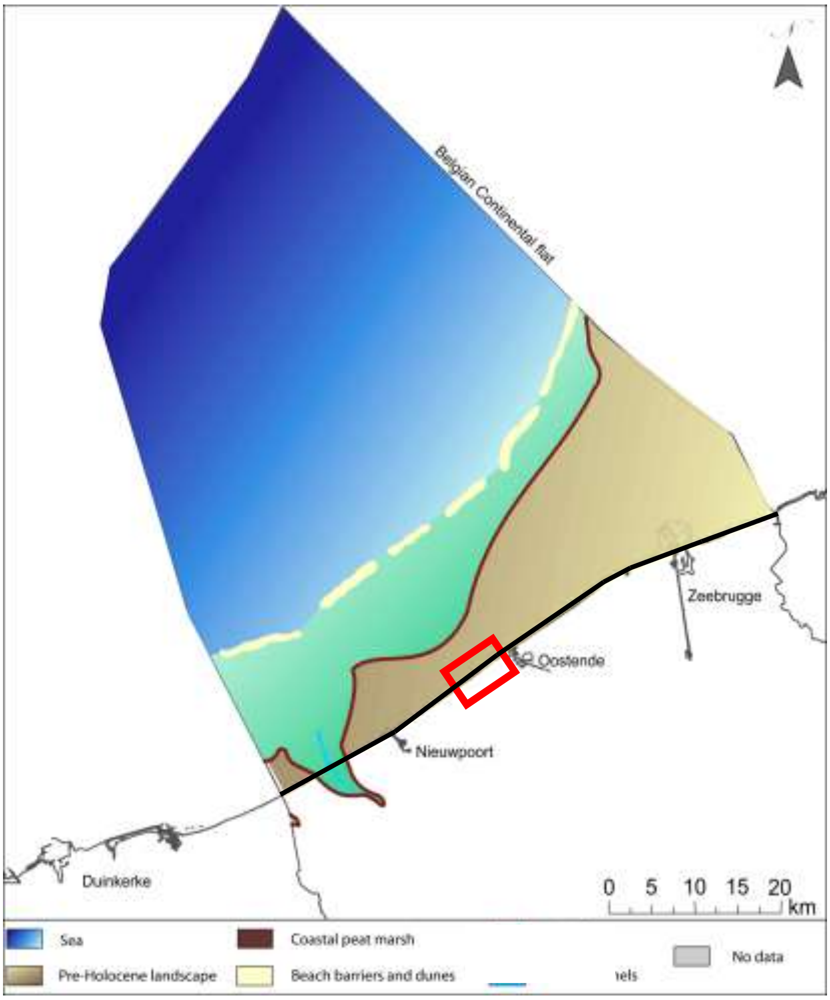

Figure 3L4: Very tentative reconstruction of the coastal plain around 9000 BP (De Clercq, 2014, http://www.sea-arch.be/nl/content/kaarten). The red rectangle marks the survey area of Ostend-Raversijde. The thick black line marks the present coastline.

Over the next 2000 years, sea level kept on rising fast and the coastline shifted further towards the land (green line in FigureL3). This caused considerable infilling of the tidal gullies with marine sand and clay. In the western part the sea intruded far inland. Around 7,000 yrs BP sea level rise started to slow down and the dune barrier system stabilized. This finally resulted in rising of the intertidal area to a level that prevented frequent flooding. For the second time, a fresh water marsh developed and peat growth was started (so-called 'surface peat') (Figure 3L5) (Baeteman, 2007; Mathys, 2009)

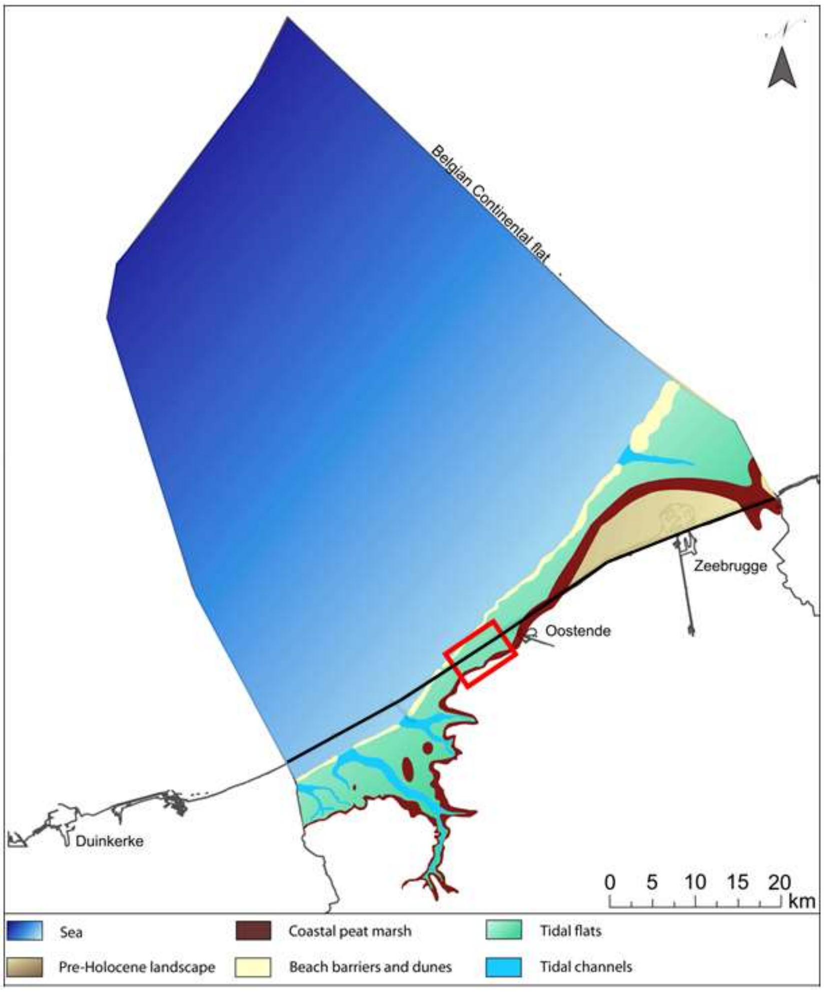

Figure 3L5: Very tentative reconstruction of the coastal plain around 7500 BP (De Clercq, 2014, http://www.sea-arch.be/nl/content/kaarten). The red rectangle marks the survey area of Ostend-Raversijde. The thick black line marks the present coastline.

Around 5500 BP sea level rise slowed down even further, causing a constant accumulation and growth of peat. An extensive coastal marsh, characterized by reed vegetation, started to cover almost the entire coastal plain (Figure 3L6). In the east the coastline shifted further inland, whereas in the west the coastline shifted slightly back (orange line in Figure 3L3).

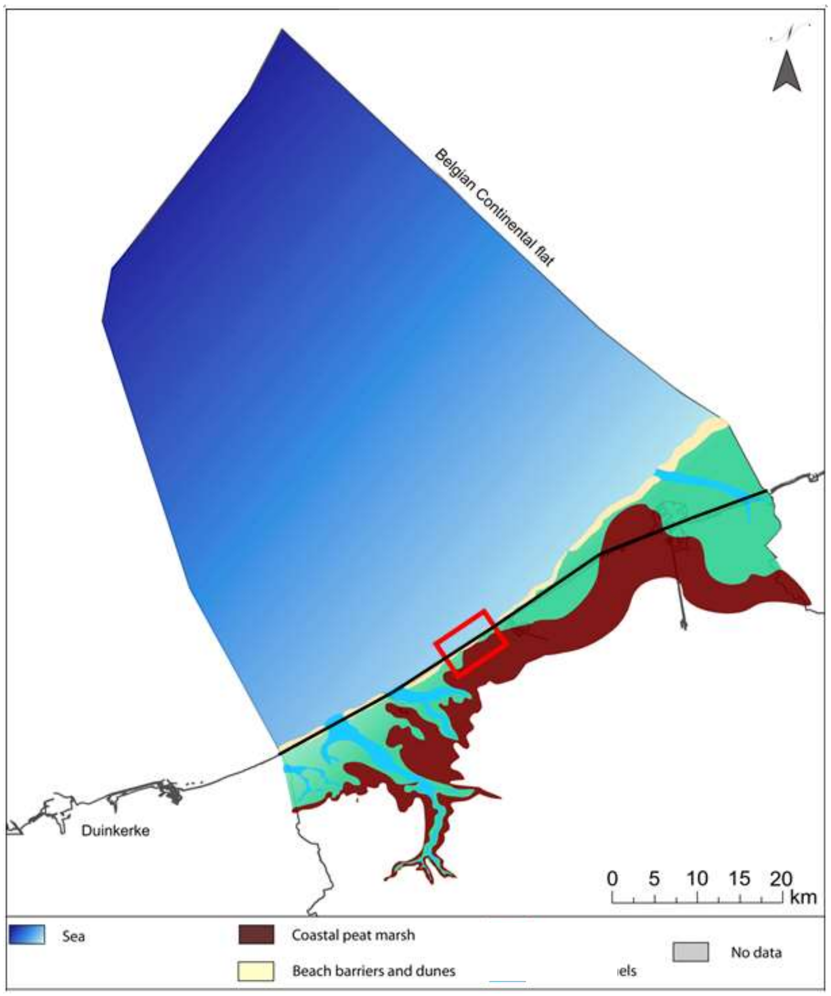

Figure 3L1: Very tentative reconstruction of the coastal plain around 5500 BP (De Clercq, 2014, http://www.sea-arch.be/nl/content/kaarten). The red rectangle marks the survey area of Ostend-Raversijde. The thick black line marks the present coastline.

Over the next 2000 years peat growth expanded over a vast area. Towards the east a wide beach barrier system developed (Figure 3L7). In the survey area, the position of the coastline does not change significantly (blue line in Figure 3L3). Around 2,500 yrs BP peat growth started to slow down. Tidal channels cutting through the marsh were now becoming eroded by enlarged precipitation run off from the *hinterland* (due to climate change and deforestation). At the fringes of the tidal channels, the peat eroded completely, causing drainage of the peat layer and subsequent lowering of the surface (ca. 1 to 1.5 meters). Due to this compaction, the fresh water marsh was converted to an intertidal area again. By 1,500 BP the peat growth comes, even in the most landward areas, to a definitive halt (Baeteman, 2007).

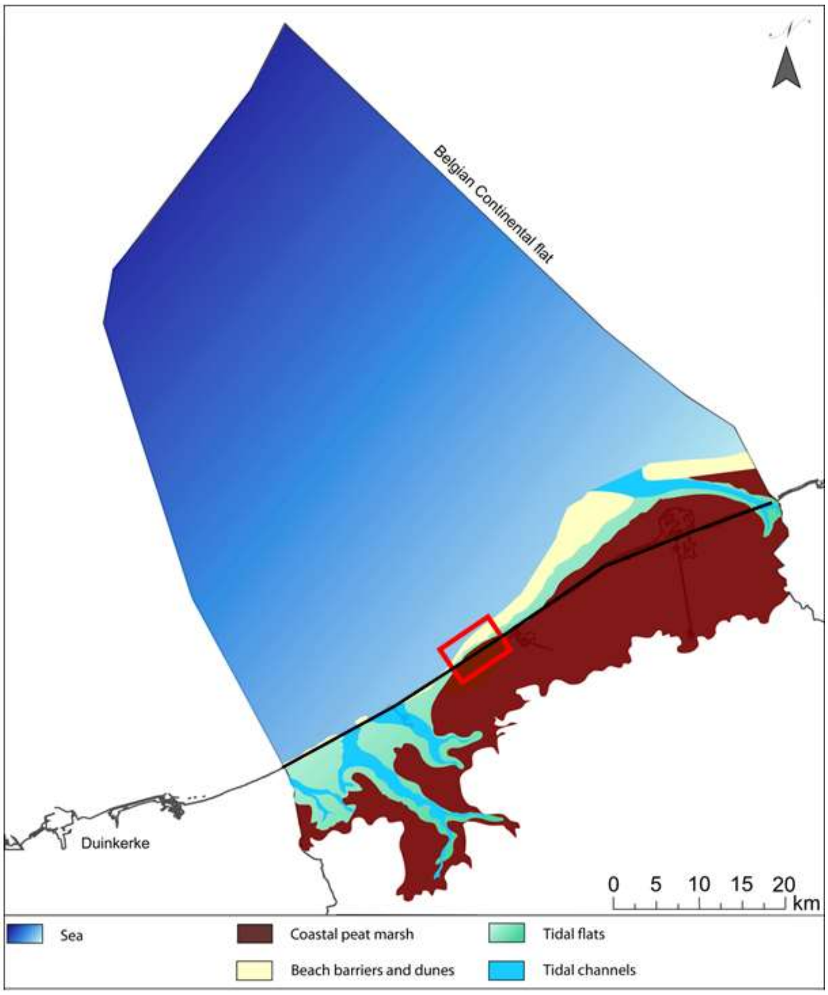

Figure 3L2: Very tentative reconstruction of the coastal plain around 3500 BP (De Clercq, 2014, http://www.sea-arch.be/nl/content/kaarten). The red rectangle marks the survey area of Ostend-Raversijde. The thick black line marks the present coastline.

During the Iron Age and Roman era the sea was located a few miles offshore from today's coastline and an area of sandy dunes formed the border between sea and land. The area behind the dunes was marsh-like and crossed by numerous creeks and tidal gullies.

From the Roman period onwards the coastal plain noticed a growing human influence. Drainage and peat extraction (see next section) further caused the surface to be lowered. After the Roman period the sea slowly progressed more inland, and a tidal flat was again installed in almost the entire coastal plain (Figure 3L8) (Baeteman, 2007). It has been suggested that this increased tidal activity was possibly the result of increasing neglect of the water management systems during the late Roman period (Ervynck et al., 1999).

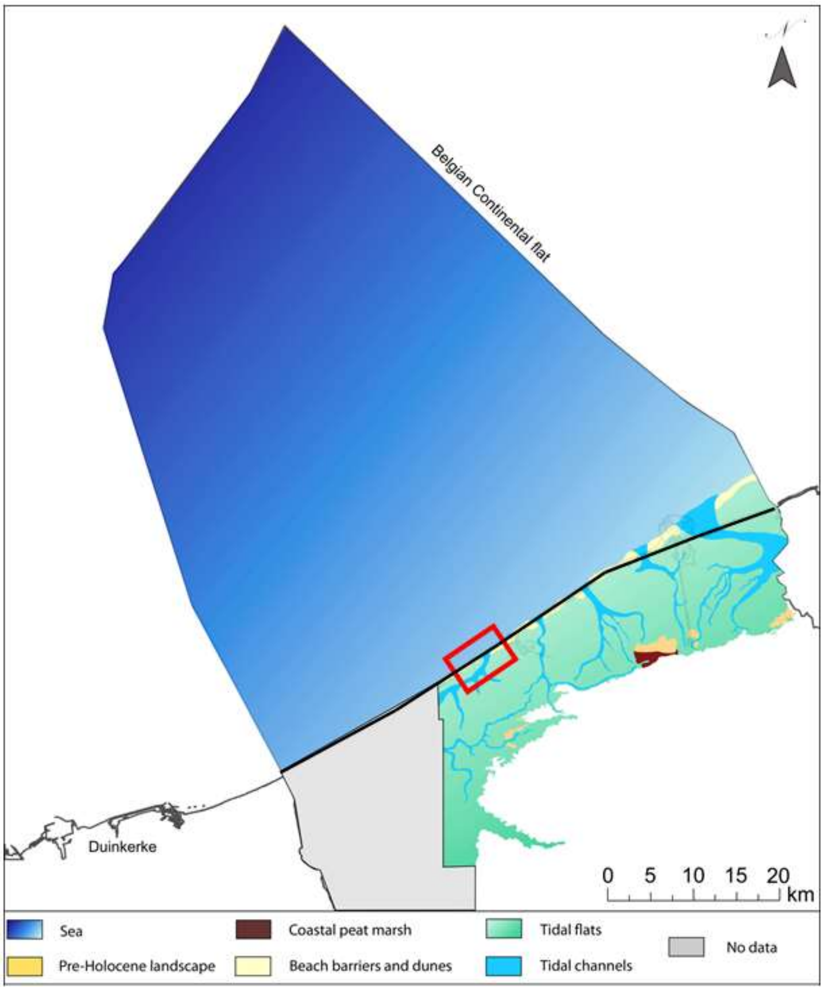

Figure 3L3: Very tentative reconstruction of the coastal plain in the Early Middle Age (De Clercq, 2014, http://www.sea-arch.be/nl/content/kaarten). The red rectangle marks the survey area of Ostend-Raversijde. The thick black line marks the present coastline.

The palaeo-geographical setting of the study area during the early Middle Ages (9th-10th century) is illustrated in Figure 3L4. The coastal plain had silted up to high-tide level, except for some tidal channels that remained open (Mathys, 2009). The village of Walraversijde, as Raversijde was called in that period, was then situated on an island/peninsula called "Testerep". The island of Testerep stretched out from (the former settlement of) Ostend (Oostende) in the east to Westende in the west, and was entirely surrounded by channels and creeks (the medieval town of Ostend was located slightly offshore the present-day coastline). In between, a few fishing settlements were located, Walraversijde being one of them. This former settlement of Walraversijde was located roughly 1 km offshore from the present day location of the hamlet Raversijde (see also section 3L.1.2). The main tidal channel which separated *Testerep* from the mainland was called the "Testerep gully". Walraversijde was located along a small tidal inlet called the Yde (hence the name).

Figure 3L4: Map of the medieval island "Testerep", with the most likely location of Walraversijde indicated in red. (http://www.oostende.be, 5/8/2014)

During later medieval times human interference enlarged exponentially and large parts of the coastal plain are reclaimed; people were building dikes perpendicular to the coast to protect themselves from the flooding of tidal channels. The remaining intertidal area was often silted up. In the area of Ostend-Raversijde the coastline retreated over 1 km during the storms in the 14th/15th century. By the 16th century, the old town of Oostende was almost completely drowned and the present coastline was more or less reached (Mathys, 2009).

3L.1.2 Summary of the Archaeology and History of the Study Area

Pre-Roman period

Archaeological findings on the beach of Raversijde date back from the final-Palaeolithicum (14,000-12,000 yrs BP) to the Neolithicum/Early Bronze Age (around 4000 yrs BP), and point towards prehistoric human occupation of the area. Furthermore, in the surface peat layer a wooden paddle, dating back to 5000-2800 BP was found (Demerre et al., 2013; Pieters, 1992).

Roman period

Numerous artifacts found at the Ostend-Raversijde site date back to the Roman period. Next to pottery, waste pits, and ploughing traces also traces of peat and salt exploitation were found (Demerre et al., 2013; Thoen, 1978; Pieters et al., 2010). In order to extract salt, saltpans were constructed, where the seawater flowed via trenches through a number of shallow basins. Here, the water slowly evaporated (during summer) leaving behind a thick salt layer. The final stage was to boil this down to salt blocks by heating in fires and using ''briquetage''-elements. Remnants of salt production sites were found at Wenduine and Raversijde (Thoen, 1978). It is believed that the peat was used as fuel for the salt ovens but it may also have been used as source of the salt, since this peat contained a lot of salt. With the increasing influence of the sea and the retreat of the Roman troops from the area around 300 AD the salt production was largely put to a stop.

Since 1992 detailed archaeological investigations have been carried out in the polder area behind the present dike. During these investigations the remains of a Roman dike were discovered (Figure 3L5, Pieters et al. (2013)). The dike is mainly built of stacked clay blocks, on its western side reinforced with peat blocks. The dike is oriented roughly perpendicular to the present coastline, which suggests that its purpose was most likely to embank a tidal gully that stretched further inland.

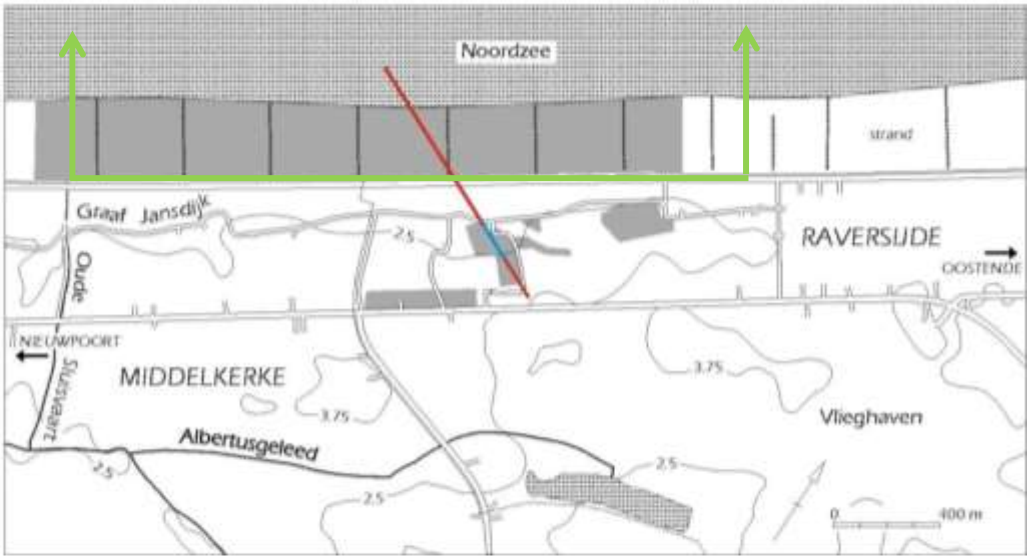

Figure 3L5: Map of present-day Raversijde. The blue line marks the remnants of the Roman dike that was excavated, the red line represents the possible continuation of the dike (Pieters et al., 2013). The (landward side of the) Ostend-Raversijde test site is indicated in green.

Middle Ages

As mentioned in section 3L.1.1, during the Middle Ages the fishing village of Walraversijde, as Raversijde was called in that period, was then situated on the island "Testerep". The fishing village was first mentioned in 1290 (Tys and Pieters, 2009). The island of Testerep was owned by the Counts of Flanders, who rented it to the Sint-Pieters abbey of Ghent (http://www.oostende.be/blogdetail. aspx?id=1887). Around the 11th century dikes were installed along the Testerep tidal channel, in order to protect the land from flooding but which adversely also resulted in rising flood levels. As a consequence, in the late 14th and early 15th century, large parts of the island were flooded during fierce winter storms and parts of Walraversijde were destroyed. The final abandoning of the village in the 15th century was a more gradual process, also induced by war (Tys and Pieters, 2009).

The fishing village of Walraversijde was subsequently re-located behind a new dike (and from now on was called Raversijde). This so-called "Graaf Jansdijk" (see Figure 3L5) had been constructed behind the dunes, and protected the new village from floods and storms. From the original settlements of Walraversijde only a few houses and the remains of a chapel were left. The chapel finally collapsed in the middle of the 19th century (Tys and Pieters, 2009).

Traces of digging pits suggest that peat exploitation was also very common along during the Middle Ages. Except from traces of digging pits (Figure 3L6), remnants of the late Medieval fishing settlement have been discovered at Raversijde (Figure 3L7). Furthermore, in the 1950s remnants of housing (ground-plan of a late medieval house) were found on the beach (Figure 3L8).

Figure 3L6: Remnants of the trench systems and peat digging on the beach of Raversijde. (Photo E. Cools).

Figure 3L7: Aerial photo of peat excavation remnants at the beach of Raversijde (Photo E. Cools, around 1970).

Figure 3L8: Ground-plan of a late medieval house discovered on the beach of Raversijde, picture taken in 1950's (Photo E. Chocqueel).

3L.1.3 Archeological potential

Until now, only limited prehistoric (Palaeolithic) traces are found on the Belgian coast. This is mainly due to the fact that relatively few Pleistocene deposits are left (De Clercq et al., 2013). The archeological potential for the Palaeolithic is therefore rather limited. The main exceptions are the eastern coastal area close to the Dutch border, the Ostend valley and the extreme western part of the coastal area (offshore IJzer valley), where sediments pre-dating the Holocene are present.

Most of the sediments along the Belgian coast date back to the Middle and Late Holocene. Therefore discoveries of archeological artefacts (or even large-scale infrastructure) from the Mesolithic or younger are more likely. The exact location of the areas with high archaeological potential however, often remains uncertain. Peat layers can form a key role, since they offer excellent preservation qualities. In view of the recent geological history (e.g. the island Testerep) and the archaeological findings on the beach and further inland behind the dike, the Ostend-Raversijde site suggests a high archaeological potential. Furthermore the excavation of peat is a clear indication of past human activity.

3L1.4 Early Modern maps of the area – two examples

This particular case study did not aim to evaluate large series of historical maps (see case study 3M Scheldt polders), but two examples of interesting maps of the Early Modern city of Ostend and its inundated surroundings were found and ranked. The first map (Figure 3L9) was made in 1725 by land surveyor Nollet. The map shows that the entire area South of Ostend consists of tidal marshes. These came into existence due to tactical inundations during the Eighty Years' War (1568-1648). Only in 1748 first attempts to reclaim this area were made (http://www.watererfgoed.be). The topographical accuracy in the coastal area is outstanding, with detailed depictions of large and small tidal channels. It is not clear if the terrain was actually measured for making this map, and the geometrical accuracy is only mediocre, leading to a total score of 65. The inset shows a similar map, also with excellent topographical accuracy. Due to the fact no date for the map is known, chronometric accuracy is lower than for the 1725-map, leading to a total score of 60.8. For detailed information on the ranking methodology see Section 2.

Figure 3L9: Map of Ostend and surroundings (1725, Rijksarchief Brugge, Kaarten & Plans, 113, n° 8). Inset: Undated map of Ostend and inundated surroundings (Algemeen Rijksarchief, Kaarten & Plans, 8480)

3L.2 Current environmental impacts/threats and coastal management approach

The Belgian coast is one of the regions directly impacted by climate change. The sea defense is formed by only a small strip of land, which is in most areas strengthened by sea dikes and other “hard” structures, leaving only little space for natural response to for instance storms or sea level rise.

The Flemish government is aware of these threats and already in the early 1970’s breakwaters were constructed at regular intervals along the coast to protect the beach from erosion. More recently a “Masterplan for Coastal Defense” was put forward. Since 2007, investigations took place in order to define measurements which should provide safety against for instance flooding, at least until 2050. Recently an initiative for the future, called “Vlaamse Baaien” was developed by a consortium of marine industrial companies (Figure

3L10). In 2010 “Vlaamse Baaien” was included in the political agreement of the Flemish government.

Figure 3L10: Overview of the “Vlaamse Baaien” initiative, which a.o. includes the development of artificial islands in front of the Belgian coast.

The first phase of the “Vlaamse Baaien“ initiative foresees in a supply of large volumes of sand on the present beaches, thus forming a more or less natural sea defense. This phase is currently under way. A second, much more contested phase of the plan, involves a.o. the heightening of sandbanks in front of the coast and the creation of small islands, with the aim to provide a more “soft” and flexible sea defense (http://www.vlaamsebaaien.com/tijdslijn). Currently a number of studies are undertaken to investigate the effect of such islands on the current pattern.

However, more knowledge on the evolution of islands and coastal barriers in the past, on how they were formed and how they disappeared (e.g. the island of Testerep) will provide a better grip on the evolution of future artificial constructions and the effects these will have on the present coastline.

The planned large-scale sand suppletion works on the beach of Ostend-Raversijde (already partially under way) are a serious hindrance for the scientific research and subsequent field studies, and will also cause further burial of the archaeological material. Furthermore, clearance of WWI munition (by deliberate explosions) on the beach of Raversijde poses another direct threat for possible buried archeological remains.

3L.3 Archaeological and Palaeoenvironmental Fieldwork

3L.3.1 Key research questions in relation to coastal change to be addressed via fieldwork

The main objective of the fieldwork at Ostend-Raversijde is to gain more insight into the recent geological evolution of the area, stretching a time period of over 5000 years, and to identify possible archaeological layers or (pre)historic artifacts buried below the current seabed/beach. This also includes former (Roman/medieval) coastal defense structures and relics of human activities related to peat extraction which took place in the area during the Medieval and Roman periods. The mapping of former tidal gullies will provide more insight in the local environmental conditions and the location of the past coastline, including the island “Testerep” whose exact location still remains uncertain.

In order to do so, several (exploratory) geophysical and geotechnical surveys were carried out in 2007, 2010 and 2012. During these campaigns a wide range of techniques was used: marine seismics, eletromagnetic measurements (EMI), hand corings and cone penetration tests (CPT). Intertidal areas offer great technological challenges due to the water depth, wave action, strong currents, salt content, and general inaccessibility of the terrain (the latter two preventing the use of radar and land seismic techniques). However at the same time the tidal effect offers a big advantage as different overlapping techniques can be applied both on land (e.g. EMI) and marine (e.g. seismics), thus covering the entire intertidal area. The latter makes this research very unique.

3L.3.2 Field data gathering methods

2007 and 2010 seismic surveys

In 2007 and 2010 two seismic surveys were carried out offshore Raversijde (Missiaen, 2008; Missiaen, 2010). The main objectives of these surveys were (1) to map the palaeogully system in more detail in the nearshore area, and (2) to map the distribution of possible man-made artefacts in the intertidal zone.

For both surveys a parametric echosounder was used. This source, which is mounted onto a pole attached to the side of the ship (Figure 3L11) emits two signals with a different frequency. The high-frequency signal (100 kHz) allows a very detailed image of the sea floor. The lower-frequency signal (between 6 and 14 kHz) penetrates deeper, resulting in an image of the underlying structure. The fast pulse rate (20-25 pulses per second) resulted in a high lateral coverage. During the measurements the echosounder was attached on a long iron pole fastened to the side of the ship. A motion sensor was used to filter out the wave movement. Positioning was done using a DGPS antenna with an accuracy of ±1 m. Different networks were recorded in the area: a large-scale network in the subtidal nearshore area (up to 1.2 km from the shore, line spacing 50 -100 m) and several small-scale networks focusing on intertidal zones in between the groynes (line spacing between 10 and 25 m) (Figure 3L12). It was hoped that the latter could provide more insight into the distribution of nearshore palaeogullies and possible remnants of ancient coastal defense structures.

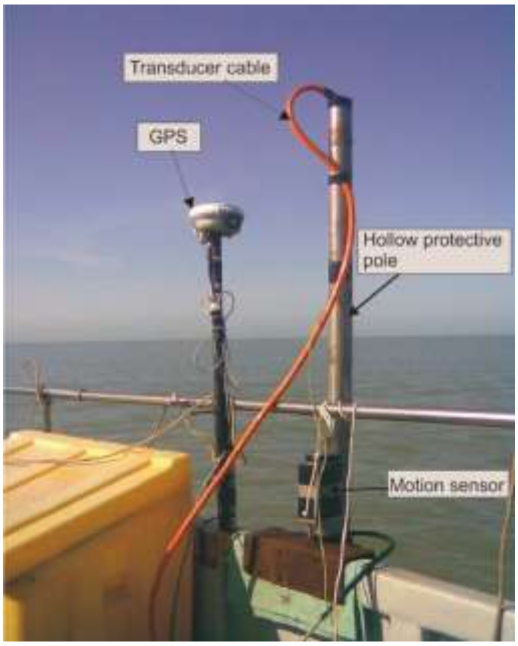

Figure 3L11: Motion sensor and GPS antenna attached to the pole holding the transducer source.

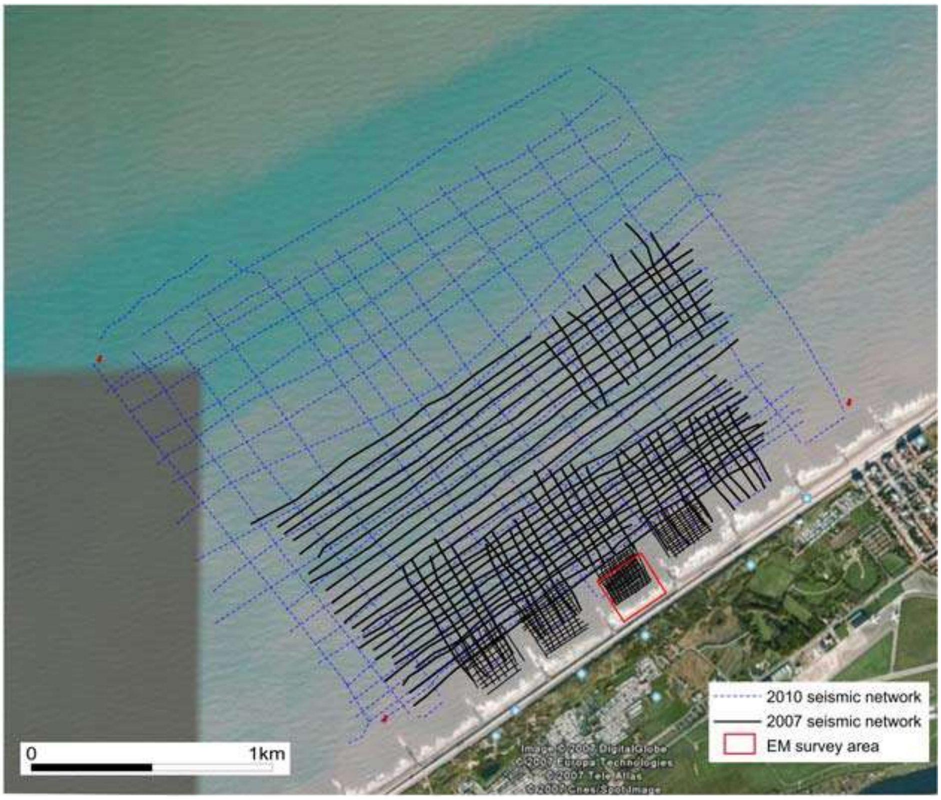

Figure 3L12: Seismic networks recorded in 2007 (blue lines) and 2010 (black lines) offshore Raversijde. The red rectangle marks the intertidal site where detailed investigations (Seismic, EMI) were carried out in 2010 and 2012.

Seismic data processing was very straightforward and included band pass filtering, stacking (where needed), smoothing and time varyable gain. Tidal correction of the seismic data was carried out using tide data obtained from a tidal gauge at Ostend and interpolated for the survey area. All seismic data were corrected to a common level. Arrival time to depth conversion was done using a sound velocity of 1550 m/s.

2010 electromagnetic (EMI) survey and shallow coring

In addition to the seismic campaigns a first series of electromagnetic induction (EMI) test measurements was carried out in 2010 by the department of Soil Management (Ghent University) at low tide on the beach (Figure 3L17). The choice for this specific area was based on photographic material (see Figure 3L7 and 3L13), suggesting the possible (buried) presence of peat exploitation remnants as well as medieval habitation. In EMI measurements an electromagnetic field is generated (induced) in the subsoil. This EM field is closely related to the conductivity of the soil. The latter will vary with the lithology: high conductivity is often related to peat deposits, and also, in a lesser extent, to (thick) clay layers. Also the presence of metal objects will increase the conductivity, making interpretation a complicated matter.

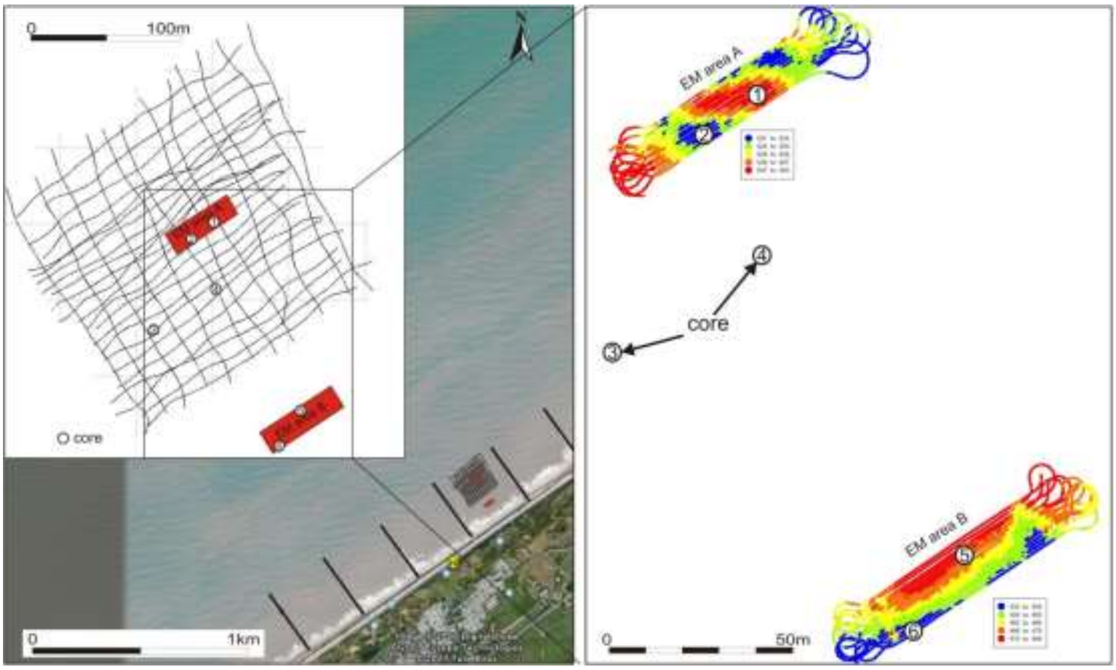

Figure 3L13: Left: Overview of the 2010 small-scale seismic network, electromagnetic (EMI) survey areas and core locations in a small intertidal area. Right: close-up of the EMI data (apparent electrical conductivity ECa, in mSm-1) (red=high conductivity, blue=low conductivity).

Additionally, in 2010 a few shallow test cores were taken on the beach to provide more ground-truth for the seismic and electromagnetic data (Figure 3L13). The cores were taken using a so-called “van der Staay suction corer”, a simple hand-operated coring device especially designed for coring in water-logged sandy sediments (Verrijken and Demerre, 2010). In total 6 short cores were obtained, with depth varying between 2 and 4 m. Working with the Van der Staay core proved very difficult and time-consuming, mainly due to the large lithological variation encountered (dense peat and clay layers interfingering with loose saturated sand).

Figure 3L14: Left: Taking a Van der Staay core on the beach at Raversijde. Right: describing the core contents.

2012 seismic survey

In 2012 an additional seismic survey was done in the intertidal area where previously EMI data were gathered (for location see Figure 3L12). This time a more closely spaced network of seismic lines was collected, again using the parametric echosounder. In total 103 new profiles were recorded (Figure 3L15).

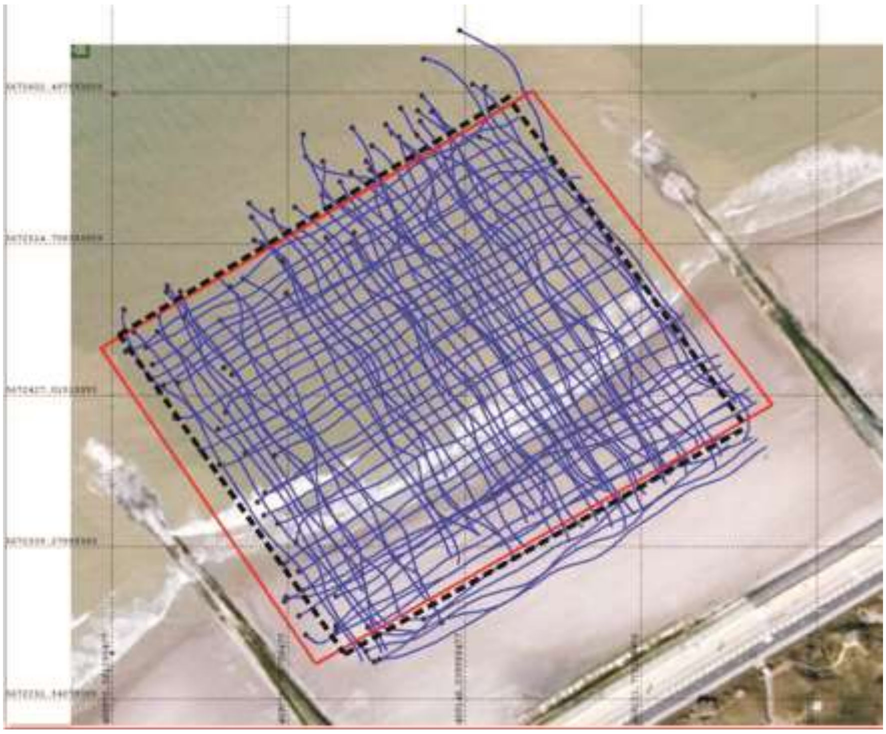

Figure 3L15: Seismic network in the intertidal area recorded in 2012 (projected against a google earth image). The red rectangle marks the area of the 2012 electromagnetic investigations. The two breakwaters can be clearly seen at the edges. For location of the network see Figure 3L12.

2012 electromagnetic (EMI) survey

In 2012 a second, larger electromagnetic (EMI) survey was carried out, again in cooperation with the department of Soil Management (Ghent University). The area covered was much larger than the previous EMI survey in 2010 (roughly 250 x 250 m), encompassing the entire intertidal area between the two breakwaters (red rectangle in Figure 3L15). The penetration depth of the electromagnetic signal into the bottom varied between 0.5 and 3m. The device that was used consisted of a Dualem-21S sensor with three different coil sizes (depth penetration of the different coils was respectively. 0.5, 1, and 3 meter). The sensor was dragged over the beach by a quad (Delefortrie et al., 2014)

2014 seismic survey

In January 2014 a last seismic survey was carried out in the area west of the previously studied area (Figure 3L16). Three different networks were recorded: one larger spaced network in the subtidal area further offshore, and three closely spaced networks in the intertidal area. Also here the parametric echosounder was used. In total 157 profiles were recorded.

Figure 3L16: Seismic networks recorded in 2014 (projected against a google earth image). The red rectangle marks the area of the 2010-2012 investigations.

2012 hand cores and cone penetration tests (CPT)

After a first attempt for shallow hand augering in July 2010 (see above), a second and third coring campaign were carried out on the beach at low tide in October-November 2012 and January 2013 (Figure 3L17). Due to the high tidal coefficient no cores were obtained from the seawardmost area. The location of the corings is given in Figure 3L18. A combination of Van der Staay and conventional augering devices were tried out this time. Again, coring was extremely tedious due to the water saturated conditions of the sand and the large (and often abrupt) variation in lithology (dense clay, loose sand, compact peat). Maximum depth reached with the hand cores was 3.5 metres (average depth 2 metres). The best technique seemed to be a combination of suction core with a pulse, used intermittingly. Still it remained extremely difficult to obtain good (and complete) core samples.

Figure 3L17: Hand augering on the beach at Raversijde.

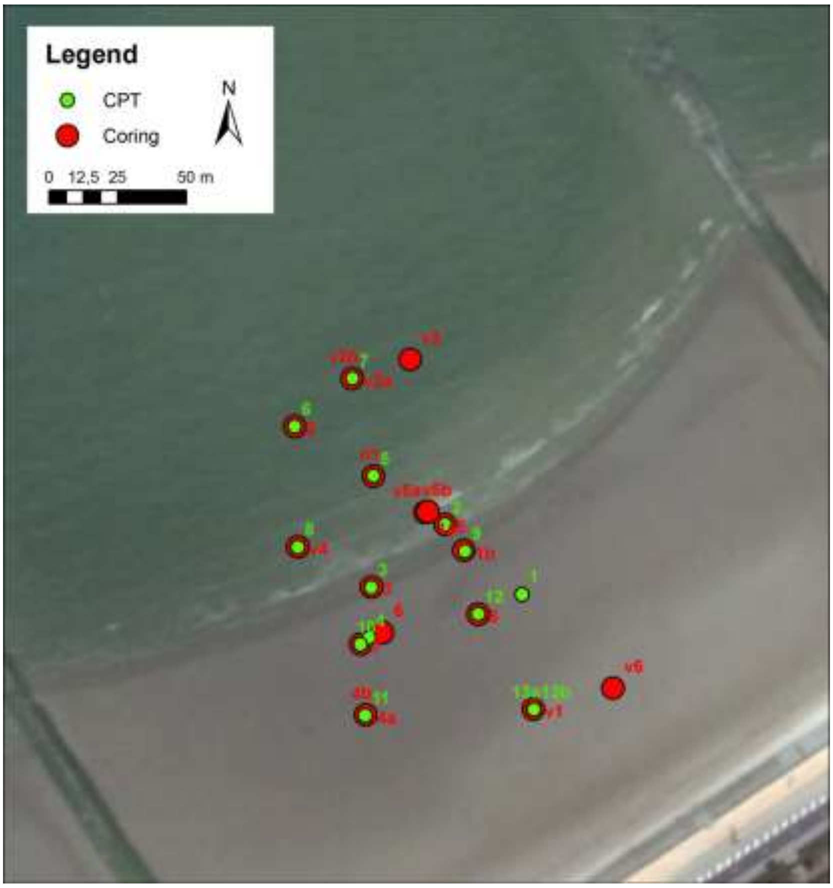

Figure 3L18: Location of the hand corings and CPTs on the beach at Raversijde.

In addition to the hand cores also 13 (electrical) cone penetration tests (CPTs, Figure 3L18) were carried out in November 2012 on the beach at low tide (Figure3L 19). Depth of the CPTs was on average 10 m. Cone Penetration Testing is a geotechnical method to sound the composition of the subsurface. The method allowed us to obtain information regarding the geology (nature and sequence of the subsurface strata) and hydrology (groundwater conditions) as well as the physical and mechanical properties of the subsurface strata (Lunne et al., 1997; Robertson and Cabal, 2012). The CPT method allows fast and continuous profiling with repeatable (and reliable) data, and is highly economical (Lunne et al., 1997).

In Cone Penetration Tests (CPT) a cone is pushed into the ground at a constant rate while continuous measurements are made of the cone resistance (i.e. resistance of the cone tip to penetration) and the sleeve friction (i.e. resistance of the sleeve). The ratio of sleeve friction divided by cone resistance, called the friction ratio, is used to classify the soil.

Figure3L 19: Cone penetration testing on the beach at Raversijde.

3L.4 Field data analysis and discussion

3L.4.1 Sea floor topography

Based on the seismic data recorded in 2010 and 2012 a map was made of the seafloor topography in the survey area (Figure 3L20). The map clearly shows that the sea floor sloping towards the shore is marked by a step-like form, creating a distinct terrace. This can also clearly be observed on the NS-oriented profiles shown in Figure 3L21.

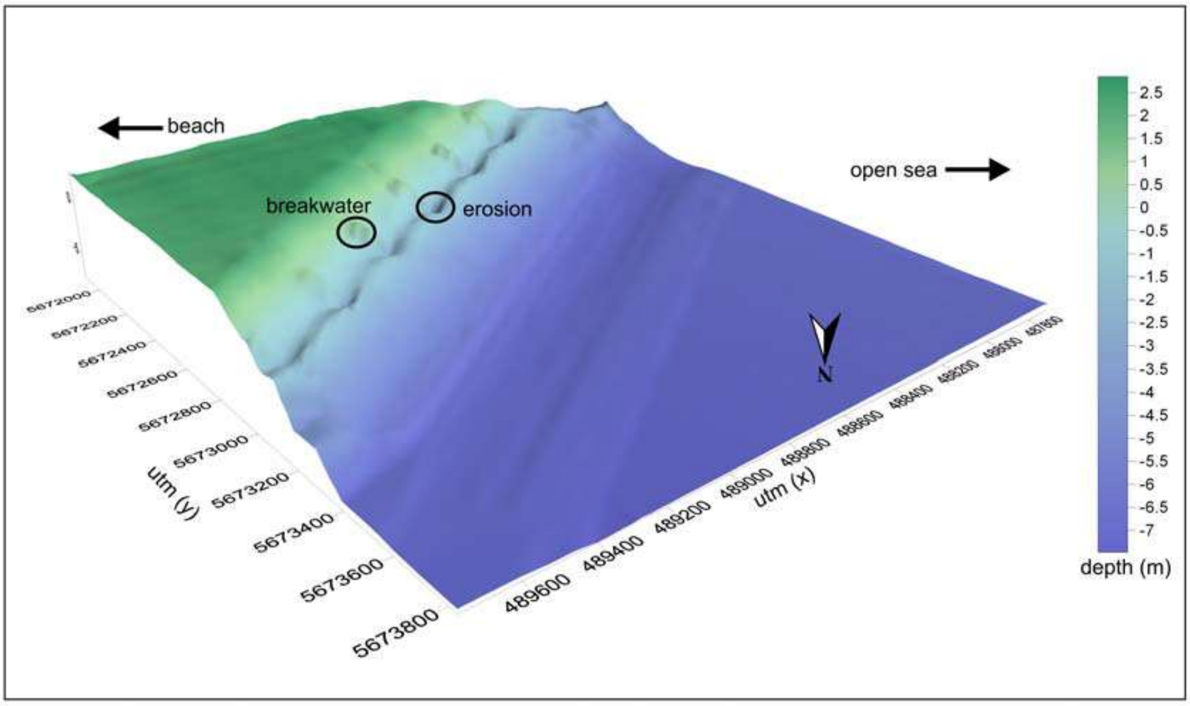

Figure 3L20: Seafloor topography map of the survey area based on the high-frequency (100 kHz) seismic data. The breakwater constructions and associated erosion areas are clearly observed.

On the whole the seafloor surface is very smooth. Only on a few locations some small irregularities were observed on the seafloor, as shown in Figure 3L21. The seafloor irregularities are all located in the nearshore area. At first sight they do not seem to be directly associated with buried structures or channel infill structures. However in some cases there seems to be a link with outcropping layers (e.g. Figure 3L21 - top) which suggests a natural origin. However the marked location of the seafloor irregularities -in a narrow band parallel to the coast- suggests that they may well be related in some way to remnants of an old dike or coastal defense structures.

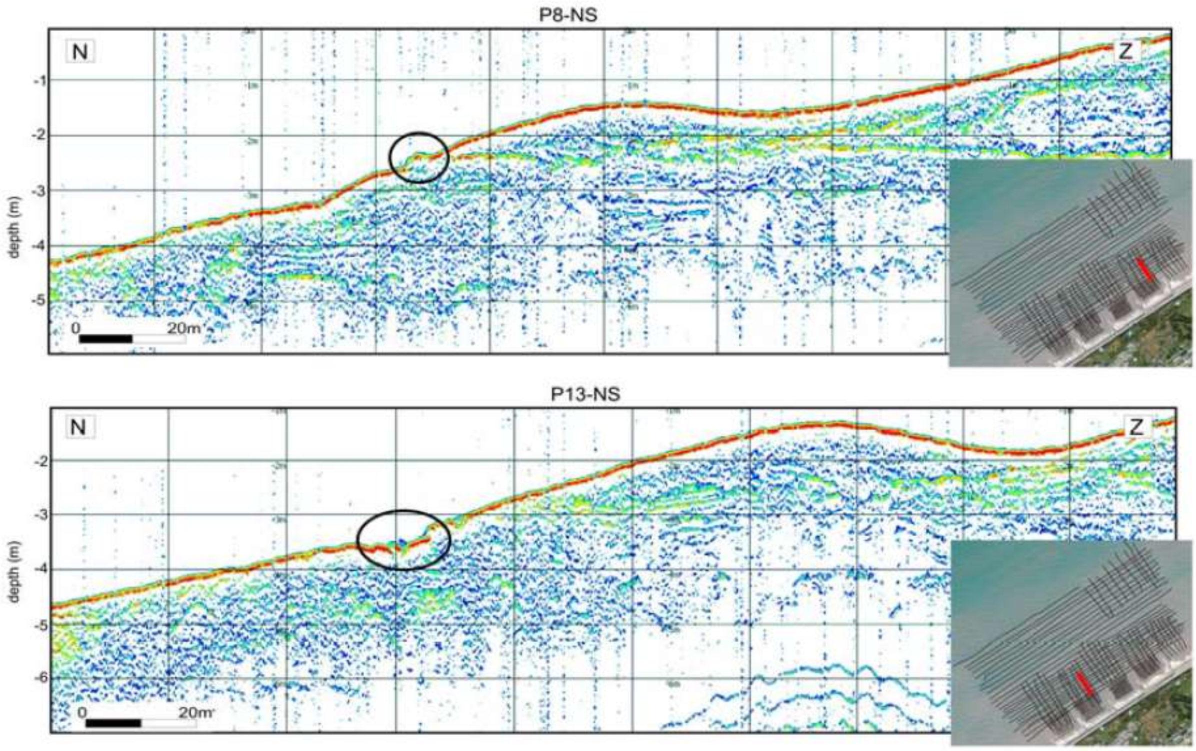

Figure 3L21: Seismic profiles offshore Raversijde showing small irregularities in the sea floor. The location of the profile is marked in the inset on the right (red line). Depth in meter below MLWL (Mean Low Water Level).

The regularly spaced breakwaters also stand out clearly on the topography map (Figure 3L20), as well as the erosion pits seaward of the breakwater constructions. The latter are most likely a result of scouring around the obstructions. Figure 3L22 shows two seismic profiles parallel to the coast that cross two of the groyne constructions and the associated erosion areas. The erosion areas are marked by a shallow infilling structure (dotted lines).

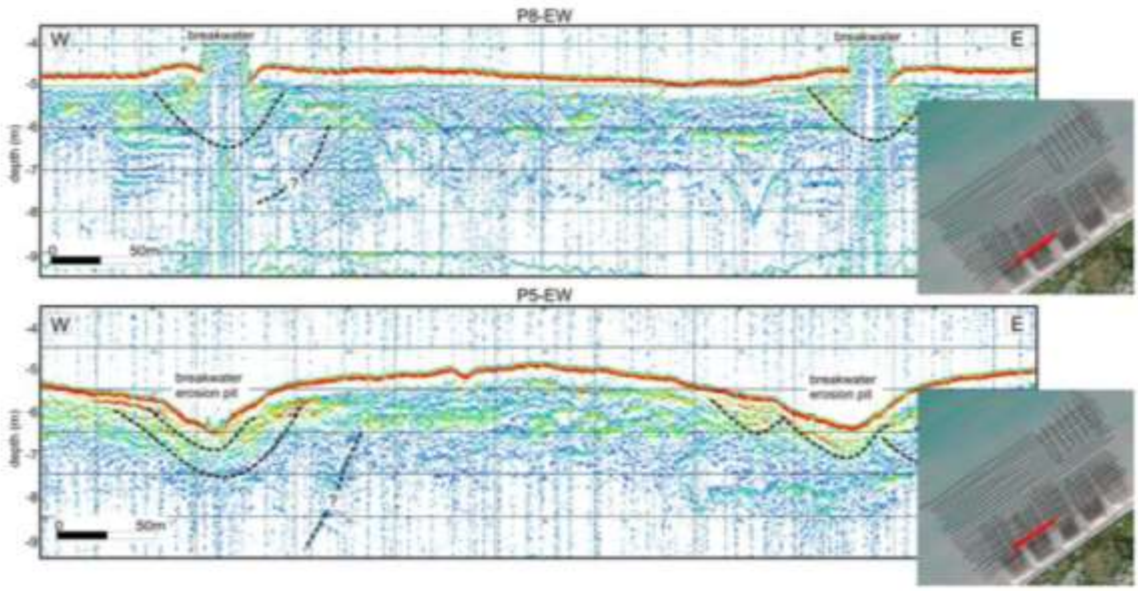

Figure 3L22: Seismic profiles offshore Raversijde showing two breakwater constructions and associated erosion areas. The location of the profile is marked in the inset on the right (red line). Depth in meter below MLWL.

3L.4.2 Large-scale palaeogully system

The seismic data obtained in 2007 allowed us to identify the remnants of a number of buried tidal palaeochannels. However, due to the high spatial variability of the shallow sediments and the relatively large profile spacing it was not possible to accurately map the channel pattern. The latter was only possible after the 2010 survey. The results show that the channel system is in fact much more complex than previously presumed. Figure 3L31 shows a new (tentative) interpretation map of the palaeogully system in the nearshore area. However even with a much closer line spacing in 2010 it was still not always possible to precisely track the channel pattern.

The seismic images are furthermore often hampered by the presence of shallow gas, which limits the penetration depth. Especially in those areas it was difficult to map the channels. Nevertheless a general pattern can be observed of more or less parallel (or sub-parallel) palaeochannels that are oriented roughly perpendicular to the coast. The latest data from 2014 further confirm this channel pattern (Claerhout, 2014).

In addition to this large-scale channel pattern, traces of a recent tidal channel were observed running roughly parallel to the shoreline (Figure 3L23). The same feature was also observed more towards the west, on the 2014 data. At first it was thought that this could indicate an old coastal defense feature. But a closer look at the data revealed that we are most likely dealing here with a palaeochannel that marks the northern (seaward) edge of the island Testerep (see Figure 3L4) (Claerhout, 2014). Indeed it is known that islands are often marked by strong tidal currents that 'encircle' the island (Pingree and Maddock, 1979).

Figure 3L23: Interpretation map showing the palaeogully system observed offshore Raversijde. The yellow line marks the recent palaeogully parallel to the shore. The red circles mark small seafloor irregularities.

Figure 3L24 shows an example of a seismic profile marked by buried palaeogullies (the location of each profile is indicated on the bottom right, depth is indicated in meters below mean lowest low water at springtide MLLWS). The gullies sometimes show a chaotic crisscross pattern, and younger gullies overlying older gullies at different angles. In most cases the channel fill is marked by a clear lateral stacking structure. In some cases a more chaotic infilling was observed which may be due to a local increase in shallow gas or to minor collapse events. A clear distinction between the steep erosional side (=outer bend) and more gradual sloping side (=inner bend) of the channel was often not possible.

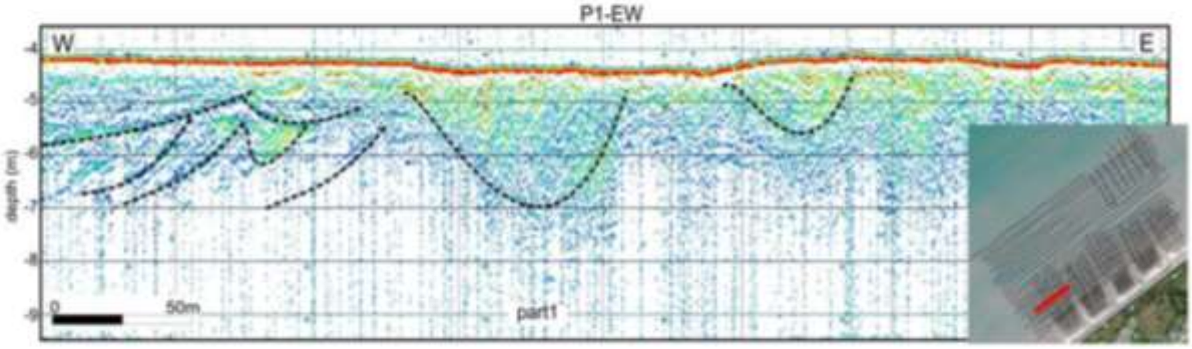

Figure 3L24: Seismic profile parallel to the shore showing various palaeogully systems (dotted lines). The location of the profiles is marked in the inset on the right (red line). Depth in meter below MLWL.

On the latest seismic data from 2014 a particularly large and wide palaeochannel was observed running roughly perpendicular to the shoreline (Figure 3L30). The location of the channel suggests a possible relation to the Yde gully running close to the village of Walraversijde on the island of Testerep (see above and Figure 3L8).

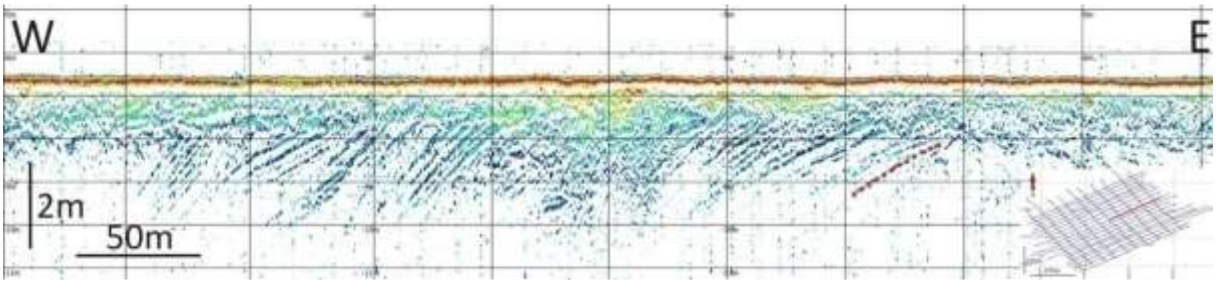

Figure 3L25: Seismic profile parallel to the shore showing a large and wide palaeochannel system, possibly related to the Yde gully. The location of the profile is marked in the inset on the right (red line).

3L.4.3 Small-scale palaeogully systems in intertidal areas

In general, the seafloor in the intertidal areas is very smooth, with a gradual shallowing towards the coast from roughly +2.5 m to – 1.5 m (all depths relative to MLWL). Interpretation of the seismic data nearest to the shore is often hindered by the shallow echo which obscures the underlying structure. Locally the presence of shallow gas limits the seismic penetration making a correct interpretation very difficult.

In general the observed palaeochannel pattern in the intertidal zones is very chaotic, with both shallow and deeper gullies often crisscrossing (Figure 3L26) The channels do not always stand out very clear and their infill structure is often rather chaotic, which suggests that some of these presumed channels could also be related to shallow gas. The areas nearest to the shore are rather marked by gullies running perpendicular to the shore, whereas the zones further offshore show a channel pattern running more parallel to the shore. On many of the seismic profiles also an undulating reflector pattern can be observed. In the extreme nearshore part often an irregular, shallow reflector is observed which is locally interrupted and which could be human-induced (peat extraction, settlement remnants?).

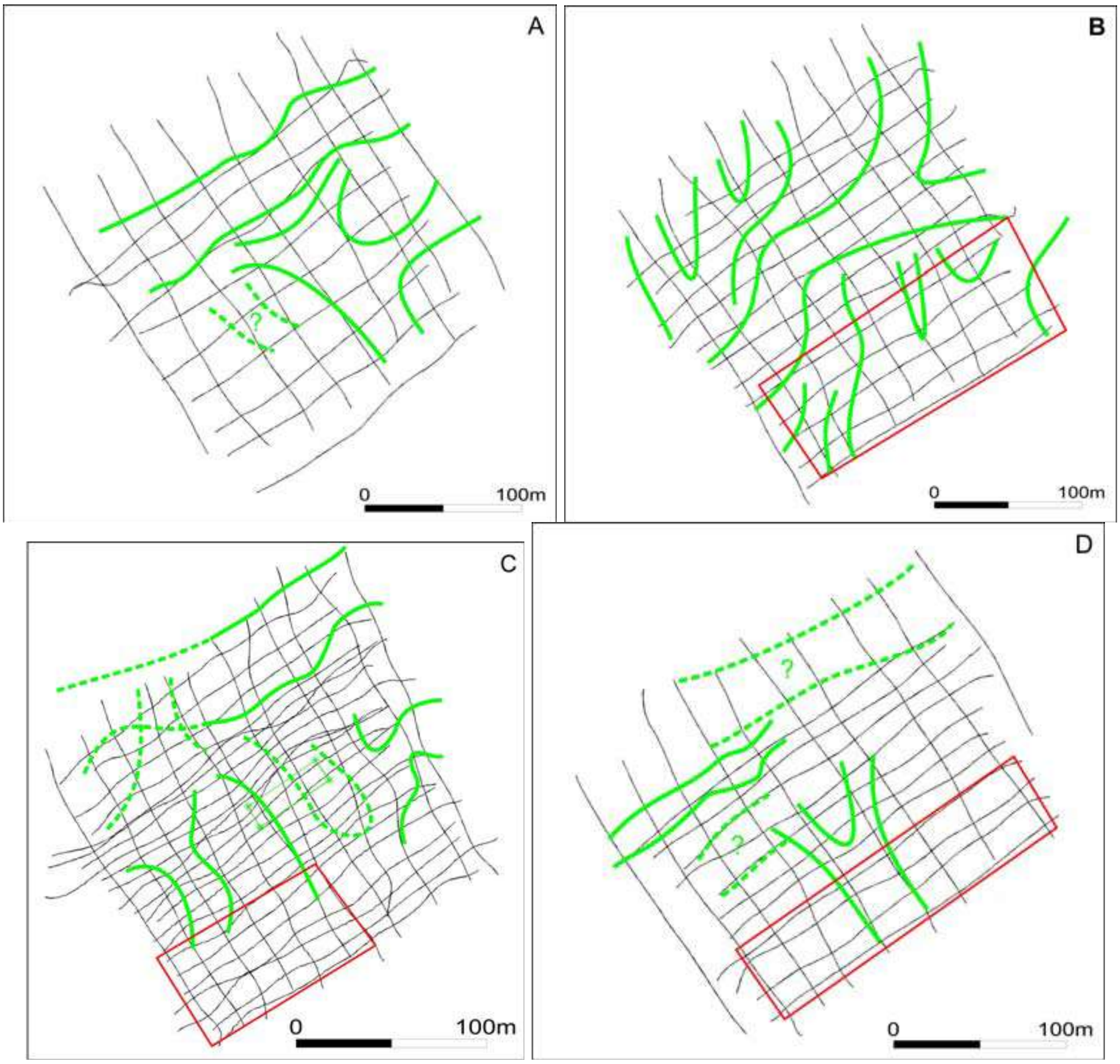

Figure 3L26: Tentative interpretation map of the palaeogully system (thick green lines) in different intertidal areas. The red area indicates the presence of a shallow interrupted reflector which is possibly related to human intervention.

3L.4.4 2010 electromagnetic (EMI) data and shallow cores

The first EMI measurements in 2010 only yielded two small data areas, one close to the dike and one further offshore (see Figure 3L13). Only the latter showed an overlap with the seismic data. Four of these cores overlap with the seismic network, of which also two overlap with the offshore EMI data.

Figure 3L27 shows an example of a seismic profile crossing the offshore EMI area. Areas of high conductivity seem to correspond with a relatively strong shallow reflector, whereas low conductivity seems more associated with a chaotic seismic image. This suggests that the shallow reflector could be related to a peat-rich layer – indeed peat will enhance the electrical conductivity. However, we should keep in mind that this interpretation is still very tentative due to the limited areal extent of the EMI data in 2010.

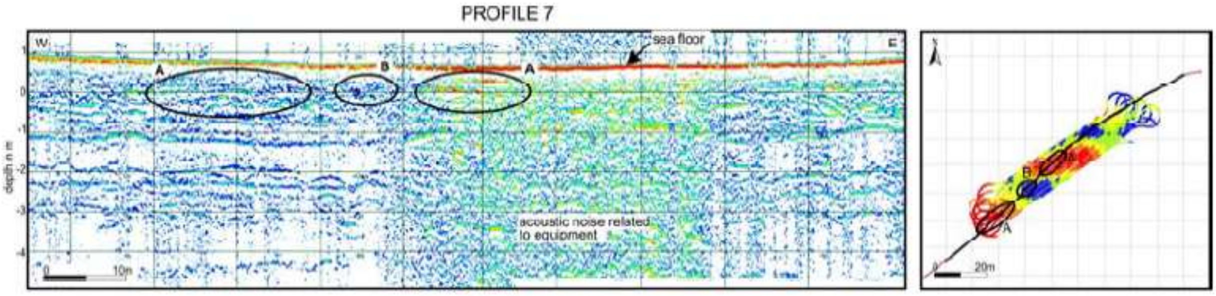

Figure 3L27: Seismic profile crossing the offshore EMI area. Depth in m below MLWL. The location of the profile is shown on the right (black line), plotted against a background map showing the electrical conductivity. A and B refer to the zones corresponding with respectively high (red) or low (blue) conductivity zones.

Comparison with shallow core data shows that in general there seems to be a fairly good correlation between seismic and core data (due to gas disturbance, however, the lower part of core 1 cannot be correlated precisely with the seismic data). Shell-rich layers mostly stand out as marked reflectors on the seismic data, and also the transition from clay to sand and vice-versa often yields a distinctive reflector. As expected the dense clay layers stand out clearly on the seismic data, regardless of the adjacent sediment.

3L.4.5 2012 seismic data and EMI results

Seismic data

Five strong sub-bottom reflectors were identified on the 2012 data in the intertidal area (see Figure 3L28). The reflectors are parallel or sub-parallel, sometimes wavy. The two shallowest reflectors appear only in the nearshore part.

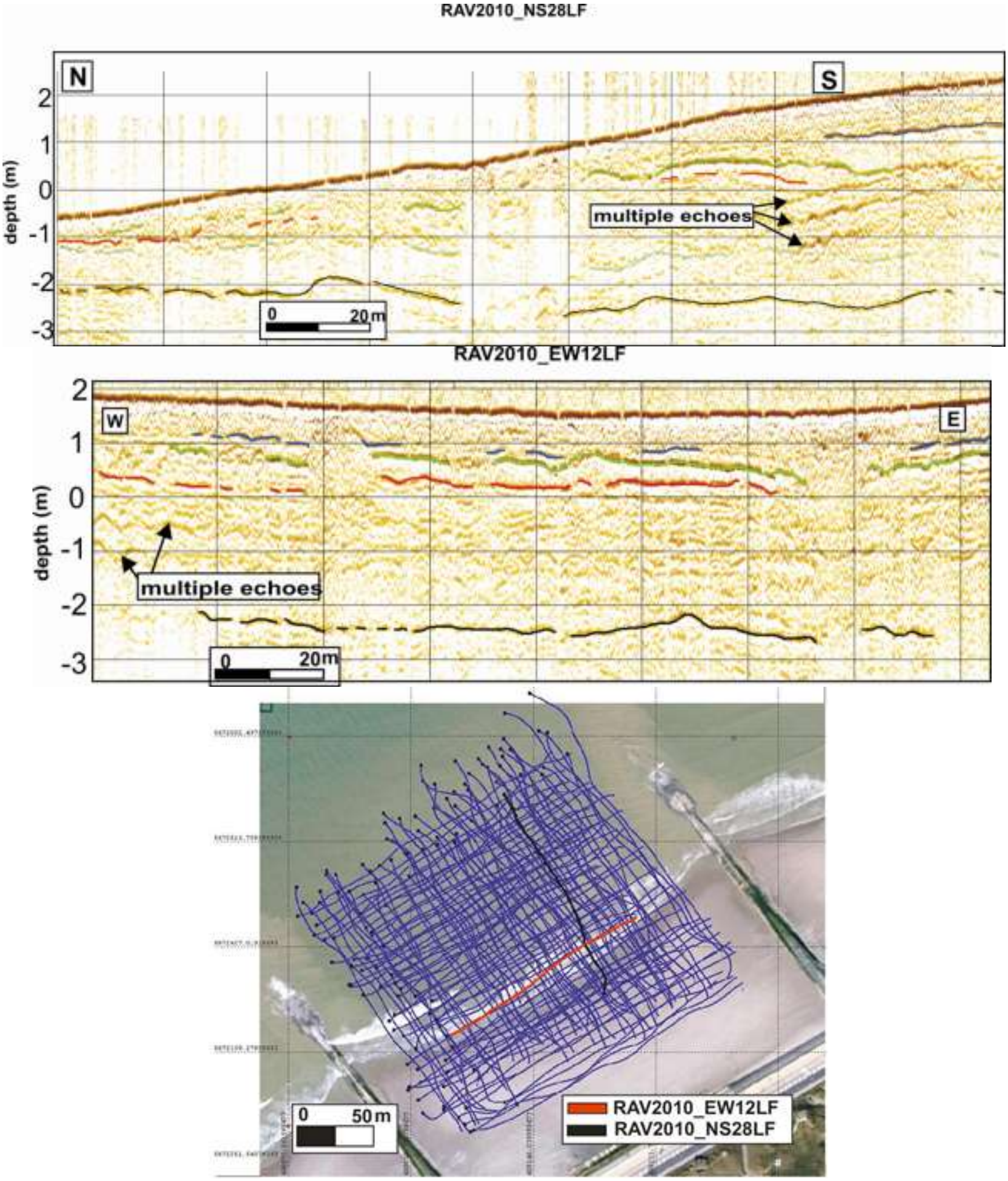

Figure 3L28: Seismic profiles showing the different strong reflectors observed in the intertidal area in 2012 (top: NS profile, bottom: EW profile). The light blue reflector was not well visible on the EW profiles. The location of the profiles is shown at the bottom.

Apart from the 5 main reflectors, the densely spaced seismic data of 2012 demonstrate a wide variety of phenomena in the area. The first feature is related to the presence of shallow gas. This was observed in the whole study area. Near the shore, the gas starts roughly at 1m and reaches down to 3.5 m below the sea floor. In the offshore part the gas appears between 1m to 2m below the sea bed. A number of features were related to palaeochannels. In the offshore part, both a deep palaeochannel and shallower complex palaeochannel were observed. In the central part of the study area, an additional complex shallow channel system was observed oriented roughly parallel to the shore.

The most important feature was related to strong shallow reflectors that are often interrupted (Figure 3L29). These reflectors are observed in the entire network, but they are most marked towards the shore. The nearshore area is marked by the presence of two parallel to subparallel strong shallow reflectors. Towards to the north both of the shallow reflectors are discontinuous and show abrupt gaps. The gaps in continuousness of the reflectors are possibly related to human interventions, e.g. peat excavation. Figure 3L29 shows the location of the strong shallow reflectors in the area.

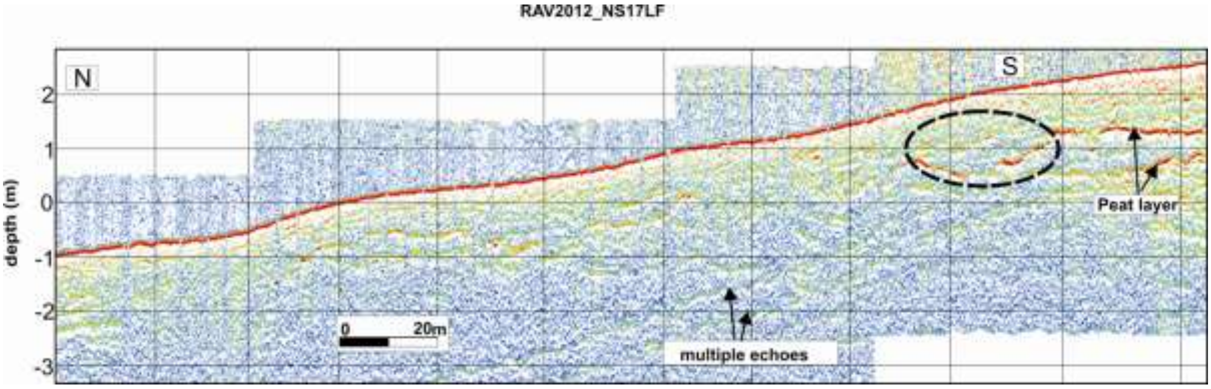

Figure 3L29: Seismic profile showing a strong shallow reflector on the right marked by irregular gaps (black dotted circle).

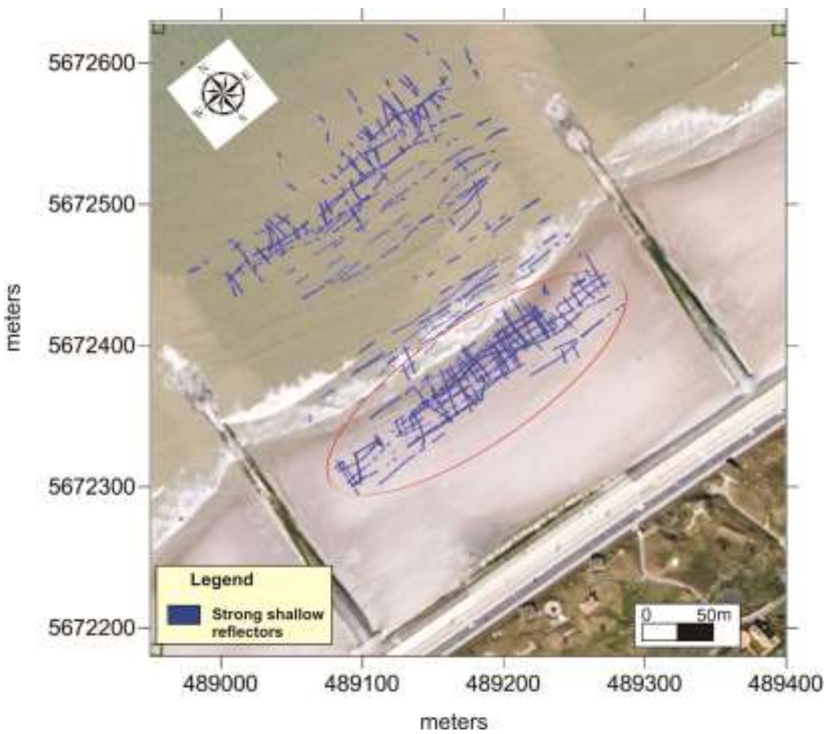

Figure 3L30: Spatial distribution of strong shallow reflectors in the intertidal area. The red ellipse is the area where two (sub-)parallel reflectors have been observed. Outside of this area the shallow reflectors are less strong and less continuous.

Electromagnetic data and correlation with seismic data

The conductivity data resulting from the EMI measurements in 2012 were corrected for the influence of the salty sea water (the sand being much dryer (and therefore less salty) closer to the dike). After this trend removal, and notwithstanding the overall very high conductivity values, still a characteristic pattern could be observed on the data. The results of the electromagnetic data are shown in Figure 3L31. A distinct area with low conductivity (in black) was observed towards the dike in the south, and an area with high conductivity (in white) was observed further offshore. Although the resolution of the data decreases for deeper penetrations, the pattern remained clearly visible on all data for the different coil configurations.

Pronounced high conductivity on the data may be caused by different things, for instance the presence of metal objects, or shallow peat layers. However, also thick shallow clay layers are known to produce an increase in conductivity.

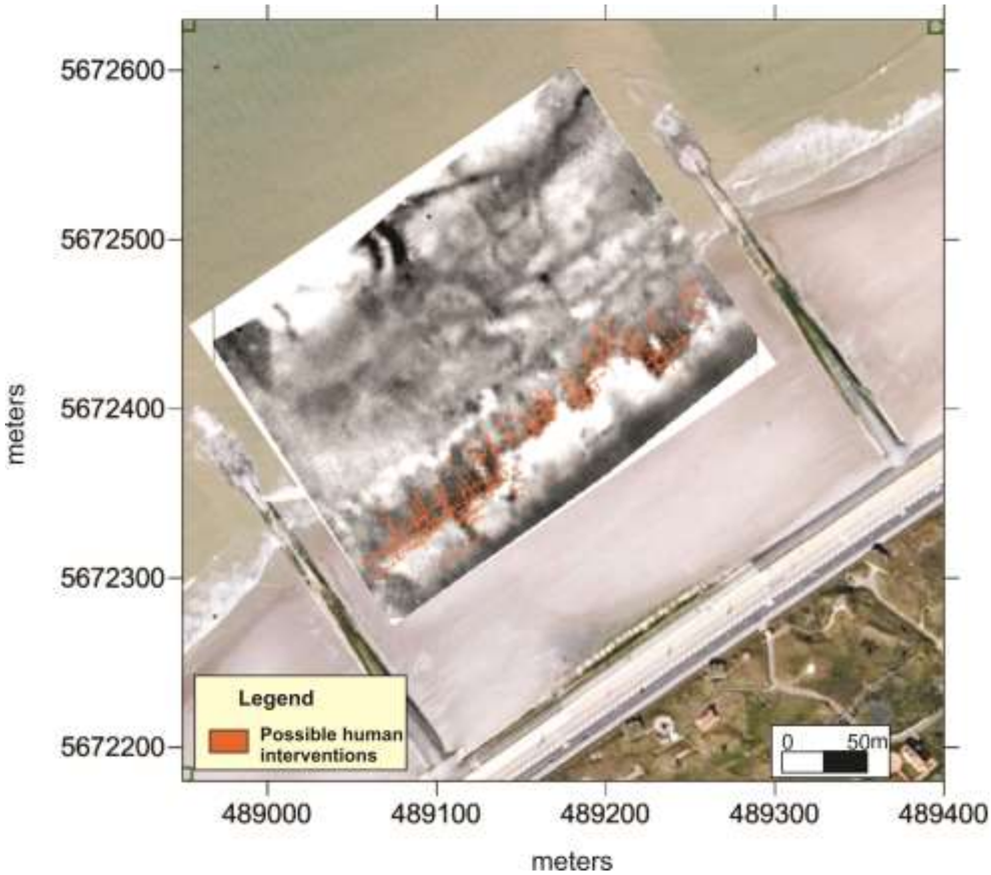

Figure 3L31: Results of the 2012 electromagnetic measurements in the intertidal area (after Delefortrie et al. (2014)).White areas indicate high conductivity, black areas indicate low conductivity. The orange lines mark the gaps in the strong shallow reflectors on the seismic data, supposedly related to human interventions. The correlation between the seismic and EMI data is obvious.

Combining the seismic data with the EMI data showed a good correlation between the two (Figure 3L36). The high conductivity on the electromagnetic data (white zones on the map) are likely caused by shallow peat layers (since peat increases the conductivity). It is clear that there is a strong correlation between the interrupted high-amplitude shallow reflectors observed on the seismic data and the area of high conductivity. The two fit almost perfectly. This seems to confirm that the gaps in the shallow seismic reflectors are most likely related to peat extraction patterns.

The correlation between the other features (palaeochannels etc.) observed on the seismic data and the electromagnetic data was not always very clear. That is likely due to the depths of the channels which are locally deeper than the penetration depth of the electromagnetic signal. In the offshore part of the EMI data a circular area with extremely low conductivity (black color) was observed. Its location and distribution seems to suggest a possible link with shallow palaeochannels.

3L.4.6 Comparison of hand corings and CPT´s

A comparison between the results of the CPTs and the hand corings was made, especially with relation to the presence of peat layers. The results were reasonably good. As an illustration two CPT-logs are shown in Figure 3L32 . The CPT-log on the left in Figure 3L32 clearly shows the presence of peat (blue peak in the friction ratio, marked by an arrow) at 2 - 2.5 m depth. Coring 4b, at the same location, confirms this peat layer. The CPT-log on the right in Figure 3L32 shows no clear peaks in the friction ratio, which is confirmed by corings v2a and v2b at the same location.

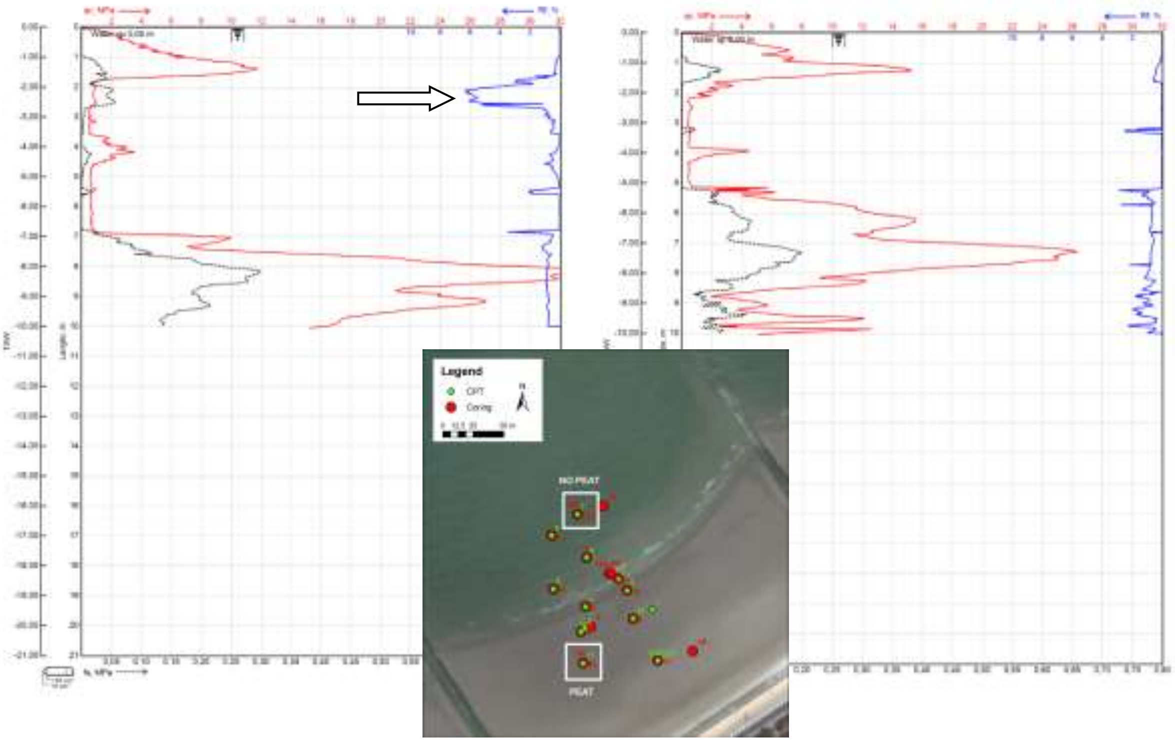

Figure 3L32: CPT-log 11, clearly showing a peat layer (marked by the arrow) at 2 - 2.5 m depth. Right: CPT-log 7, showing no peat layers in the upper few meters. The location of the CPTs and cores is shown at the bottom.

The results were not always straightforward however. In a few cases peat was detected in the CPT but not in the nearby core (or the other way around). This is possibly due to the large lateral heterogeneity in the subsurface sediments, and also to the fact that many cores did not reach deep enough. Also the fact that hand coring was extremely difficult in the intertidal area (taking up to 1-2 hours for a core of 3 meter) and core depths may often be erroneous due to compaction of peat in the core.

3L.5 Conclusions and recommendations

3L.5.1 Conclusions of the field work

The results of the different field surveys at Ostend-Raversijde so far confirm that we are dealing with a very complex area which is marked by a high level of heterogeneity and lateral variability in the shallow subsurface structure, typical of high-energetic (inter)tidal areas. A complex pattern of often criss-crossing (both shallow and deeper) palaeogullies was mapped. Some of these palaochannels seem to be related to the (vanished) medieval island of Testerep and the Yde gully that gave its name to the village of Walraversijde. It is the very first time that proof for the existence of this island has been given.

Also in the intertidal zones in between the breakwaters a chaotic palaeochannel pattern was observed, with both shallow and deeper gullies. Due to the presence of shallow gas the channel pattern is not always easily followed.

The seafloor is generally very smooth and slopes towards the shore in a step-like form, creating a distinct terrace. It is not clear yet whether this 'terrace' can be linked to the former island of Testerep (some sort of relic?). A number of small seafloor irregularities were observed close to the shore. Although there may be a link with locally outcropping layers, their location (in a zone roughly parallel to the shore) suggests a possible relation to coastal defense structures.

In the intertidal areas patterns of irregular, interrupted shallow reflectors were observed on most seismic data. This reflector pattern seems to be related to human interference. This is confirmed by electromagnetic measurements carried out at low tide in one of the intertidal zones. The results indicate that the interrupted reflector pattern is most likely due to the extraction of peat. The latter is also confirmed by old aerial photographs of the area showing chaotic patterns of outcropping peat. In the presence of (larger) palaeochannels the peat seems to be eroded.

Shallow hand cores and CPTs obtained in the intertidal area further confirm the link with buried peat sediments. One of the cores located near to the dike showed a thin layer of ash which could be related to remnants from human settlements. However, so far no further (geophysical) proof of these house remnants was found.

3L.5.2 Recommendations

The current research is one of the first studies that has been carried out in the intertidal and subtidal area integrating overlapping marine and terrestrial data (geophysical, geological and geotechnical). This was mainly possible due to the high tidal variations that allow us to obtain marine data very close to the shore and land data relatively far offshore on the beach.

The marine seismic data gives a clear image of the geological layers and features below the sea floor. However, shallow gas often disturbs the seismic image, especially in the presence of peat layers (due to the organic material). Over the years, however, new acquisition methods such as the parametric echosounder have been developed which allow us to obtain high-quality seismic data in increasingly shallow water (less than 1 meter water depth) and even in the presence of shallow peat layers.

Electromagnetic data so far has only been used on land, and in salt-free conditions. The good results of this study are very promising for future work of this technique in intertidal environments marked by a high (and variable) salt content. In this case study for the first time marine seismic data and terrestrial electromagnetic data were combined from the same area. The results were impressive and show that there is good correlation between these very different and complementary data. Both techniques are very efficient, able to provide high-quality data in a fast way (a couple of hours for areas of roughly 300 x 300 m). This is crucial in view of the short measurement periods due to the tide. However, additional ground-truth data such as shallow cores and CPTs are always needed for a final confirmation. Obtaining high-quality shallow cores on the intertidal beach remains very problematic, and it seems that electrical CPT's may be a good alternative here.

The results of the fieldwork presented here open important new perspectives for detailed research of intertidal areas with regard to archaeological and palaeolandscape studies.

As a concrete example of the applicability of above mentioned techniques, Ostend might prove to be an interesting case. Ostend was, just as Raversijde, formerly located on the

Testerep island. At the end of the 14th century, storm floods forced the inhabitants to leave. A new city was erected southeast of the tidal channel that divided Testerep from the mainland. In the following centuries both the old and the new city remained intact. The division was by then formed by the harbor (Figure 3L33).

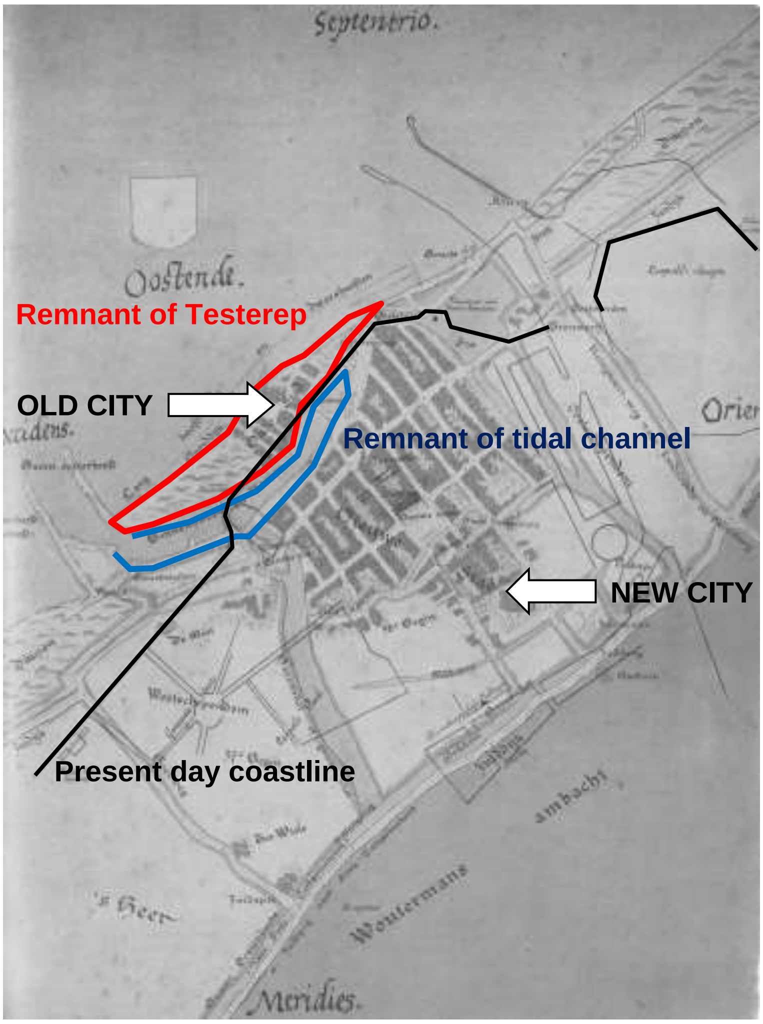

Figure 3L33: Map of Ostend around 1560 (copy of the original map of J. Van Deventer), with indication of important elements.

During the Eighty Years war (1568-1648), the verges of the city were converted to fortifications. Due to this modifications and the fighting in and around the city, the old town was largely destroyed (http://www.watererfgoed.be). Today, parts of the old city are under water and remain unknown, and also the exact location of Ostend on *Testerep* is still unknown. Integrated use of the new techniques discussed in the previous chapters could provide valuable new insights here.

In this matter also the very recent (May 2014) acquisition of a vibrocorer by the Flemish Marine Institute (VLIZ) may play an important role in the future. The cores that can thus be obtained may provide the necessary offshore groundtruth that is currently still lacking, including absolute dating of the sediments. This will allow more detailed information on the landscape evolution of this highly complex area.

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For further information on the project and to access the full Technical Report please go to www.archmanche.hwtma.org.uk/downloads

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3L.6 Case Study References

Baeteman, C. 2007. De ontstaansgeschiedenis van onze kustvlakte. *De Grote Rede: Nieuws over onze Kust en Zee,* 18, 2-10.

Claerhout, C. 2014. *Marien seismische studie van een getijdengebied (Raversijde-Oostende) met het oog op geo-archeologische kartering.* Unpublished Msc.-thesis, Ghent Univeristy.
De Clercq, M., Vos, P., Missiaen, T. & Pieters, M. 2013. Archeologische en Geo-archeologische indicatoren. *Internal report IWT SBO Project 120003 "SeArch"*.

Delefortrie, S., Saey, T., Van De Vijver, E., De Smedt, P., Missiaen, T., Demerre, I. & Van Meirvenne, M. 2014. Frequency domain electromagnetic induction survey in the intertidal zone: Limitations of low-induction-number and depth of exploration. *Journal of Applied Geophysics,* 100(0), 14-22.

Demerre, I., De Clercq, M., Missiaen, T., Pieters, M. & Van Haelst, S. 2013. *Selectie van Testsites - internal report IWT SBO Project 120003 "SeArch".*

Ervynck, A., Baeteman, C., Demiddele, H., Hollevoet, Y., Pieters, M., Schelvis, J., Tys, D. & Van Strydonck, M. 1999. Human occupation because of a regression, or the cause of a transgression? A critical review of the interaction between geological events and human occupation in the Belgian coastal plain during the first millenium AD. *Probleme der Küstenforschung im südlichen Nordseegebiet,* 26, 97-121.

Lunne, T., Robertson, P. K. & Powell, J. J. M. 1997. *Cone Penetration Testing in Geotechnical Practice.* London, Spon Press Taylor & Francis Group.

Mathys, M. 2009. *The Quaternary geological evolution of the Belgian Continental Shelf, southern North Sea.* Unpublished PhD-thesis, Ghent University, department Geology and Soil Science.

Missiaen, T. 2008. Marien seismisch onderzoek voor de kust van Raversijde. *RCMG internal report*.

Missiaen, T. 2010. Acoustic imaging offshore Raversijde. Results of the 2nd survey, april 2010. *RCMG internal report*.

Pieters, M. 1992. Archeologisch onderzoek te Raversijde. Interim Verslag. *Archeologie in Vlaanderen*, 247-264.

Pieters, M., Baeteman, C., Bastiaens, J., Bollen, A., Clogg, P., Cooremans, B., De Bie, M., De Buyser, F., Decorte, G., Deforce, K., De Groote, A., Demerre, I., Demiddele, H., Ervynck, A., Gevaert, G., Goddeeris, T., Lentacker, A., Schietecatte, L., Vandenbruaene, M., Van Neer, W., Van Strydonck, M., Verhaeghe, F., Vince, A., Watzeels, S. & ZeebroeK, I. 2013. *Het archeologisch onderzoek in Raversijde (Oostende) in de periode 1992-2005.* Brussel, AOE.

Pieters, M., Demerre, I., Lenaerts, T., Zeebroek, I., De Bie, M., De Clercq, W., Dickinson, B. & Monsieur, P. 2010. *De Noordzee: een waardevol archief onder water. Meer dan 100 jaar onderzoek van strandvondsten en vondsten uit zee in België: een overzicht.* VIOE.

Pingree, R. D. & Maddock, L. 1979. Tidal flow around an island with a regularly sloping bottom topography. *Journal of the Marine Biological Association of the United Kingdom,* 59(3), 699-710.

Robertson, P. K. & Cabal, K. L. 2012. *Guide to Cone Penetration Testing for Geotechnical Engineering (5th edition).* Signal Hill, Gregg Drilling & Testing, Inc.

Thoen, H. 1978. *De Belgische kustvlakte in de Romeinse tijd. Bijdrage tot de studie van de landelijke bewoningsgeschiedenis.* Brussel, Paleis der Academiën.

TYS, D. & PIETERS, M. 2009. Understanding a medieval fishing settlement along the Southern North Sea: Walraversijde, C. 1200–1630 *In:* Sicking, L. & Abreu-Ferreira, D. (eds.) *Beyond the catch. Fisheries of the North Atlantic, the North Sea and the Baltic, 900-1850.* Leiden/Boston, Brill.

Verrijken, V. & Demerre, I. 2010. Intern verslag boorprospectie juli 2010. *VIOE internal report*.

CASE STUDY 3M – (WAASLAND) SCHELDT POLDERS, BELGIUM

Case Study Area: Scheldt Polders

Main geomorphological types: Estuary (partially embanked), tidal basin

Main coastal change processes: Natural Flooding, Breaching, Human induced

Primary Resources used: Archaeological/Palaeoenvironmental Data and Historical Maps

Summary: The Scheldt polder area, located in the NW of Belgium at the Dutch border, is mainly made up of estuarine tidal marsh and embanked areas. The area is known for human occupation since prehistoric times (Late Palaeolithic). The case study demonstrates the use of (new) techniques for detailed palaeo-landscape reconstruction, on two different time scales: (1) natural evolution of the landscape during the Holocene (last 10.000 years, pre-medieval), based on geotechnical and geophysical data; and (2) man-induced evolution of the landscape since the Middle Ages, based on historical maps.

Recommendations: This novel approach is especially valuable in view of the ongoing harbor extension and nature compensation works in the Scheldt polder area.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the technical report on the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

Scheldt polders is one of two Belgium case study areas for the Arch-Manche project. This case study report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented along with the results of the map and chart studies. The analysis of these results and the potential for demonstrating the scale and rate of coastal change are then presented. For further details about the project methodology see Section 2.

The case study "Scheldt polders" has the intention to demonstrate, use and evaluate (new) techniques for palaeogeographical landscape reconstruction. This will be done on two time scales: (1) palaeogeographical Holocene (pre-medieval) reconstruction based on geotechnical and geophysical data; and (2) post-medieval landscape reconstruction based on historical maps.

The aim of applying these (new) techniques is to improve and facilitate (especially time wise) current methods of landscape reconstruction, based on for instance extensive and time consuming coring.

Based on the results of the analysis of historical maps and the results of the fieldwork, complemented with existing corings, the final part of this report will present maps of the landscape evolution of the study area since the start of the Holocene to the late 19th century.

3M.1 Introduction to the Scheldt polders Study Area

The Scheldt (also called Waasland) polder area (which comprises the Doelpolder) is located in the northern part of Belgium, at the Dutch border (Figure 3M1). It is an area where interactions between nature and humans are intensely intertwined and it is a beautiful example of how environmental change affects human life, but also the astonishing capability of mankind to sculpt a landscape to his own needs. The area is an almost flat, low lying region on the western bank of the river Schelde. Geographically it is limited by the Dutch/Belgian border in the northwest. North of the border lies the Drowned Land of Saeftinghe, an extensive tidal marsh (Figure 3M1).

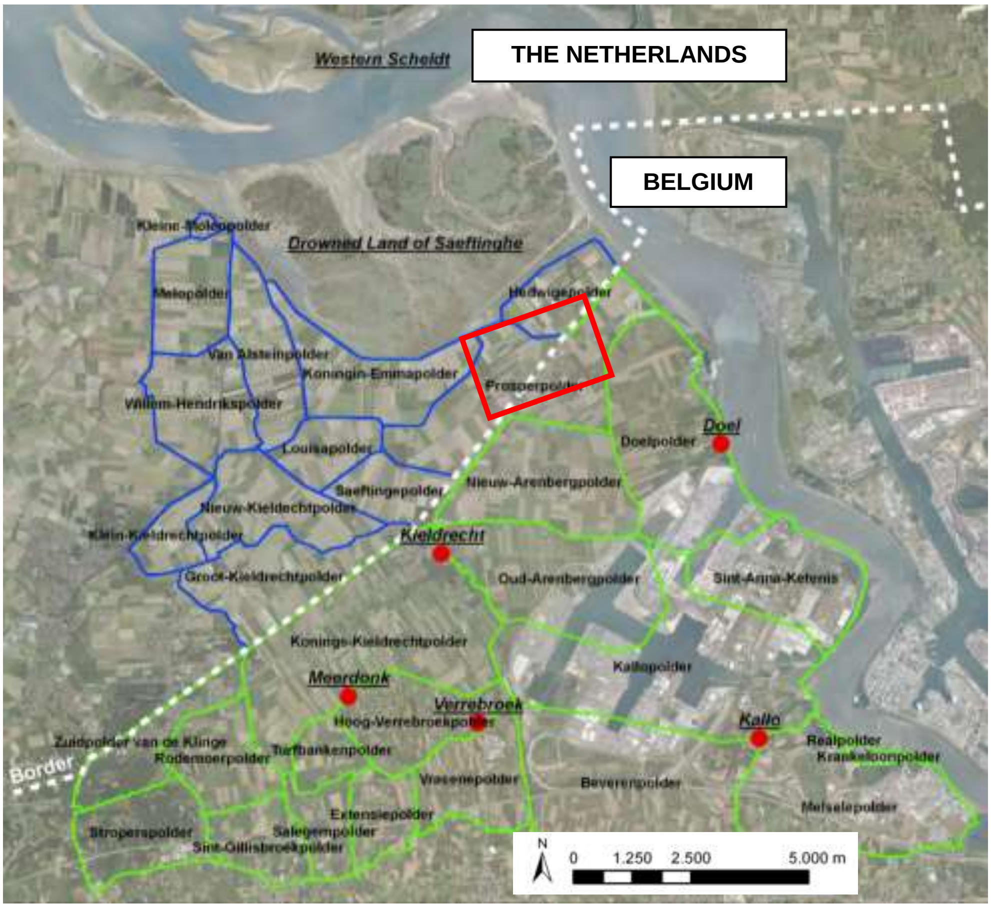

Figure 3M1: Overview of Waasland study area, the different polders included (green: Waasland polders, blue: Dutch polders) and the Drowned Land of Saeftinghe in the north. Note that some of the Waasland polders have (partly or completely) disappeared due to the Antwerp harbor extension. The red rectangle marks the site of Doelpolder-Noord (background: Google Earth).

The elevation in the polder area varies between roughly 0.5 and 5m TAW (Dutch level approximate to lowest astronomical tide or LAT) (Figure 3M2). This means that the majority of the region would be flooded by high tide if no dikes were present. In the Early Middle Ages, this landscape used to be a tidal flat environment that changed into dry land due to drainage and the creation of polders. The faint microrelief in the Digital Elevation Model (DHM) is due to old creeks and dikes. In general the younger polders have a higher elevation as they silted up for a longer period of time (Figure 3M2).

The typical polder landscape is, however, only partially preserved, because of the expansion of the harbour of Antwerpen. Locally the elevation has been changed by adding up to 10 m of soil on top of the original topography.

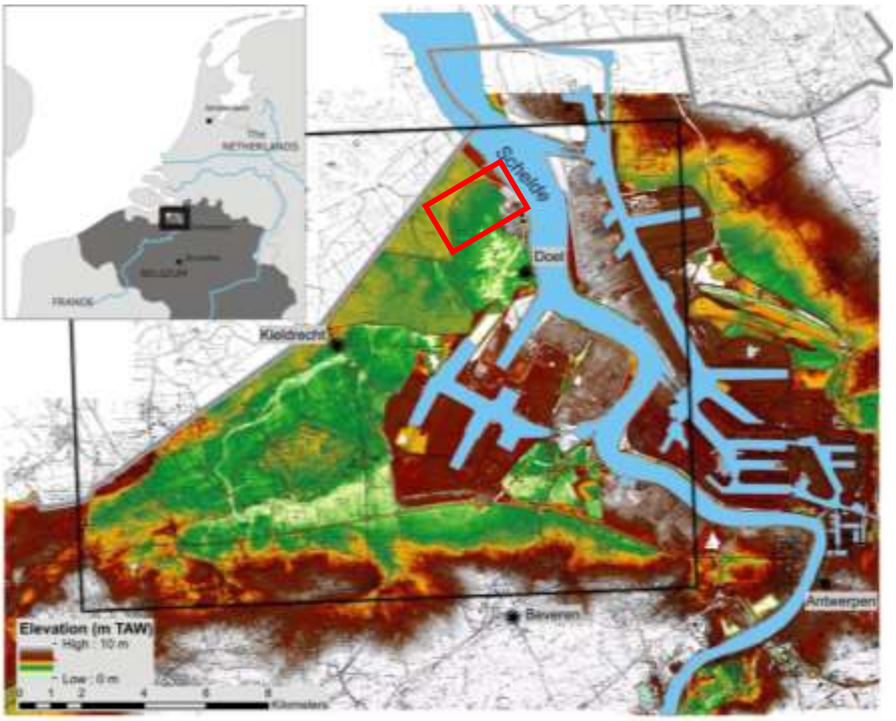

Figure 3M2: Digital elevation model (DHM) of the Waasland (Scheldt) polder area. The black box indicates the extent of the study area. The grey line indicates the Dutch-Belgian border. The inset in the top left shows the location of the study area. The red rectangle marks the site of Doelpolder-Noord. (Digitaal Hoogtemodel Vlaanderen, AGIV (2003)).

3M.1.1 Geology of the Study Area

The Waasland polder area is a geologically young region. The current landscape and shallow deposits are of Late Quaternary age and are highly influenced by the proximity of the North Sea and the river Scheldt. Over the past 30.000 years the river has changed its course and pattern, greatly impacting the depositional environment and river-sea interactions. The delicate balance between sea-level rise and river sedimentation has led to phases of transgressions and regressions. More recently, ca. 1000 years ago, the impact of man has become dominant by building and rebuilding dikes. This battle between man and water left traces in the current landscape.

Tertiary sediments

The Tertiary geology in the study area consists of sandy deposits (Formation of Lillo, in the extreme southeast also the Formation of Kattendijk and Formation of Boom). No Tertiary outcrops are present. The depth (top surface) ranges from less than 5m below the current topography in the southwest, to 25-30m in the northeast.

The Formation of Lillo (Mid to Upper Pliocene) consists of shell-rich sand deposits (Jacobs et al., 2010a). The Formation of Kattendijk (Lower Pliocene) consists of glauconitic sand (with shell fragments), locally rich in clay (Jacobs et al., 1993; Jacobs et al., 2010b). The Member of Putte (Formation of Boom) (Early Oligocene) consists of organic-rich clay (Jacobs et al., 1993; Jacobs et al., 2010b).

Quarternary sediments

The Quaternary sediments in the Waasland polder area were all deposited in a dynamic environment. This implies a lot of lateral variability.

In the central part of the study area Late Glacial and Holocene deposits lie directly on top of the Tertiary formations. In the eastern and western part a sandy deposit forms the transition between the Tertiary and Quaternary (Holocene) deposits. The sand was deposited by a braided river system in the Mid Weichsel (ca. 30 000 years ago) in a periglacial environment (Adams et al., 2002; De Moor and van de Velde, 1995; Bogemans, 1997) (Figure 3M3). Due to the cold and windy climate during the Late Glacial the vegetation cover was limited, creating a surface extremely vulnerable to wind erosion (Verbruggen et al., 1991) and a thin layer of sandy deposits covered the entire study area. Furthermore, sand dunes were formed due to these aeolian processes, the largest being the sand-ridge Maldegem-Stekene, of which the eastern end reached into the study area. The braided river systems were only seasonally active, and locally river dunes and cover sand ridges were created (Kiden, 2006). At the end of the Late Glacial (ca. 13.000 years ago) temperatures started to rise and the braided Scheldt river transformed into a meandering river and depending on the location fine sand, silty clay and clay were deposited (Bogemans, 1997) (De Moor and van de Velde, 1995).

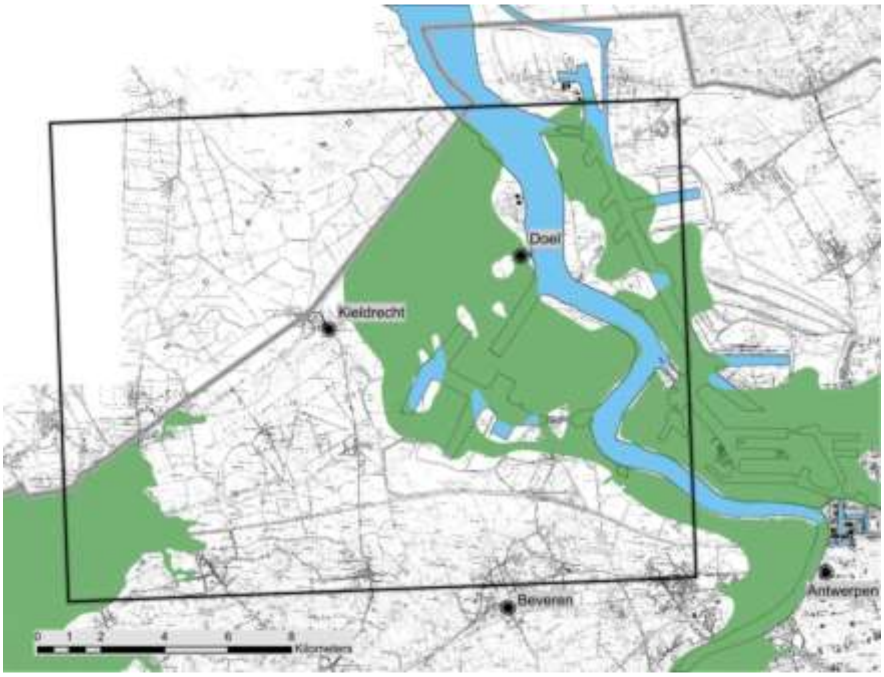

Figure 3M3: Presence of the Mid Weichsel braided river deposit in the Scheldt polders (Bogemans, 2005). The black box indicates the extent of the study area. The grey line indicates the Dutch-Belgian border.

The Holocene sediments consist of peat, marine and estuarine deposits. Most of the peat was deposited in a marsh environment along the river Scheldt estuary. The peat marshes were groundwater fed and the level of the groundwater table was most likely determined by the height of the mean sea level at that time (Kiden, 2006; van de Plassche, 1982). However, peat was also growing in higher locations. These peat fens were probably also groundwater fed, due to the bad drainage of the Pleistocene surface (van de Plassche, 1982). Locally the peat sequence is intercalated by marine deposits related to a marine transgression in de Mid Holocene (Vos and van Heeringen, 1997); in some places this marine incursion eroded the peat. It consists of mainly grey to almost black clay, often with peat fragments. The overlying estuarine deposits consist of sand and clay often with remains of organic matter or marine shell fragments. These sediments were deposited in a dynamic tidal flat environment with salt marshes, mud flats and creeks. Consequently there is a lot of lateral variability within this deposit.

During the Holocene the river Scheldt flowed northward through the present-day Eastern Scheldt. The Western Scheldt came into being when during the Middle Ages (ca. between 800 and 1000 AD) the tidal channel *Honte* expanded further landward and became connected to the Scheldt river just north of Antwerpen (Vos and van Heeringen, 1997). However for centuries after this the Eastern Scheldt still remained the main outlet of the river Scheldt to the sea; the Western Scheldt being only navigable at high tide due to the presence of a large sand bar between Saeftinghe and Bath.

For more information about the local geology and the geological history of the Scheldt polders we refer to the report "Holocene palaeogeographical evolution of the Waasland Scheldepolders" by Heirman, Missiaen & Vos (2013).

3M.1.2 Summary of the Archaeology and History of the Study Area

During harbour construction works at the *Verrebroek* and *Deurganck docks*, the late Pleistocene landscape proved to be well-preserved under the more recent deposits. On the tops and flanks of (micro) sand ridges, numerous traces of prehistoric archaeological sites, dating as far back as the Final Paleolithic and Early Mesolithic , were found. (Crombé, 2005). Mesolithic/Neolithic traces have been found at three well-preserved settlements (Crombé et al., 2009; Sergant et al., 2006; Crombé, 2005). These sites have been attributed to the Swifterbant culture (Crombé et al., 2011), during which an adaption from a hunter-fisher-gatherer economy to an extended broad spectrum economy, involving cattle-breeding and small-scale agriculture, took place. So far no direct archaeological proof of human activity was found that dates from the Middle Neolithic to the Middle Ages, when the area was a large peat marsh, but archaeological records from nearby locations in the Netherlands suggest that occupation took place even in these wet situations (De Clercq, 2009).

History of the study area since the late Middle Ages

During the late Middle Ages large-scale flooding (partly due to embankment tactics) shifted the local current pattern of the river and the Western Scheldt now became the main outlet, whereas the Eastern Scheldt slowly started to silt up (Soens, 2013). Still the Western Scheldt was probably not deep and wide enough to allow the navigation of large ships until the early sixteenth century.

Landscape development of the Waasland polder area became more and more intertwined with human activity. Large-scale inundations caused the need for (re-)embankments, which were often carried out by mighty abbeys. The embankment history between the thirteenth and sixteenth century is tightly intertwined with large-scale peat extractions. Indeed population growth and economic welfare had resulted in an increasing demand for fuel (in the form of dried peat or *turf*). Large centers of peat exploitation were set up (e.g. in Kieldrecht, Verrebroek and Meerdonk) (Augustyn, 1985; Augustyn, 1999), and ditches and roads were built to transport the peat.

During the early peat extractions (12^{th}-13^{th} C) so called *moerdijken* ('peat dikes') were constructed for peat transport. This gradually changed in the 14^{th} and 15^{th} C when (larger) dikes were primarily built for flood defense (Van Gerven, 1977). The embankment activities resulted in an almost entirely embanked situation of the Waasland area by 1570. During the subsequent Eighty Years' War however the dykes of Saeftinghe were breached and the entire area was inundated (De Kraker, 2002; Guns, 2008), resulting in a large tidal marsh (Figure 3M4). This inundation was facilitated by the lowered surface of the former embanked areas due to peat extraction, drainage and soil compaction.

Figure 3M4: The church of Verrebroek in 1602, arising in the inundated area (Algemeen Rijksarchief Brussel, ARA in the following, Arenberg, LA n° 4413) (for location see Figure 3M1).

In the following centuries the Waasland area was gradually re-embanked (also made possible by the more stable (political) situation after the end of the end of the Eighty Years' War). One particular family, the Arenberg family, played a crucial role in this. At first only as land owner, later also as embanker and finally as direct exploiter. The main focus of these new embankments, often performed from large exploitation centers (such as the Prosperhoeve, Figure 3M5), was on agriculture since the peat was now covered by a (thick) layer of tidal sediments resulting from the inundation.

Figure 3M5: The Prosperhoeve in Prosperpolder, second half nineteenth century (www.inventaris.onroerenderfgoed.be (02/01/2014))(for location see Figure 3M1).

For more information about the recent (late and post-Medieval) history of the Scheldt polders we refer to the report "Recent landscape evolution of the Waasland Scheldepolders based on historical maps" by Jongepier, Missiaen & Soens (2013).

3M.1.3 History of Mapmaking in the Waasland polder Area and Surroundings

Coastal Flanders has known an exceptionally large map production, often (but not solely) linked to the numerous embankment enterprises. References to land surveyors in Flanders can be found as early as 1190 (Janssens, 2006), and the oldest cartographical products date from the 14th C (Augustyn, 1999; Gottschalk, 1955-1958). Also the Waasland area had an early tradition of land surveying, as documented by trial documents from 1469 concerning the measuring and selling of tidal marsh and peat lands by Duke Filips the Good (Rijksarchief Beveren, P13, n°1).

Over the next centuries the number of land surveyors grew, but still could not keep up with the large demand for measurements and maps (often related to embankment practices). This is not surprising in the light of the large embankment works in the area that required a great number of detailed maps (e.g. Figure 3M6), which were mostly obliged in the embankment licenses.

The combination of the rapid development of mapping techniques (De Maeyer et al., 2004), the need for measurements for new embankments and the certified quality of land surveyors resulted in a large number of maps for the Waasland area. Luckily, numerous maps have been preserved. It is perhaps important to note that the most interesting maps are often not to be found in open access internet databases but in (local) archives, for instance the (State) Archives in Brussels, Ghent, Beveren and Middelburg. Many of these maps were ordered by (or linked to) the Arenberg family since they took part in numerous embankments.

Figure 3M6: Example of an embankment map of the Nieuw-Arenbergpolder (1783, ARA, Kaarten & Plans, n° 8573)(for location see Figure 3M1).

For more information about the late and post-Medieval map production of coastal Flanders and the Scheldt polders we refer to the report “Development of a uniform methodology for evaluating historical maps and their use for coastal research” by Jongepier, & Missiaen (2013).

3M.2 Current Environmental Impacts/ Threats and Coastal Management Approach

Most of the Waasland polder is under imminent threat of harbour extension, since it is located near to the Antwerp harbour. In 2013 the Flemish government approved a new plan for the extension of the harbour zone, which comprises the construction of a large dockyard (Saeftinghedok) at the location of Doel-town, stretching through the Doelpolder up to the

Nieuw-Arenbergpolder. Surrounding the dockyard an industry zone is to be constructed. As a compensation for this industrial expansion part of the Doelpolder area is to be converted into a nature compensation zone (some parts have already been converted), including the expropriation of most inhabitants. Recently however the Council of state (Raad van State) has demanded a temporarily suspension of these plans, asking for revisions. In the meanwhile, almost the entire village of Doel-town is already deserted.

In the north of the study area, plans have been approved by the Flemish and Dutch governments to de-embank the Hedwigepolder and part of the Prosperpolder, thus creating one large intertidal area that will join the exiting Drowned Land of Saeftinghe (Figure 3M7). Extending this tidal marsh will create important new (water) storage capacity, which will help to minimize inundation risks in the Western Scheldt estuary.

Figure 3M7: Schematic of the Hedwige- and Prosperpolder before (top) and after (bottom) the de-embankment plans (http://www.hedwigeprosper.be (18/09/2014)).

3M.3 Archaeological and Palaeoenvironmental Fieldwork

3M.3.1 Key research questions in relation to coastal change to be addressed via fieldwork

Buried palaeolandscape reconstruction is conventionally based on detailed in-situ information such as sediment cores and (archaeological) augerings. These techniques however are very time consuming, and therefore often expensive. Furthermore they are not always easy to perform in coastal or estuarine sites that include intertidal marsh and subtital areas, especially where the landscape is buried relatively deep (more than a few metres). The fieldwork presented here focuses on the application of other geotechnical techniques (cone penetration testing) and geophysical techniques (land and marine seismics) for geoarchaeological & palaeogeographical research and coastal change studies. How efficient are these techniques to obtain reliable field data, in a less time consuming way than the conventional methods?

3M.3.2 Field Data Gathering Methods

Cone Penetration Testing (CPT)

Cone Penetration Testing is a geotechnical method to sound the composition of the subsurface. The method allows us to obtain information regarding the geology (nature and sequence of the subsurface strata) and hydrology (groundwater conditions) as well as the physical and mechanical properties of the subsurface strata (Lunne et al., 1997; Robertson and Cabal, 2012). The CPT method allows fast and continuous profiling of the subsurface with repeatable (and reliable) data, and is highly economical (Lunne et al., 1997).

In Cone Penetration Tests (CPT) a cone is pushed into the ground at a constant rate while continuous measurements are made of the cone resistance (i.e. resistance of the cone tip to penetration) and the sleeve friction (i.e. resistance of the sleeve) (Figure 3M8). The ratio of sleeve friction divided by cone resistance, called the friction ratio, is used to classify the soil.

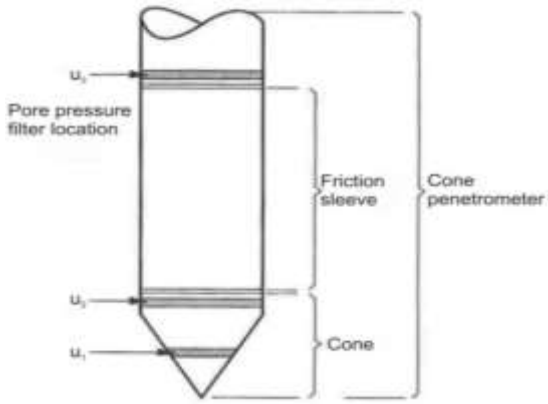

Figure 3M8: Terminology for cone penetrometers (from Lunne et al, 1997).

Additional sensors may be added to the cone. For instance in piezocone penetrometer tests (CPT-U) also the in-situ pore pressure u is recorded with depth (Figure 3M8). The latter may give valuable added information regarding the permeability of the subsoil sediments. Resistivity penetrometers (R-CPT) additionally measure the electrical conductivity of the soil with depth which may give valuable information regarding the lithology. Seismic penetrometer tests (S-CPT) combine CPT sounding with downhole velocity measurements using geophones installed into the cone rod. The velocity data will give more information regarding the soil.

For the case study, various CPT measurements were carried out in Doelpolder-Noord (DPN) (CPT, CPT-U, R-CPT, S-CPT). An overview is given in Figure 3M9. Measurements in the polder were carried out using a common CPT truck (Figure 3M10, left). This was not possible in the marsh, due to the limited accessibility and uneven terrain, and therefore an adapted mobile CPT rig was used. Moving the vehicle on the marsh proved very risky: due to a hidden gully the vehicle toppled over and had to be hauled out using a big crane (Figure 3M10, right).

For the seismic CPT measurements a heavy plate and sledge hammer were used to generate the seismic waves (Figure 3M10, left). Measurements were carried out at depth intervals of 0.5 - 1m. At each depth between 4 and 8 different hammer blows were done for each direction and these were stacked in order to improve the signal-to-noise ratio.

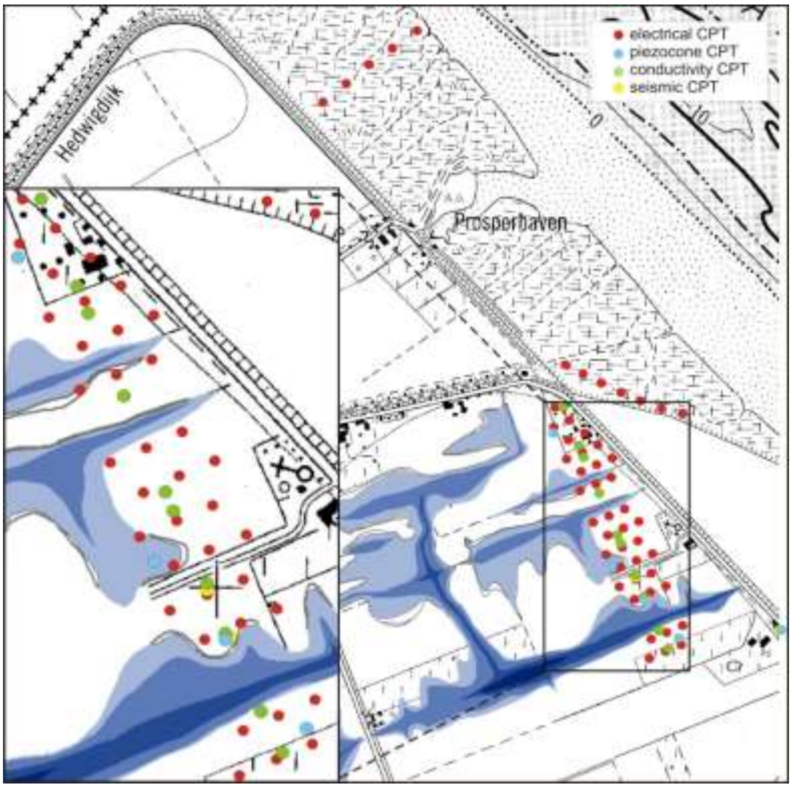

Figure 3M9: Overview of CPT measurements in Doelpolder-Noord. Different colours refer to various types CPT measurements.

Figure 3M10: Left – CPT truck used for CPT measurements in the polder. A hammer blow is used to generate seismic waves. Right - Mobile CPT rig used for CPT measurements on the marsh. Due to a hidden gully the rig toppled over and had to be hauled out by a crane.

Land seismic investigations

Reflection seismic investigations on land involve the use of a controlled seismic source and an array of receivers (geophones). The generated seismic pulse travels through the sediments and will be reflected at the interfaces between two materials with different densities. The reflected waves create an image of the subsurface. This image, or model, is not unique (more than one model adequately fits the data, typical for inverse problems) and therefore great care must be taken in data processing and interpretation.

Apart from the common compressional (P-) waves also shear (S-) waves can be generated on land. S-waves have lower velocities than P-waves and therefore shorter wavelengths which should allow an increase in resolution compared to P-waves. However S-waves also often exhibit lower frequencies than P-waves which may partly cancel the increase in resolution.

For the tests at Doelpolder-Noord a sledge hammer and a seismic vibrator system were used to generate the seismic waves (Figure 3M11). Both of these sources have shown good results in resolving the shallow subsurface layering at Saeftinghe (Missiaen et al. 2008). Because the terrain was relatively flat in the polder recording was done here using a land streamer containing 24 geophones spaced 1 meter apart. A reflection seismic profile of roughly 300 m was recorded in the central part of the study zone. Ground-truth of the seismic data was provided by three deep (mechanical) corings and various CPT located closeby.

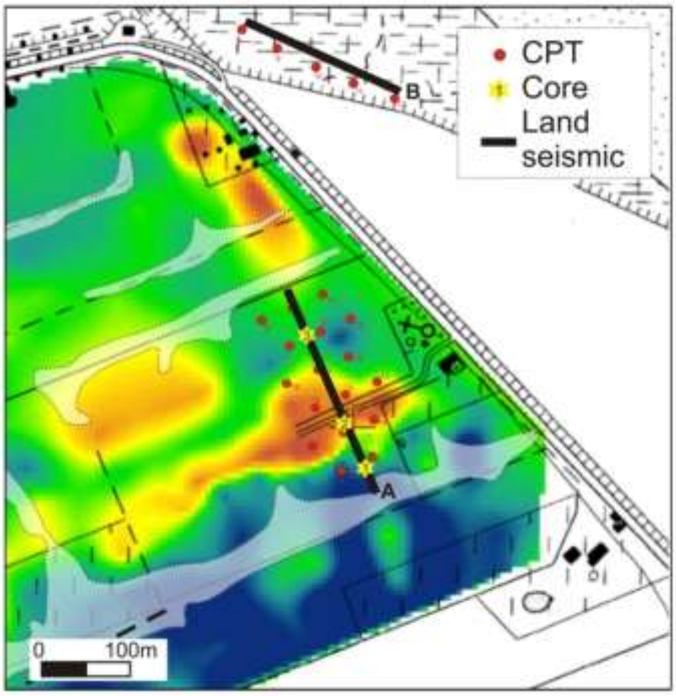

Figure 3M11: Location of the two land seismic lines recorded at Doelpolder-Noord. The deep core locations are marked by the yellow stars. Red dots indicate electrical CPTs.

On the tidal marsh (so-called 'Paardenschor') the use of the land steamer was not possible due to the uneven terrain and the amount of vegetation, and instead an array of 48 hand geophones was used. Unfortunately it was not possible to perform any mechanical coring on the marsh. Ground-truth was therefore only provided by a number of CPTs located along the seismic profile.

Marine seismic investigations

As on land, reflection seismic measurements at sea involve the use of a sound source, towed behind a vessel or mounted to the hull, to generate acoustic waves that travel through the soil. Part of the acoustic signal is reflected from the seafloor but the remainder penetrates the seafloor and is reflected when it encounters boundaries between layers with different elastic properties (Figure 3M12). The recorded reflected acoustic waves result in a continuous record of the sub-seafloor stratigraphy.

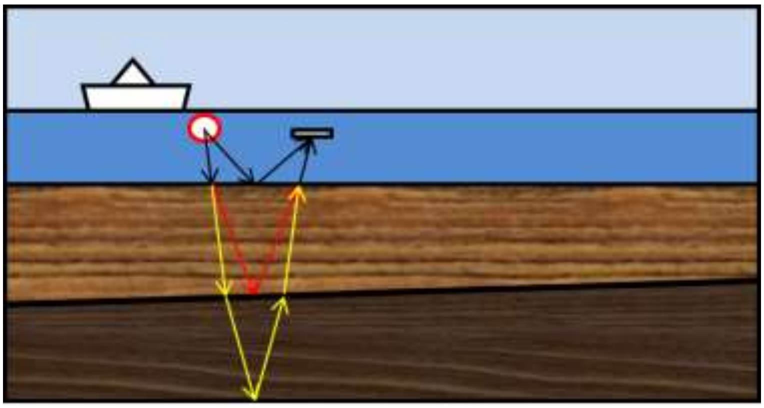

Figure 3M12: Marine seismic reflection principle.

Marine seismic measurements were carried out on the Scheldt river (subtidal and intertidal part, Figure 3M13, left) and on the inland creeks. For all surveys a parametric echosounder was used. A motion sensor was used to correct for the swell caused by wave movement. Positioning involved a DGPS antenna with an accuracy of ca. 1m. For the inland creeks a small inflatable boat was used that could be transported over land (Figure 3M13, right).

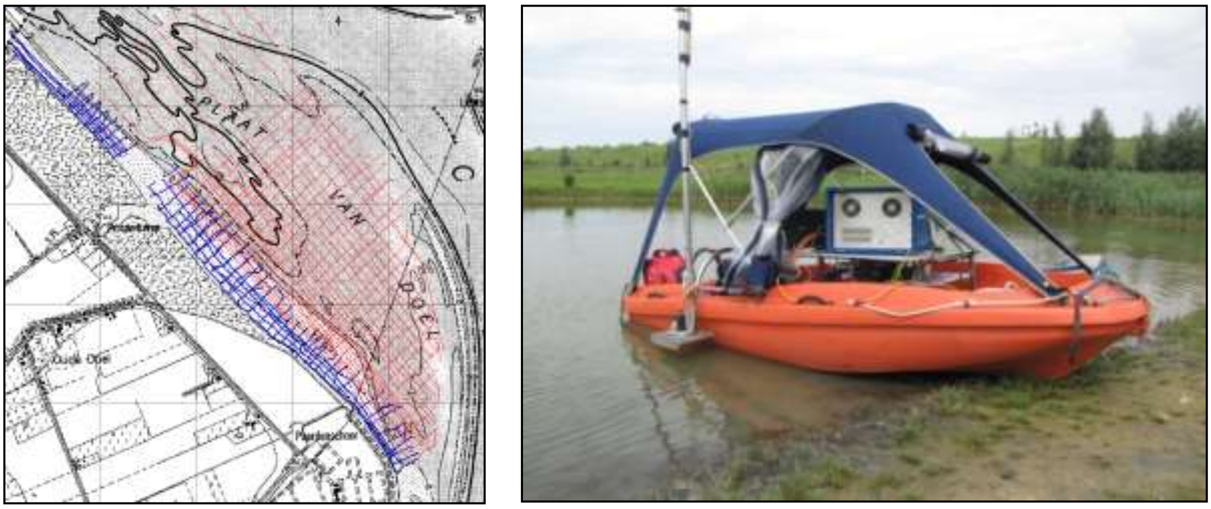

Figure 3M13: Left – seismic network on the Scheldt river (blue: intertidal; red: subtidal). Right – boat used for measurements on the inland creeks of Doelpolder-Noord.

3M.4 Field Data Analysis and Results

3M.4.1 Cone penetration test measurements (CPT)

An important focus of CPT interpretation was the identification of peat layers, since these play a major role in palaeogeographical and archaeological mapping. At Doelpolder Noord the peat sequence stood out well on the data; locally two distinct peat layers were even observed. The CPT data also allowed to differentiate between peat and intercalating organic-rich clay or sand layers (Figure 3M14). The transition from peat to the underlying (aeolian) sand deposits was generally very sharp and clear. Unfortunately the CPT data did not always allow us to distinguish between the intercalating (sand and clay) estuarine deposits.

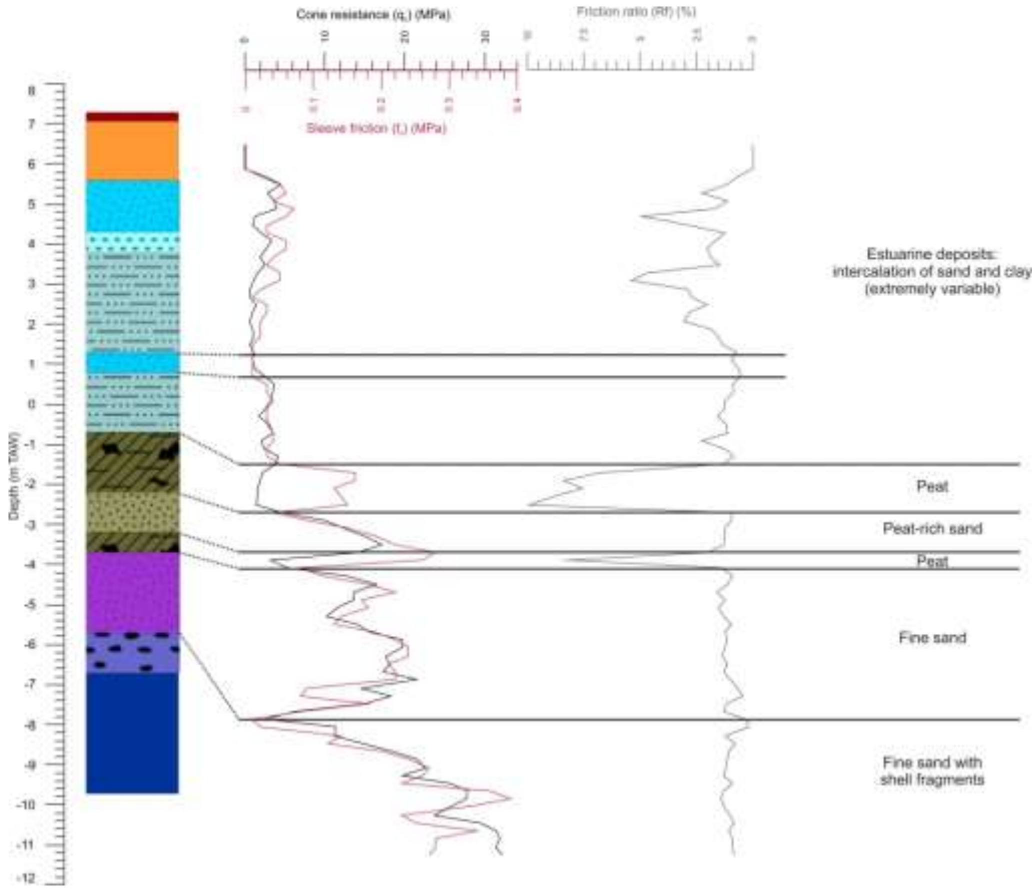

Figure 3M14: Comparison of a sediment core litholog (left) and nearby electric CPT measurement (middle and right) in Doelpolder-Noord.

It was hoped that the pore pressure and conductivity data from the CPT-U and R-CPT measurements would add valuable new information on the subsoil. However, this proved not to be the case. The seismic CPT measurements were more successful. Based on the arrival times of the seismic waves (recorded by the different geophones in the cone rod) the S-wave velocity through the subsoil could be calculated. The results fully confirm the local lithology as inferred from the CPT data (Figure 3M15), as the presence of a peat layer correlates exactly with a sharp velocity drop.

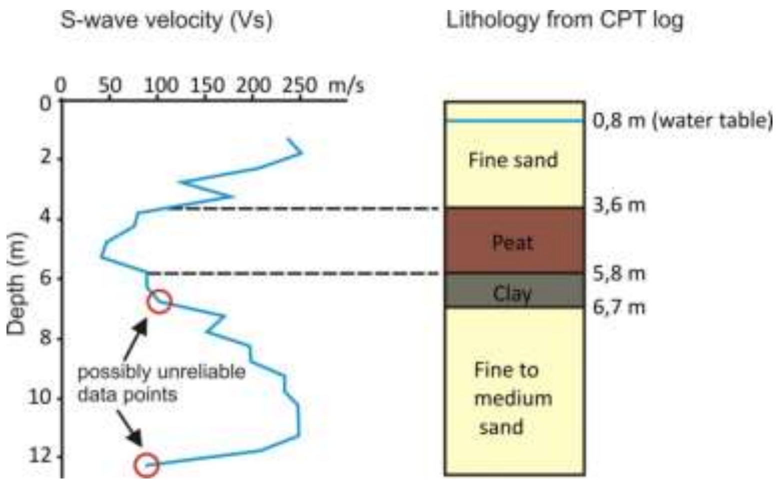

Figure 3M15: Shear wave velocities calculated from the arrival times in the seismograms (left) and corresponding lithology. The red circles are possibly erroneous data due to noise preventing accurate picking of the signal.

3M.4.2 Land seismic investigations

Interpretation and correlation of the land seismic data was only possible after extensive data processing. Important steps in the processing included a.o. the muting of surface (Love) waves, the creation of a velocity model, bandpass frequency filtering, stacking of the data and time (ms) to depth (m) conversion.

The resulting data from the polder profile shows a dome-like structure (Figure 3M16). The structure fully confirms the palaeotopography. Correlation of the seismic data with nearby deep cores (Figure 3M16, top) was not easy in view of the limited length of the cores (~ 13 m) compared to the depth of the seismic section (~ 50m) but the transition from sand to peat deposits seems to correlate well with a prominent shallow reflector.

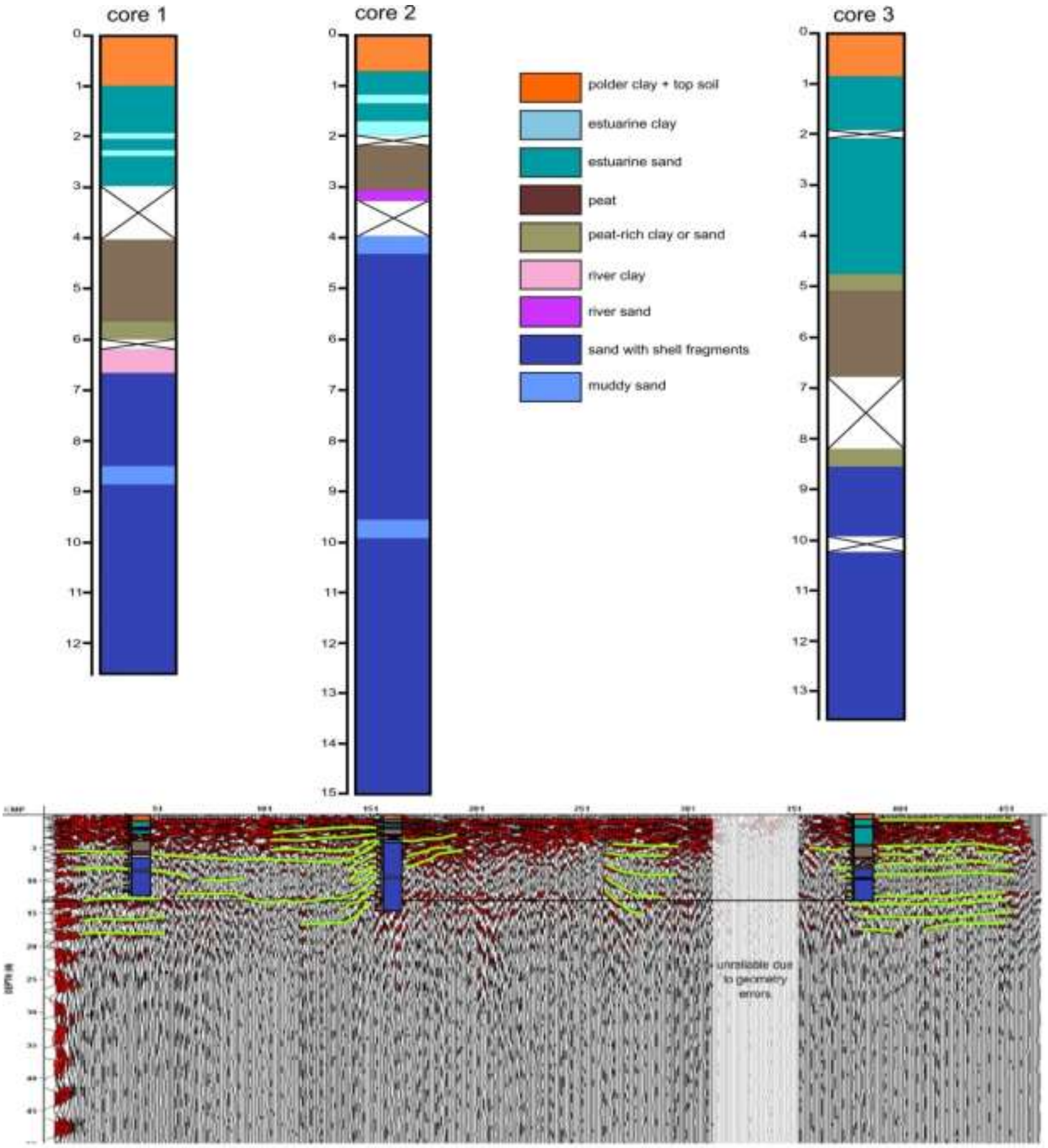

Figure 3M16: Correlation of land seismic data in Doelpolder-Noord (bottom) with nearby deep cores (top).

The seismic data obtained in the marsh proved to be more complicated. It was expected that the shallow water table at the marsh would allow a good resolution of the shallow deposits, but this was not the case. This was most likely due to the extremely weak top sediments in the marsh (upper 5-6 m), and resulting insufficient coupling between the source/geophones and the ground. As a result the image quality in the upper 20 meters was extremely low and no comparison with CPT data was possible.

3M.4.3 Marine seismic investigations

The marine seismic data obtained on the river Scheldt were highly affected by the abundant presence of (biogenic) gas in the shallow subbottom sediments. As a result the data quality was often very poor with a limited seismic penetration (often less than 1 meter). This was also the case for the data obtained on the inland creeks. The best penetration was obtained in the extreme southeastern corner of the Scheldt network and in the northern part of the intertidal area. Here a number of shallow reflectors and palaeochannels (indicating ancient tidal gullies) could be observed (Figure 3M17). However due to their extremely patchy pattern the spatial continuation of the observed seismic reflectors (including possible peat layers) was highly uncertain, and a reliable correlation with the CPT or core data nearby on land was not possible.

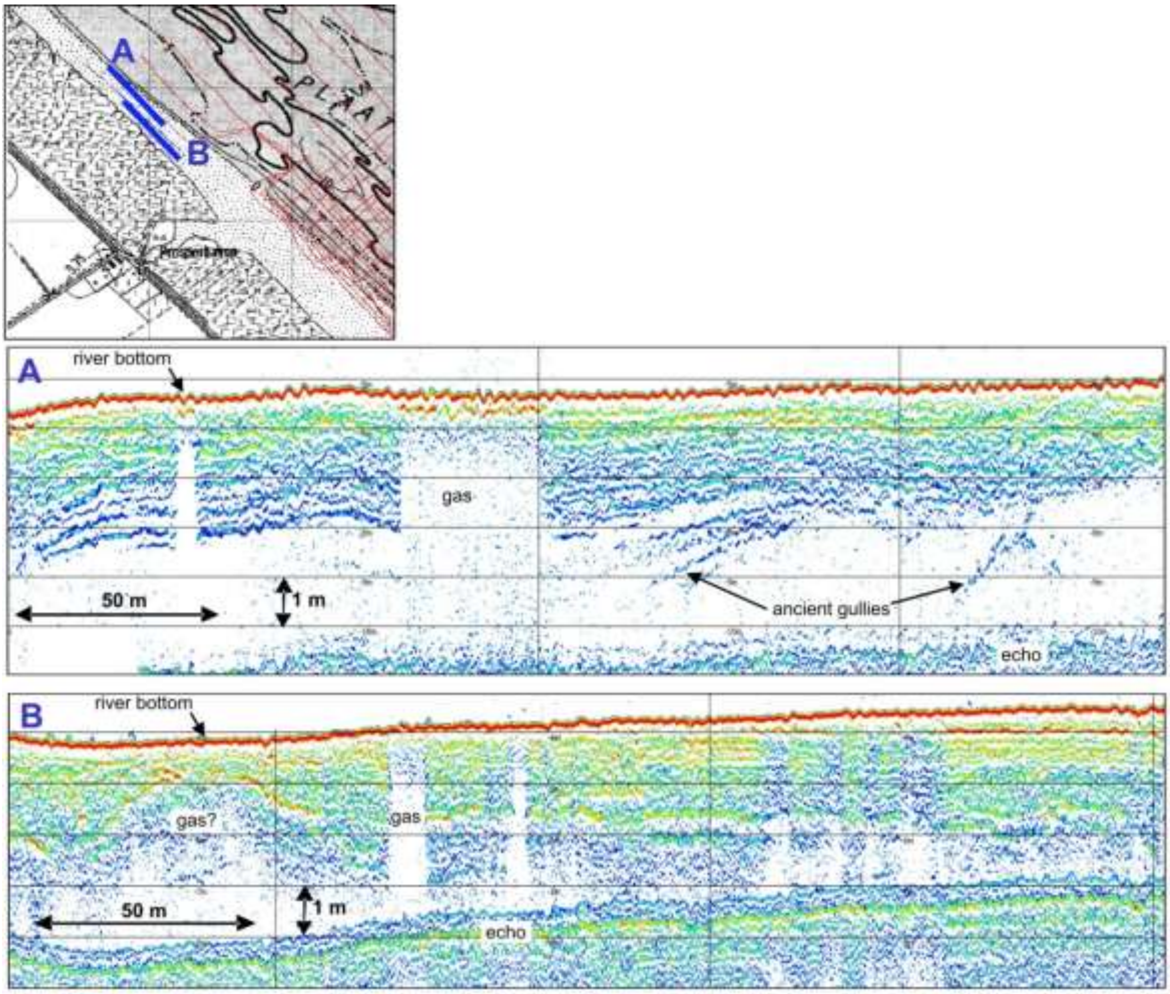

Figure 3M17: Examples of two seismic profiles in the intertidal area. A large number of (sub-) parallel reflectors can be observed in the upper meters. Below this ancient tidal gullies show up. Further offshore the gassy patches become increasingly prominent. The location of the profiles is shown in the top left.

3M.4.4 Comparison of the usefulness of the different methods

Comparison of the three geotechnical/geophysical methods (CPT, land seismic, marine seismic) shows that by far the CPT technique seems to be the most applicable and efficient method for geoarchaeological research and palaeoenvironmental reconstruction.

Land seismic investigations in estuarine and polder areas are time consuming and do not give the high resolution that is needed. Furthermore the results are highly dependent on the type of subsoil, and soft top layers such as those frequently encountered in marshy areas, will seriously decrease the data quality. Marine seismic investigations in estuarine environments seem a good alternative because this method is very quick (a close profile network can be recorded in 1-2 days) and provides very high resolution images of the sub-seafloor, also in intertidal areas. However on the Scheldt river this method was highly affected by the presence of shallow gas (likely due to a combination of thick organic-rich top layer and peat deposits in the subsoil). As a result no continuation of the geological (peat) layers below the river bottom could be obtained.

CPT measurements allow fast profiling of the soil stratigraphy, much quicker than the collection of sediment cores. Especially when peat is present, the depth measurements of the sediment layers will also be more correct as peat deposits have a tendency to compress/expand during/after coring. Nevertheless CPT data should always be ground-truthed with sufficient sediment samples from a nearby location, and the interpreter should have a good knowledge of the local geology and the geotechnical technique. Piezometric CPT (CPT-U) and resistivity CPT (R-CPT) do not seem to add a lot of significant detail compared to regular electric CPT. Seismic CPT provides valuable information on the layer velocities but it is a time consuming method, and should therefore only be applied when this information is actually required.

3M.5 The use of Historical Maps for (post-) Medieval Landscape Reconstruction

3M.5.1 Introduction

For more recent (medieval and post-medieval) landscape reconstructions, historical maps provide an important source of information. In order to use these maps for coastal research they have to be *georeferenced* (fitting the historical map on the present day situation) and *digitized* in a GIS (Geographical Information System). However, the quality and detail may vary widely between different maps, and simply using them with the assumption that they depict an accurate image of the former (coastal) situation would probably induce large mistakes in the coastal reconstruction.

Digitalization of the maps involved the following steps (using *ArcGIS 9*.3):

- Creation of shapefiles in ArcCATALOG. Three types of data are available: points (useful for villages), lines (useful for dikes) and polygons (useful for the tidal area and embankments). Fields can be added, for instance to store the data on geometric accuracy. The coordinate system should be set to the same as the base maps.
- Adding the shapefiles to ArcMAP.
- Digitalization of all relevant items. In this case each feature of the tidal marsh and the surrounding embankments was digitalized as a polygon. In the attribute table, data on the historical map used for this particular feature is stored.
- Layout of the maps, and exportation as figures.

In order to analyse the map quality a “ranking methodology” was developed (see Section 2). The following sections focus on the overall results of the ranking of maps from the Waasland Scheldepolder area. For detailed ranking outcome of individual maps we refer to the Arch Manche portal www.archmanche-geoportal.eu. The analysed maps were chosen out of a database of around 300 historical maps, found in the (State) Archives of Brussels, Ghent, Beveren and Middelburg.

3M.5.2 Ranking Results and Discussion of Historical Maps

The *topographical accuracy* of the maps varied widely (Figure 3M18) but many proved to be rich in detail. The factors that seemed most determining for this accuracy are the scale and the purpose of the map. Small-scale supraregional maps provided very schematic depictions of the tidal area, while large-scale maps showed subdivisions of higher/lower tidal marsh (sometimes even containing measurements of their size) and detailed depictions of the tidal channels. Some maps were especially made to depict the outer dike area for future embankments; these maps proved to be the most accurate and useful maps in our selection.

Figure 3M18: Topographical details in various historical maps (ARA, Kaarten & Plans, n° 176; ARA, Kaarten & Plans, n° 441; ARA, Arenberg, n° 842).

The *geometric accuracy* also varied widely between supraregional (small-scale), regional (medium-scale) and local scale (large-scale) maps.

- Supraregional maps have the lowest accuracy. Mean positional errors (MPE) varied between 500 and 1600 meters. Although positional errors could be reduced by focusing on parts of the map, their use for detailed coastal evolution reconstruction remains restricted. Nevertheless they contain a lot of information regarding more general aspects of the Scheldt estuary.
- Regional maps proved to be far more accurate and became more and more accurate over time although a large variation is also noticeable here.
- Local maps proved to be ideal for coastal research. Not only did they provide enough topographical details (especially when the maps were related to embankment activities), but they also showed a high geometric accuracy with mean positional errors of less than 50 meters (in some cases down to 20 meters).

Variation in positional errors also occurs within maps: an interesting observation is that the purpose of a map often also defines which parts of the map are more reliable. For instance the map depicted below (Figure 3M19) (copied by Coeck in 1664) showing the military frontier zone between the northern and southern Low Countries is marked by a higher MPE for the military installations (e.g. forts) (black circles) than for places further away from the frontier zone (red circles).

Figure 3M19: Distortion grid and displacement circles for the map of Coeck (copy 1664).

Also the *chronometric accuracy* varied largely over the maps. The major reason for this variation is to be found in the fact that some maps had a detailed "cartouche" (Figure 3M20) describing the date of manufacturing or the date of the originals in case of a copy and other maps did not have this information. In addition, for some maps distances were noted on the map (pointing to a land survey) or the "cartouche" mentioned the actual land surveying undertaken before the map was produced. Especially for large-scale maps, the chronometric accuracy of the outer dike area could be contested, since tidal channel structures did not have a logical pattern (compared to other, more accurate maps) or seem to be simply copied from an earlier map. Therefore this chronological aspect should be regarded carefully when conducting further analysis.

Figure 3M20: part of a "cartouche" mentioning both measured surfaces as the exact date of manufacturing of a map of the Doelpolder (ARA, Arenberg, 842)

Total map ranks were plotted against manufacturing date of original maps (Figure 3M21). A general rise in score over time can be noticed, although a lot of variation around the trendline (R^2=0,6395) exists. Therefore, an older map is not necessarily less good then a more recent map.

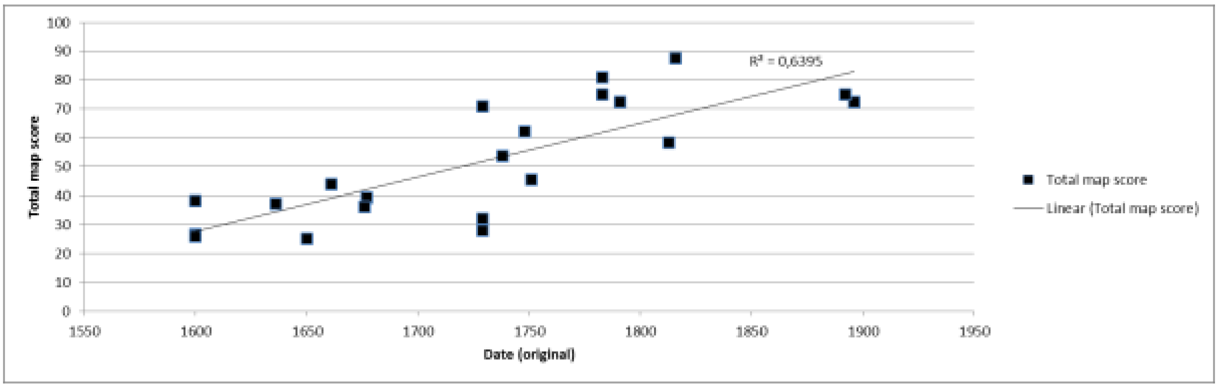

Figure 3M21: Total map rank according to manufacturing date of the original maps.

As an example of the possible effects of using lower ranking maps, Figure 3M22 compares the location of mapped tidal channels for a low- ranking and high- ranking maps, with the “true” location as given by the DHM. Clearly, the high ranking map depicts those channels far better. Note that the higher ranking map was made just prior to embankment (and therefore “fossilization” of the former tidal channel pattern, the other map was made 16 years earlier.

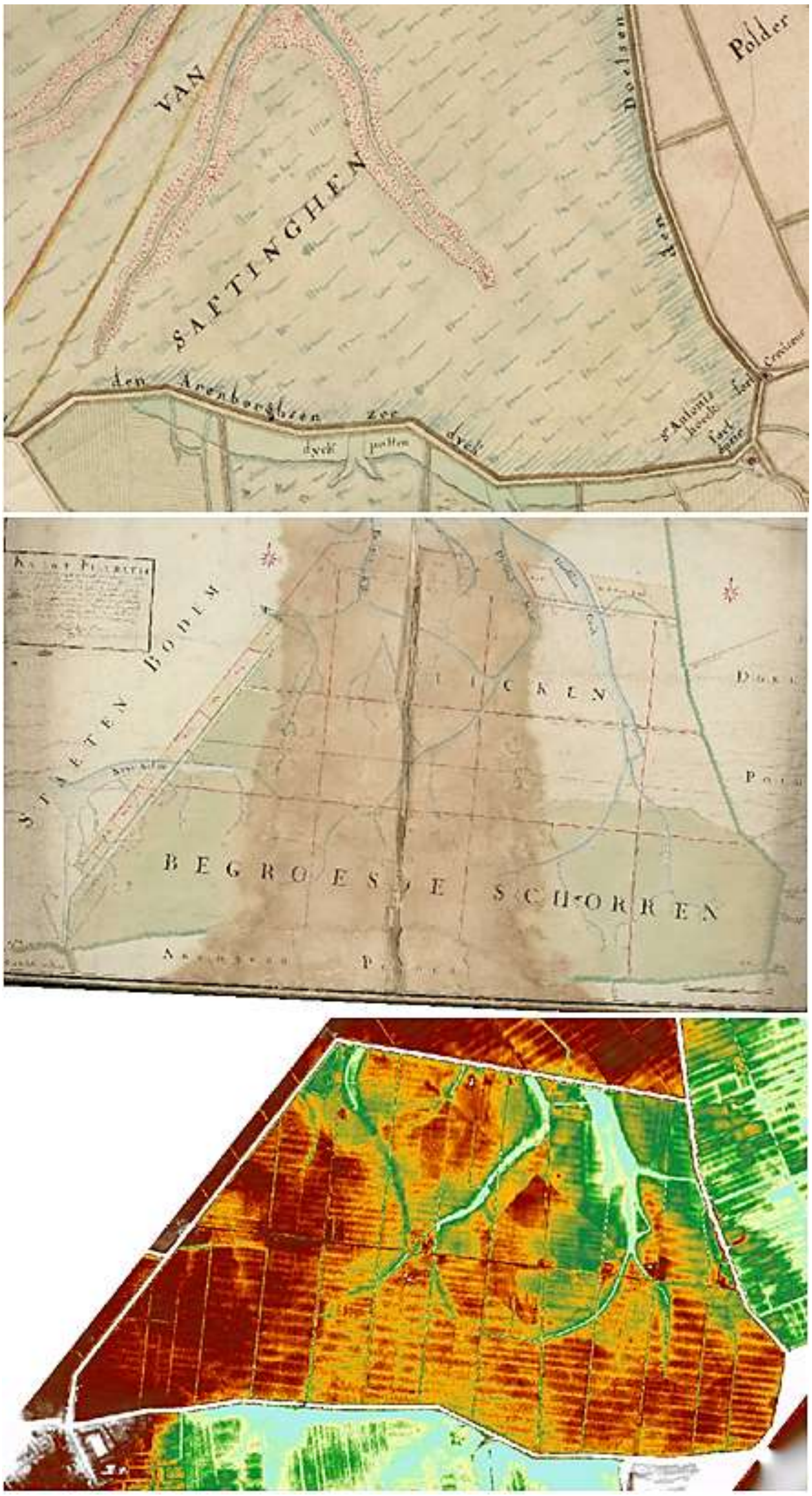

Figure 3M22: Comparison of a low ranking map (ARA, Kaarten & Plans, n° 410,1767, top) high ranking map (ARA, Kaarten & Plans II,8573,1783, middle) and actual former location of the tidal channels (DHM, right),

3M.6 Results – Palaeogeographical Landscape Reconstruction Based on Field Data and Historical Maps

This section is subdivided two parts: (1) palaeolandscape analysis and reconstruction for Holocene period (10000 BP - 1000AD), based on physical (in situ) data; and (2) recent post-medieval evolution of the palaolandscape, based on historical maps.

3M.6.1 Holocene Palaeogeographical Landscape Reconstruction Based on Physical In-situ Data (CPT, corings)

Methodology

The data obtained from the field studies (described in section 3M.4) only provided local information (restricted to Doelpolder-Noord), insufficient for a regional palaeogeographical study. Additional geological information was needed from existing data (sediment cores, archaeological augerings, CPT). The vast majority of these data was obtained from the subsurface database of the Flemish Government (Databank Ondergrond Vlaanderen, DOV). The Department of Archaeology of Ghent University provided all the geological information from augerings taken during archaeological site surveys in the area.

A major difficulty in the data integration proved to be the high diversity of the type and date (some over a 100 years old) of data, the diversity in data resolution and also the diversity of the observers (i.e. geologists, engineers, archaeologists). Consequently not only the quality of the data varied greatly, but also the interpretation of the geological data. Where possible the raw data and the original descriptions or measurements were studied and reinterpreted taking into account the current geological knowledge of the area. The total data set contained 6423 data points, of which 5783 reach the Pleistocene/Holocene boundary (Figure 3M23).

The first step in the reconstruction was the creation of an isohypse map of the top-Pleistocene relief using both geostatistical software and geological interpretation. More details on how this was done can be found in the report "Holocene palaeogeographical evolution of the Waaslad Scheldepolders" by Heirman, Missiaen & Vos (2013). In order to allow correct integration with Dutch palaeogeographical maps the NAP level was used instead of TAW.

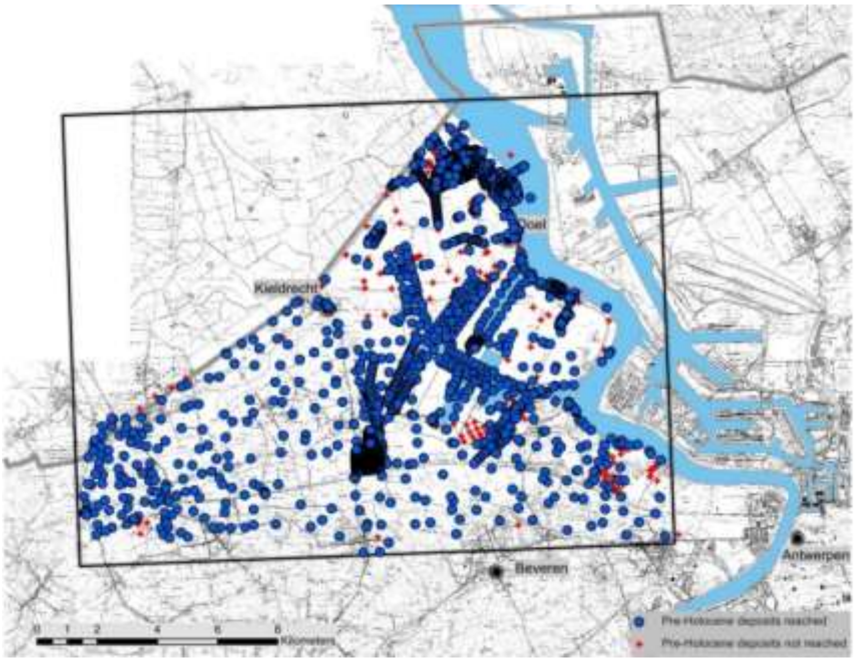

Figure 3M23: Location of data points used for the reconstruction (blue: data reaching the top of the Pleistocene; red: shallow data). The black box indicates the extent of the study area. The grey line indicates the border between Belgium and The Netherlands.

To obtain a timeframe for the reconstructions two additional sources of information were used: (1) a relative sea-level curve for the Netherlands (Kiden, 2006; van de Plassche, 1982; Hijma and Cohen, 2010; van de Plassche et al., 2010), and (2) a dated peat growth evolution model for the Waasland Scheldepolders (Verhegge at al., 2014). These finally provided an age for the altitude to which the marine influence was present or how the peat bogs expanded.

Palaeogeographical reconstructions

Early Holocene - 11000 yrs BP
At the beginning of the Holocene (ca.11000 yrs BP), sea level was still lower than -50 m. Low sea level and the disappearance of the permafrost enhanced the vertical erosion of the rivers (Mathys, 2009). Late Glacial/Early Holocene river channel erosion can be detected in the top-Pleistocene palaeotopography. Most likely only the channels deeper than -4 m NAP were active river channels, while the area between -2 and -4 m NAP might have flooded occasionally during heavy rainfall.

Early to middle Holocene – 7500-7000 yrs BP
In the early to middle Holocene (ca. 7500 – 7000 yrs BP), when temperatures kept on rising, a dense forest vegetation developed. Due to the dense vegetation, soil erosion and run off was reduced to a minimum. Consequently the river discharge lowered more and more. The late glacial alluvial planes dried out and were vegetated, only in the lowest gullies and valleys some water was present. In these areas peat started to grow (Kiden and Verbruggen, 2001). The Early Holocene landscape of the Waasland polder area consisted of a Scheldt river which was still a fresh water environment. In the deeper channels peatbogs started to develop (Figure 3M24, top left).

Middle Holocene – 7000-5000 yrs BP
During the middle Holocene (ca. 7000-5000 yrs BP) the sea reached its most inland position (Vos and van Heeringen, 1997). By 6000 yrs BP the fresh water Schelde had turned brackish south of the Dutch/Belgian border. The area changed into an extended tidal landscape with mud flats and salt marshes (Figure 3M24, top right). The limit of the marine 'invasion' in the area was determined using the occurrence of the Holocene marine deposits and the relative sea level determined from the van de Plassche et al. (2010) relative sea-level reconstruction. Most of the Early Holocene peat bogs drowned and were covered with an organic-rich marine clay. Peat bogs were still present, but they were confined to the transition zone between the tidal areas and the higher Pleistocene cover sands. The peat most likely grew in areas below -2 m NAP.

Middle and late Holocene – 5000-2500 yrs BP
During the middle to late Holocene (ca. 5000 – 2500 yrs BP) the relative sea-level rise seriously slowed down (Mathys, 2009) and this had a major effect on the lagunal environment in the area. Extensive peat expansion took place (Figure 3M24, bottom left). Over time the peat bogs most likely expanded slowly further to higher grounds. During the Late Holocene peat growth continued in the region (Figure 3M24, bottom right). Based on radiocarbon measurements on peat samples of the Waasland polder area, peat growth might have continued until at least 600 AD (1350 cal a BP) (Gelorini et al., 2006; Kiden, 1989; Van Strydonck, 2005).

The extent of the peat growth is much debated in Belgium. Jongepier et al. (2011) showed that the combination of geographical and historical data may provide an answer here. Indeed often the patterns of peat reclamations can still be identified (e.g. at Verrebroek) on the Digital Elevation Model or on aerial pictures. The low sampling resolution of cores is likely the main reason why thin peat layers that were generally left behind during the exploitation are missed out.

Early middle ages – 1000 yrs AD

It is generally assumed that man started to construct dikes in the Waasland Scheldepolders in the 10th or 11th century (Guns, 2008). It is however unclear what the landscape looked like prior to the man-induced landscape changes. The thin peaty clay cap which is sometimes found on top of the peat was dated to the 10th-11th century based on archaeological findings (Crombé et al., 2005) and the presence of cereals' pollen (Gelorini et al., 2006).

Until the Early Middle Ages the landscape must have looked similar to the landscape of the previous reconstruction, except for some tidal flats and salt marshes close to the river Scheldt. It had already been stated in the past that in the Early Middle Ages the Waasland polder area consisted of a very swampy landscape with some small sand ridges with small pools in between in the Early Middle Ages (Augustyn, 1977). This could well be a correct description.

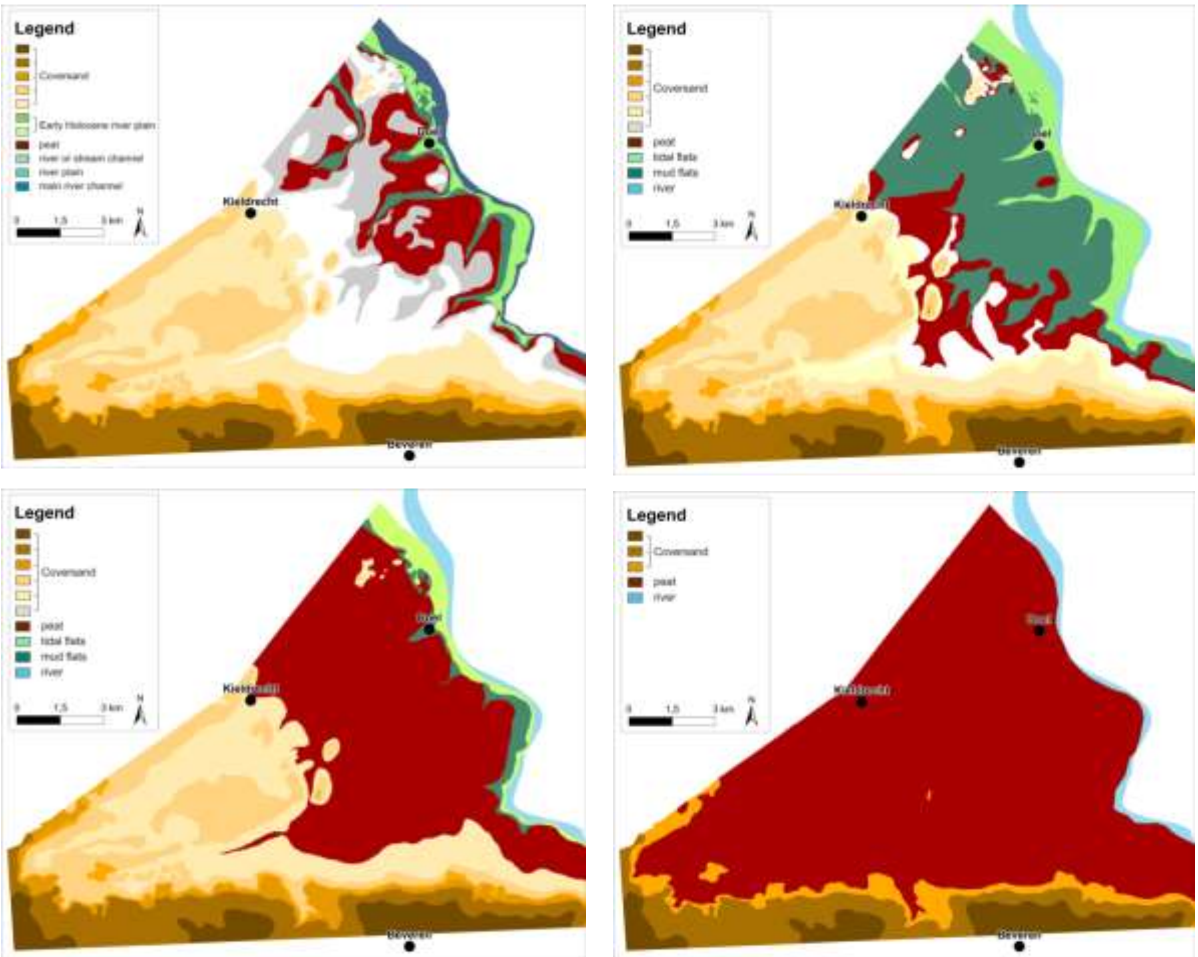

Figure 3M24: Palaeogeographical maps of the Waasland Scheldepolders around 7500 BP (top left), 6500 BP (top right), 3500 BP (bottom left), 2500 BP (bottom right).

3M.6.2 Post-Medieval Palaeolandscape Reconstruction Based on Historical Maps

Methodology

Based on historical maps, landscape reconstructions for certain time periods (depending on the availability of the maps) were made. For the Waasland Scheldepolders test-case five time sections were selected (1570, 1625, 1700, 1790 and 1850) that represent major landscape changes. The maps were selected based on their ranking results and an inherent additional criterion: the date of manufacturing should be as close to the chosen time frame as possible, in case of analysis based on multiple maps per time section. This implies a crucial role of qualitative interpretation, since a trade-off of the above mentioned factors should be made in order to acquire the best possible reconstruction. It also implies it is not always possible to use the most accurate map available.

Each time section was based on multiple historical maps, making it necessary to conduct a few interpolations, in order to “match” the different maps into one continuous reconstruction. In the following sections the different landscape reconstructions, and the maps on which they were based, will be briefly discussed. For more details regarding the landscape evolution and the choice of maps we refer to the report “Recent landscape evolution of the Waasland Scheldepolders based on historical maps” by Jongepier, Missiaen & Soens (2013).

Landscape reconstructions and discussion of the most important maps used

1570 AD

Finding maps for this time period was not easy. Logically, late medieval maps are not abundant: the older the map, the smaller the chance of conservation. Furthermore, detailed local and regional maps were only produced in large quantities from the seventeenth century onwards. Luckily, land surveyor *François Horenbault* was ordered to show the impact of late medieval small-scale inundations. One of his maps (copied in 1695, RAG, Kaarten & plans, n° 2454, see Figure 3M25), proved to be suitable for the reconstruction. It has an MPE of 722.40 meters.

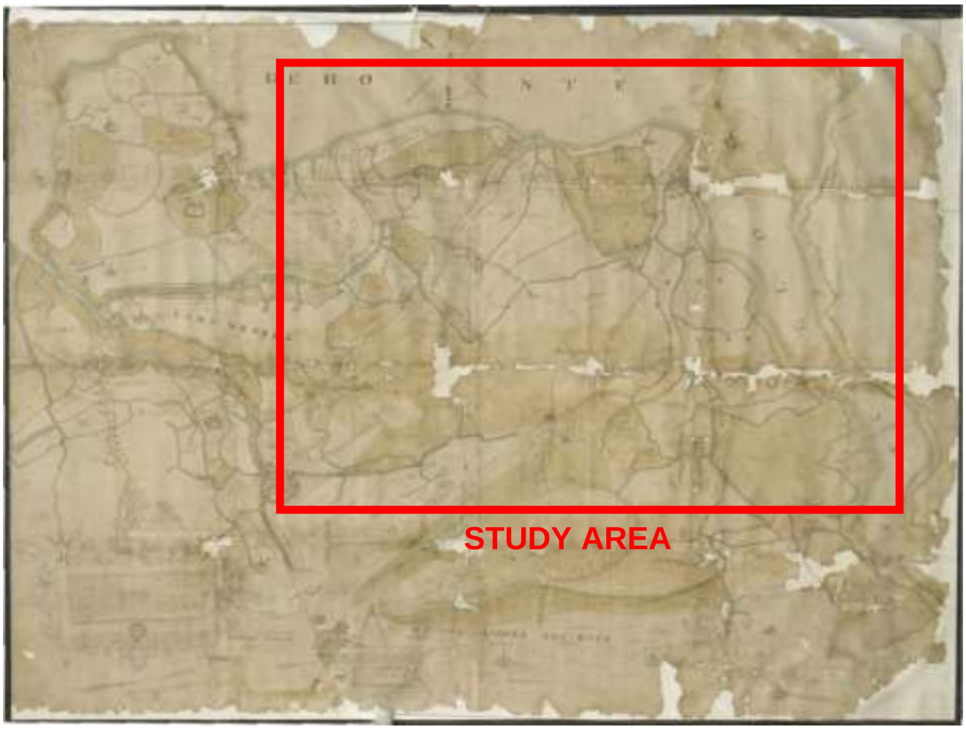

Figure 3M25: Map of 1575, made by land surveyor François in 1575 (copy by B. Speelman, 1695, Rijksarchief Gent, RAG in the following, Kaarten & Plans, n° 2454).

The resulting reconstruction (Figure 3M26) shows almost the entire study area was embanked, due to dike building during the period of large-scale peat extractions. Central in the area, remains of the former peatlands (indicated as “swamp”) are found. The breakthrough of the “Honte” is apparent and several small villages appear to have been founded. The area of tidal marsh is only limited, except for the far north of the area.

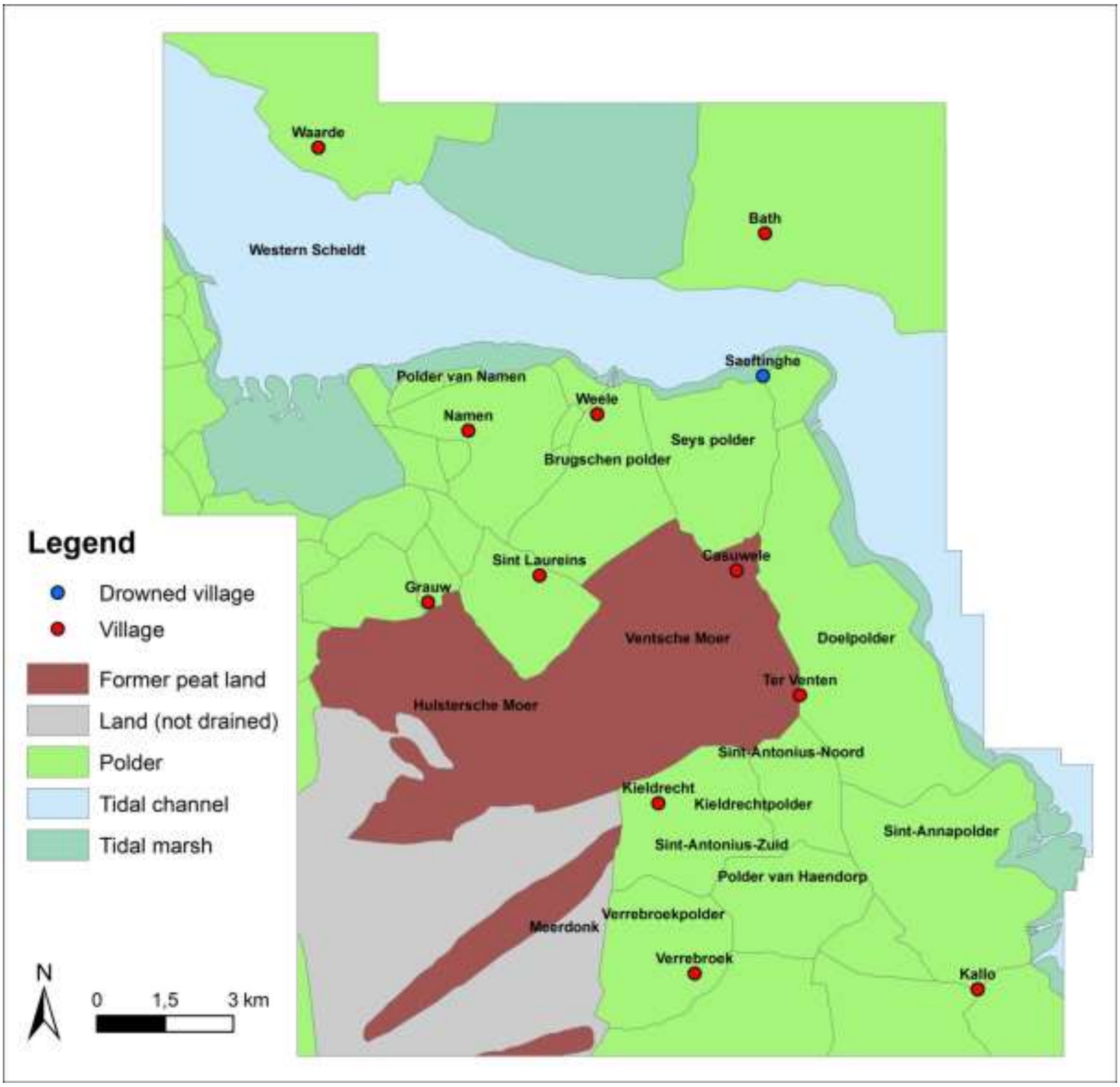

Figure 3M26: GIS-landscape reconstruction of the Waasland polder area around 1570

<u>*1625 AD*</u>

The second landscape reconstruction dates to around 1625. The most important map available for this period is the “map of Coeck” (as displayed in the *Atlas van Loon* preserved in the Scheepvaartmuseum, Amsterdam, Figure 3M27) which shows the inundations of the late sixteenth century and the first re-embankments in the south of the study area with great detail.

Geometric accuracy is only limited (1383 meters), as is for instance shown in the shape of the *Doelpolder*. However, since the first re-embankments are still present in the landscape, accurate and elaborated georeferencing results (after *splining*) in a useful depiction of the tidal marsh. Only the location of the *Polder van Namen* and surroundings (upper north) remains a bit uncertain, since no present-day GCP´s (points visible for both the historical as the present day situation, used for rectification of the historical map) could be found. The map also makes a clear division between the higher and lower tidal marsh. The map is undated, but probably dates to around 1625.

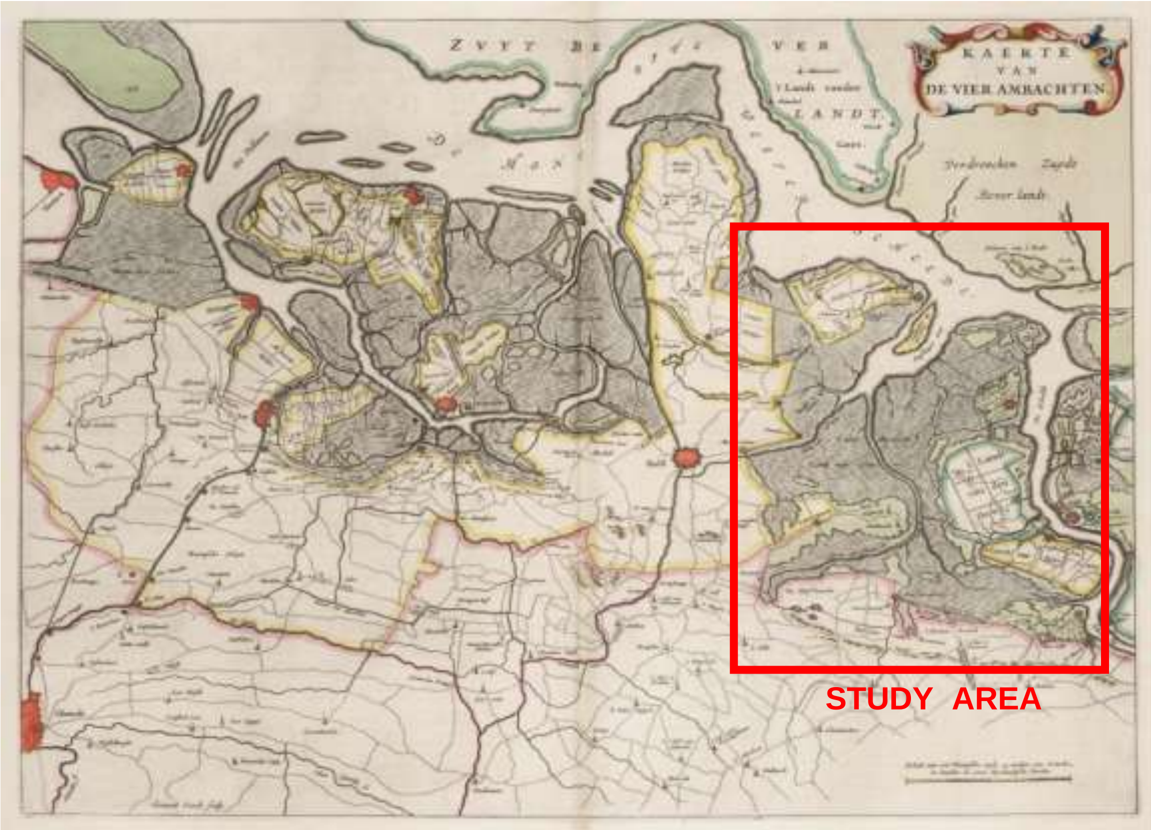

Figure 3M27: Map of Coeck (dating around 1600, Atlas van Loon, Scheepvaartmuseum Amsterdam).

The landscape reconstruction (Figure 3M28) shows the extensive tidal marsh (*Drowned Land of Saeftinghe)* formed after the inundations. A large tidal channel (the so-called *Saeftinger Gat)* crossed the entire area. Since *Kieldrecht* was located on a sandy ridge, it was not completely flooded. The largest part of the *Doelpolder* also remained intact (first as sort of an 'island', due to a higher elevation than that of the central area, later re-embanked during 1613/1614), just as the *Polder van Namen* and *St. Anna-polder* (the latter by then called *St. Anna-Ketenisse* or the *Land of Ketenissa*, both with a higher elevation than Mean High Water Level). The villages that were founded by 1570 appear to have been drowned.

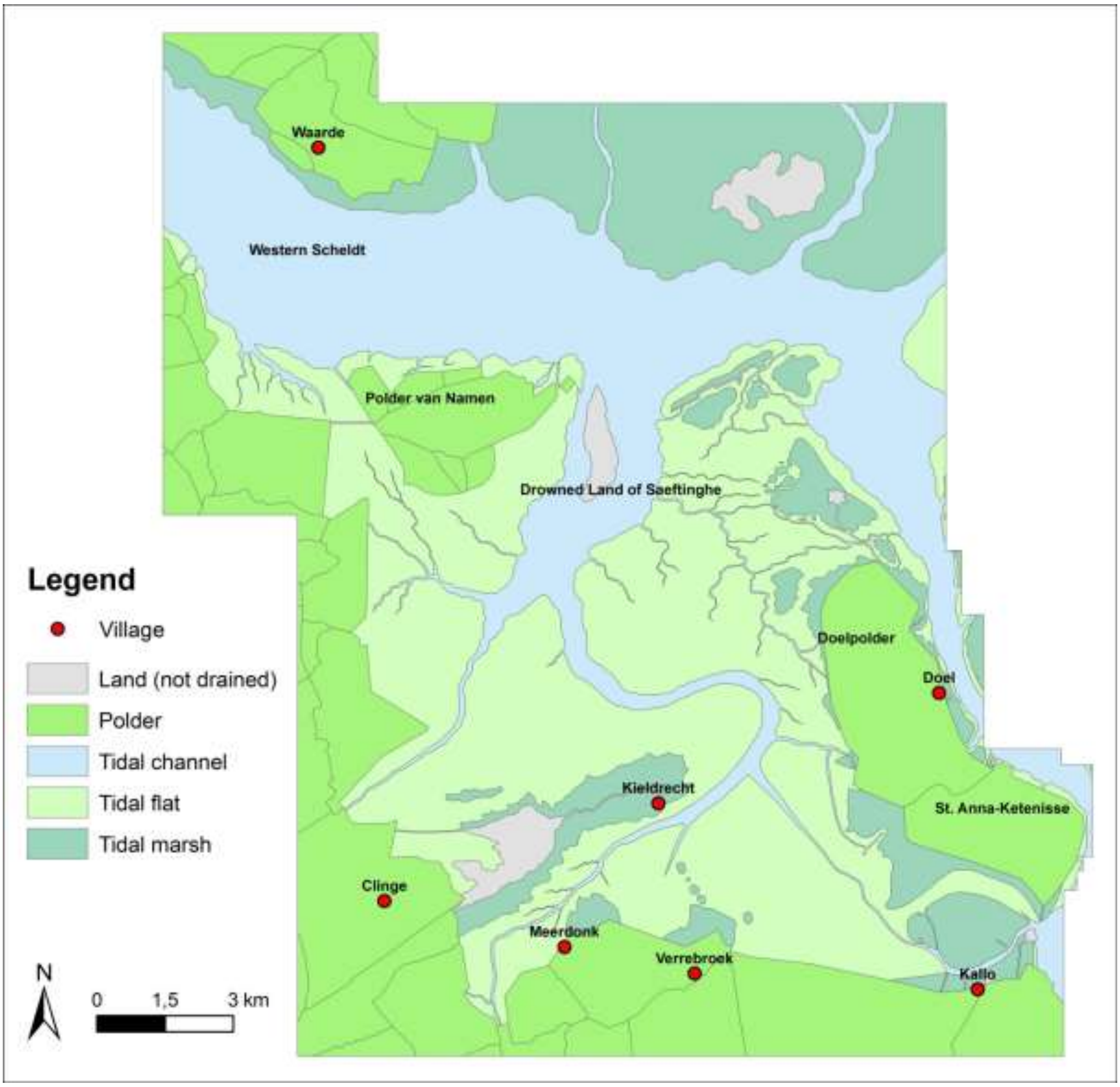

Figure 3M28: GIS-landscape reconstruction of the Waasland polder area for 1625

<u>*1700 AD*</u>

The third landscape reconstruction dates to around 1700. By then, an increasing number of highly detailed large-scale maps appear to have been made. Two high quality local maps were used for the southwestern and eastern (*Peerdenschor*) area. Map ZA-504 dates from 1710, and displays the later drowned polder *Peerdenschor* and its surrounding tidal marsh (Figure 3M29, top). Although probably highly accurate (as most local maps are), a proper mean positional error (MPE) assessment could not be conducted since only very few MPE´s could be found that correspond with the actual landscape, since the entire embankment drowned in the eighteenth century. The other local map (Figure 3M29, bottom) dates from 1687 and shows the southwestern tidal marsh (near Kieldrecht). MPE-value amounts to an outstanding 53 meters. Both maps are derived form the so-called *Atlas of Hattinga*. This atlas was made around 1750 by the famous land surveyor W.T. Hattinga and his two sons. Most of the maps concern high quality copies of older maps. The entire atlas is preserverd in the *Zeeuws Archive Middelburg.*The rest of the GIS-landscape reconstruction in the study area is based on two supraregional maps with higher MPE-values.

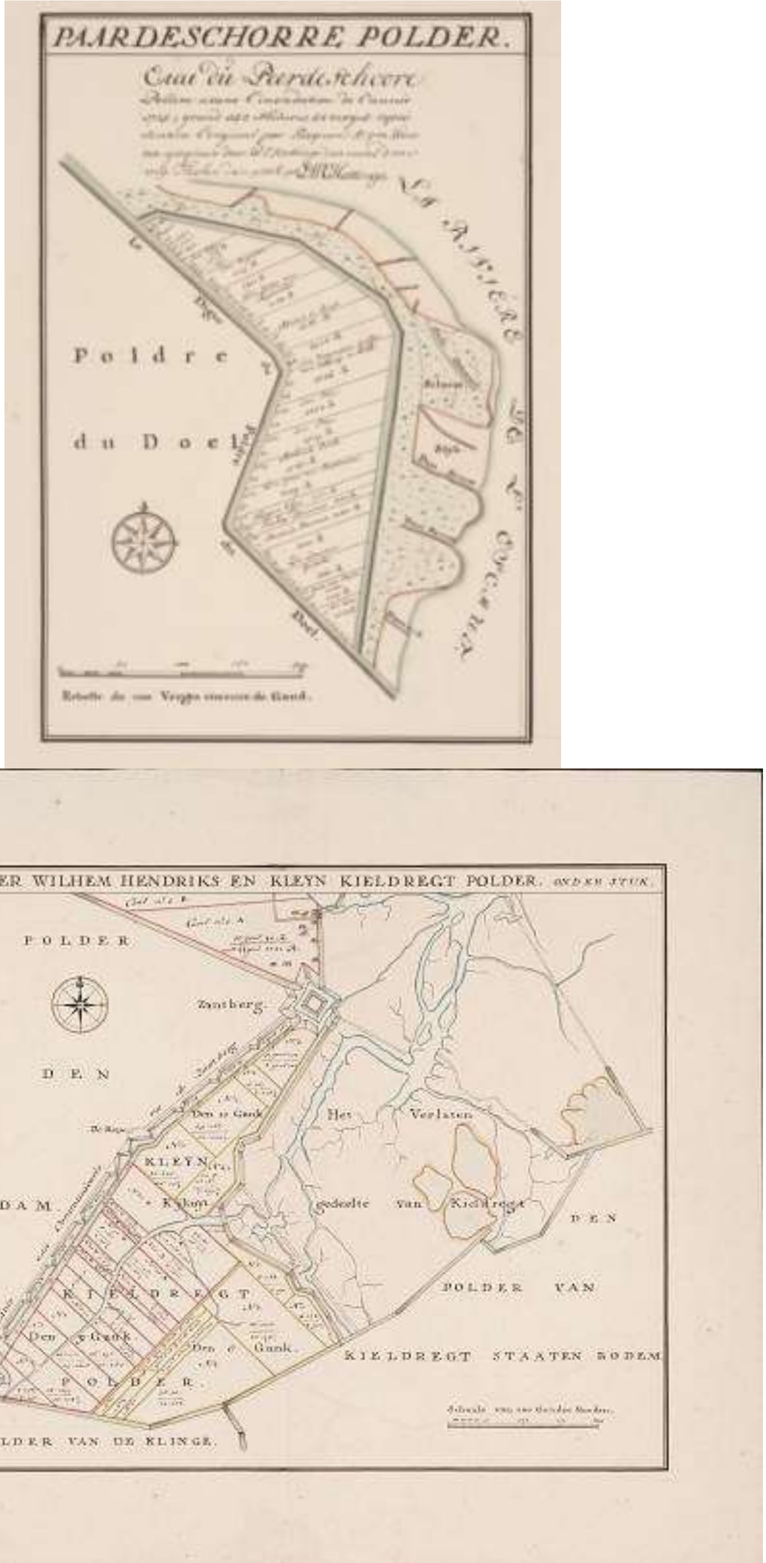

Figure 3M29: Maps of the Peerdenschor (top, 1710, Zeeuws Archief Middelburg, ZA in the following,-293-n° 504) and southwestern tidal marsh (bottom) 1687, ZA-293-n°497(495)).

The GIS-reconstruction of 1700 (Figure 3M30) shows a large continuity with the landscape in 1625. In the north the large tidal channel '*Saeftingher Gat',* originating from the Eighty Years´ War inundations, still intersects the area. The eastern course of the channel, however, had changed and now runs due east till the *Doelpolder* where an internal connection to the Scheldt river was established (the so-called *Deurganck*), probably in order to facilitate future tactical inundations. The northern frontier of the *Land of Saeftinghe* is marked by an elevated part of the tidal marsh, located near the former location of the drowned village of Saeftinghe. Most of the tidal marsh was indicated as low-lying mudflats. Due to the successive embankments, sedimentation seaward of the new sea dikes was re-initiated time and time again, leaving only little time for higher tidal marshes to be formed. Only north of the Western Scheldt, larger areas of higher elevated tidal marsh were found.

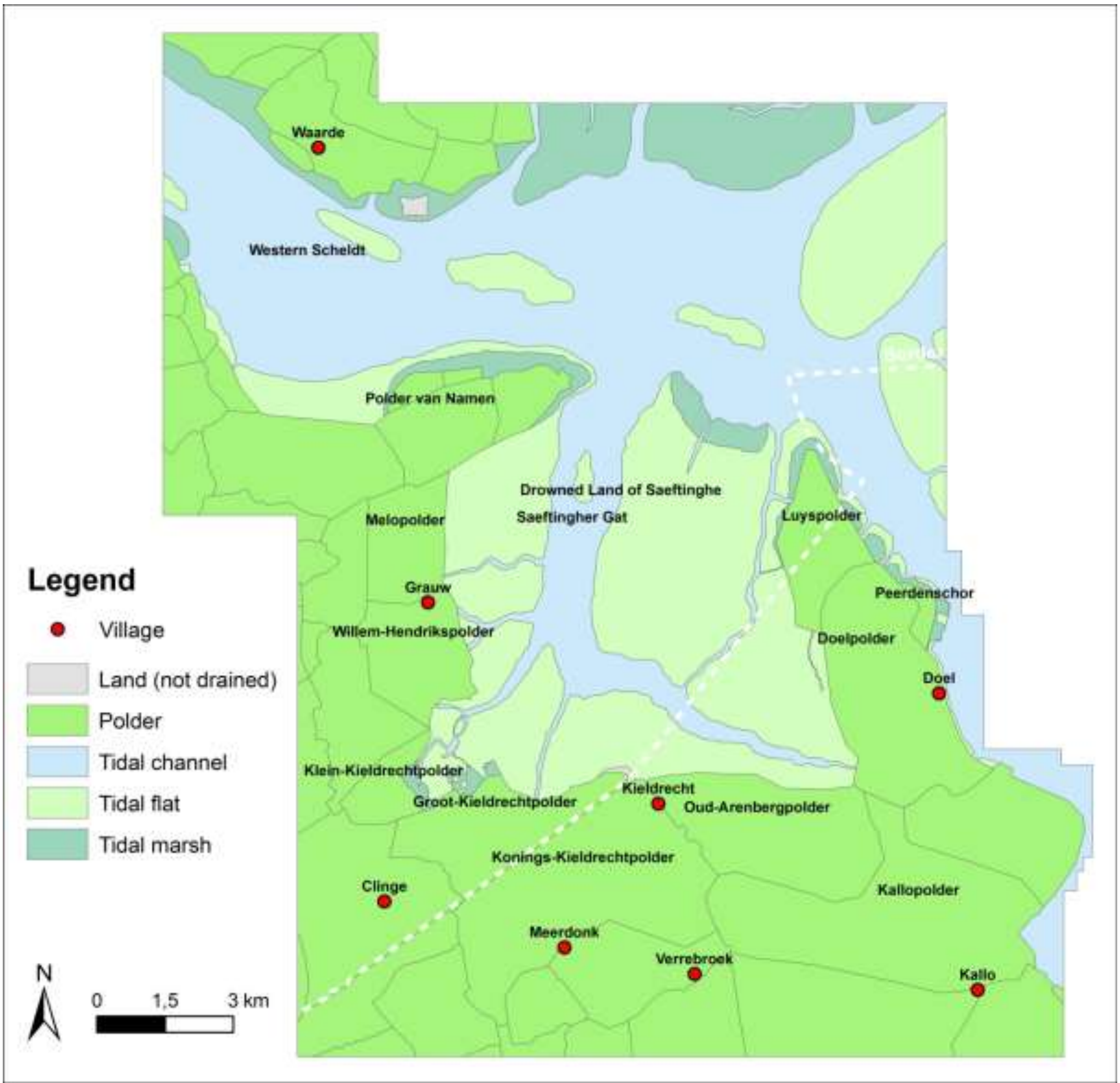

Figure 3M30: GIS-landscape reconstruction of the Waasland polder area for 1700.

<u>*1790 AD*</u>

The fourth landscape reconstruction dates to around 1790. Even more high quality maps appear to have been made for this period. For instance, for the eastern part of the tidal marsh, located at the *Doelpolder,* a local map was used (Figure 3M31). Land surveyor *J. Coppens* measured and drew the tidal marsh. Perpendicular distances from the dikes to the border of the higher tidal marsh were also indicated. This resulted in a detailed map with a good mean positional error of 103 meters.

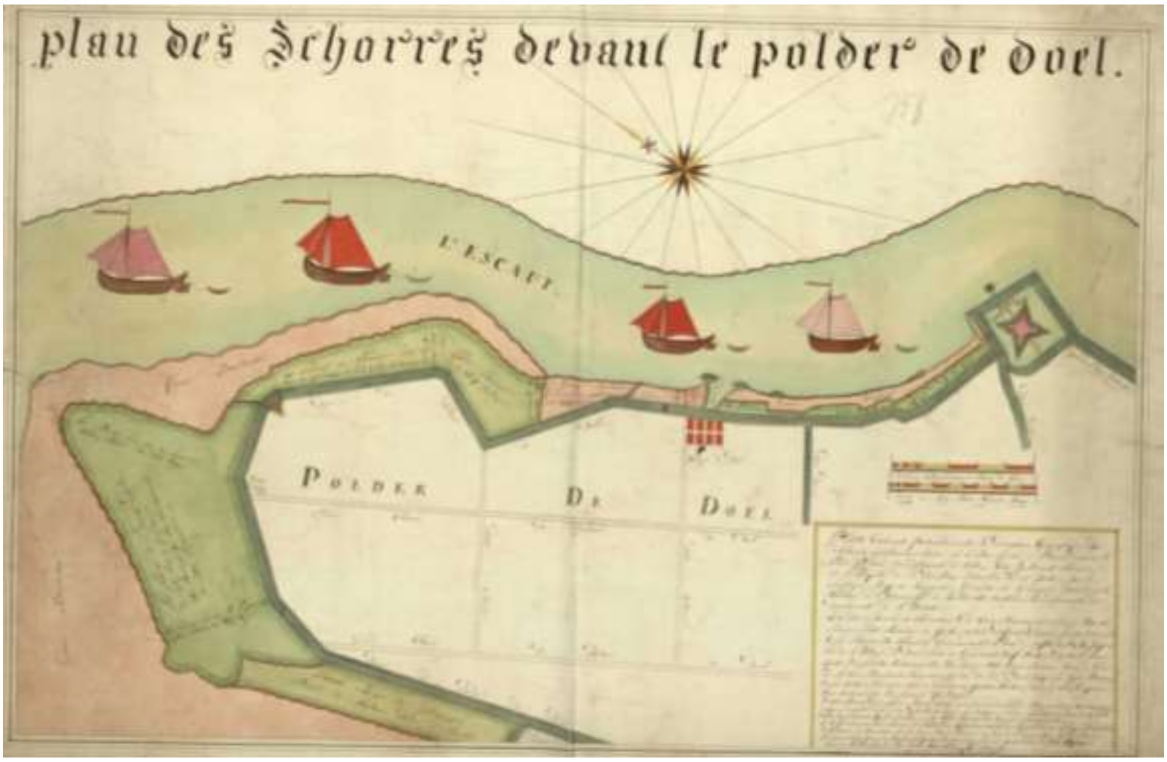

Figure 3M31: Tidal marsh surrounding the Doelpolder, 1813 (ARA, Arenberg, n°842).

The GIS reconstruction of 1790 (Figure 3M32) shows large differences compared to the previous period (1700). Apart from the embankment of the *Nieuw-Arenberg polder* also on the left bank of the river Scheldt the *Nieuw-Kieldrechtpolder* was embanked, just north of the border. In the area north of the Western Scheldt, however large embankment works west of *Bath* were conducted, converting the former higher tidal marsh to embankments streching to the older embankments surrounding *Waarde*. Looking at the unembanked area it is clear that another 90 years of sedimentation has allowed the tidal marsh to be heightened in the *Drowned land of Saeftinghe*. The tidal channel *Saeftingher Gat* is still present but it is much less wide, and especially the area of lower tidal marsh has extended. Furthermore, higher tidal marsh developed against the sea-dikes of most of the embankments.

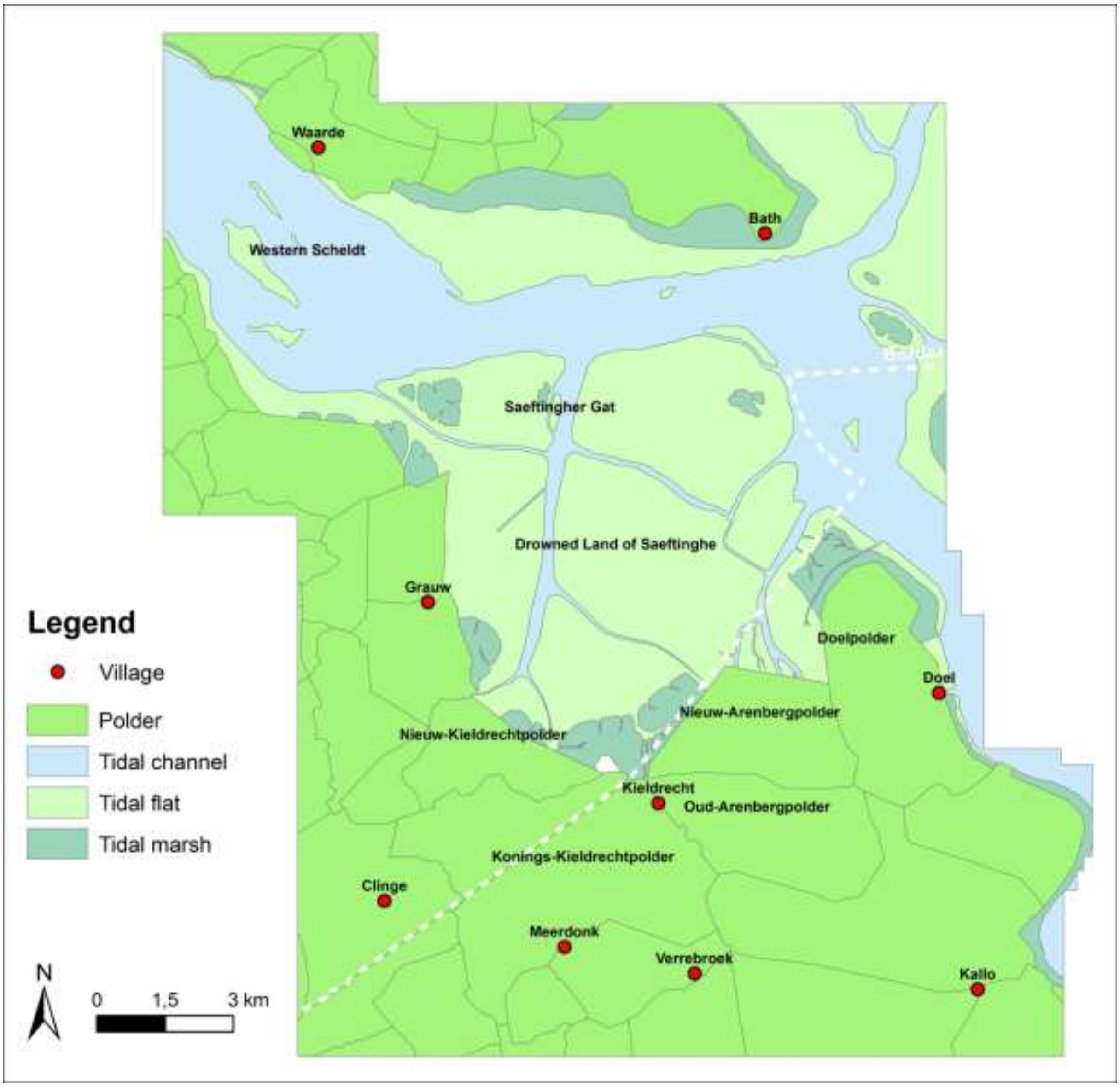

Figure 3M32: GIS-landscape reconstruction of the Waasland polder area for 1790.

<u>*1850 AD*</u>

The last landscape reconstruction dates to around 1850 and is based on two series of maps: the topographic military map (*Topografisch Militaire Kaart*) (TMK) for the part of the reconstruction on Dutch territory, and the maps of *P. Vandermaelen* for the Belgian part of the reconstruction. The maps of the TMK (Figure 3M33, left) are based on a large-scale field survey and accompanying field minutes, carried out between 1836 and 1856. The field minutes were drawn at a scale of 1:25.000, but the resulting stone engraved black and white maps are at a scale of 1:50.000. The maps of *P. Vandermaelen* (Figure 3M33, right) are derived from a large series (250) of individual maps, drawn at scale 1:20.000 between 1850 and 1854 and entitled "Carte topographique de la Belgique".

By 1850, successive embankments in the study area (Figure 3M34) had resulted in a further decrease of the tidal marsh. Next to the *Prosperpolder*, south of the *Land of Saeftinghe* the *Van Alsteinpolder, Louisapolder* and *Saeftinghepolder* were embanked. Clear sections of higher tidal marsh at the (sea) dikes surrounding the embankments were present. The tidal channel surface diminished even further and the *Saeftingher Gat* is no longer distinguishable.

Figure 3M33: Topografische Militaire Kaart, 1850 (fragment, left) and Maps of Vandermaelen, 1854 (fragment, right).

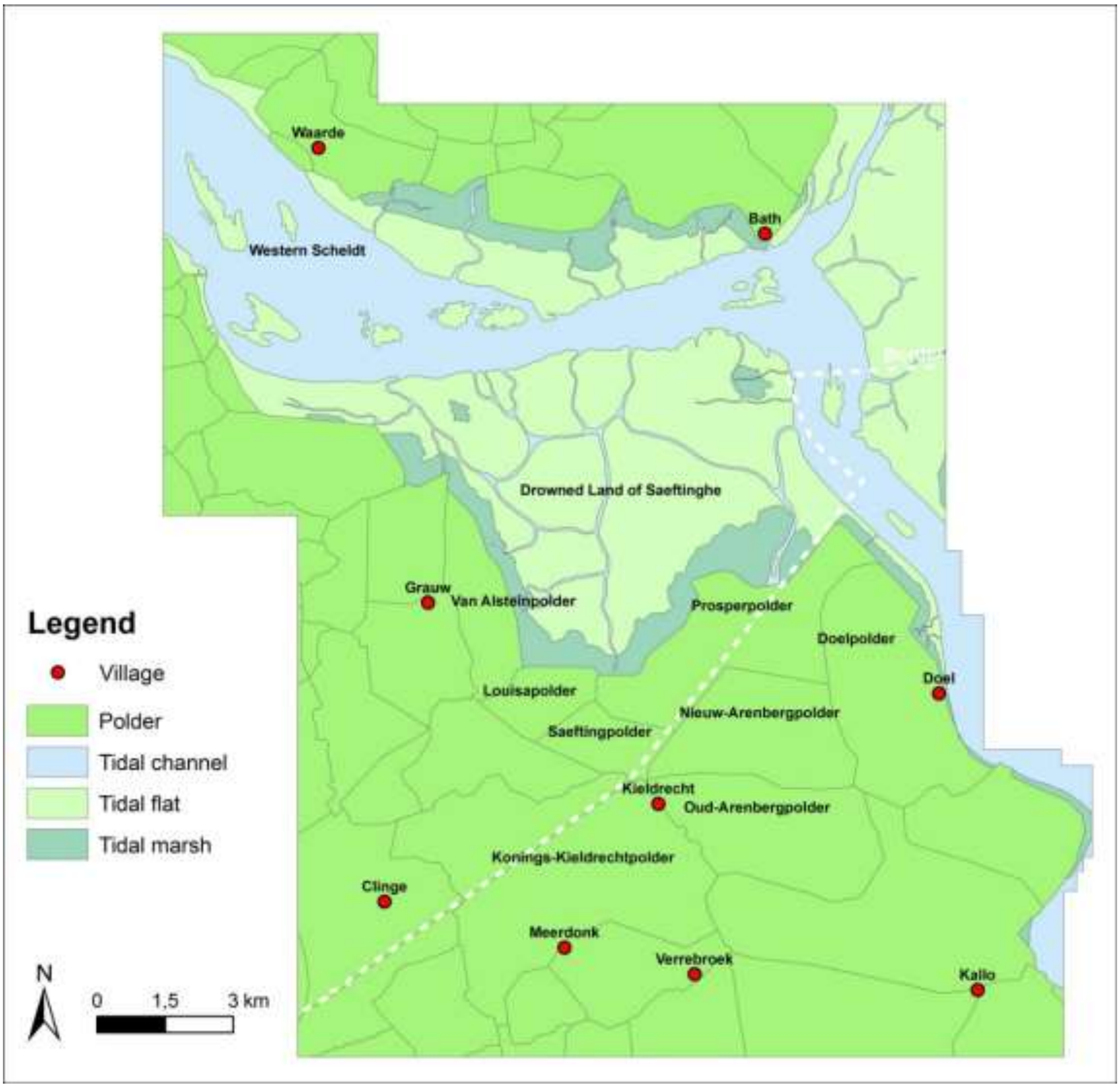

Figure 3M34: GIS-landscape reconstruction of the Waasland polder area for 1850.

3M.7 Conclusions and Recommendations

The Waasland polder area, including Doelpolder-Noord is an area under imminent “threat” of harbour extension and de-embankment. Large parts of the existing landscape might be profoundly changed over the next couple of decades, which will also have consequences for buried records of past landscapes. Hence there is an urgent need for detailed and fast archaeological and palaeoenvironmental assessment before these future changes take place, and therefore this area was chosen as one of the two Belgian case studies. The uniqueness of this study area lies in the fact that many “layers” of the past prehistoric landscape have been recorded in the soil archive: Tertiary sandy deposits, Late Glacial aeolian deposits and Holocene marine sediments and peat bogs are still retraceable in the subsoil. In the more recent period (during the late Middle Ages), the area was transformed again: deliberate inundations during wartime caused the area (which was by then embanked) to flood permanently, and an extensive tidal marsh was formed. In the following centuries this marsh was gradually re-embanked, and the present-day landscape was created.

We tried to use a combination of both geotechnical-geophysical techniques and historical-geographical methods in order to reconstruct the buried paleolandscape from the Early Holocene onwards (i.e. the last 11 000 years). This approach is quite novel but proved to be highly successful.

The prehistoric (pre-medieval) landscape was investigated using CPT (Cone Penetration Test), land seismic and marine seismics. Of these techniques the CPT seems to be the most applicable and efficient method for geoarchaeological research and palaeoenvironmental reconstruction. The CPT data must however, always be ground-truthed with sufficient sediment samples from nearby locations, and should be interpreted by experts. In this study area the obtained data led to six palaeolandscape reconstructions, ranging from roughly 11 000 BP to 1000 AD.

The post-medieval landscape was reconstructed using historical maps. These maps were evaluated according topographic, geometric and chronometric accuracy. The highest ranking maps were selected for GIS-rectification and digitalization. This resulted in five reconstruction maps that illustrate the landscape evolution from 1570 (just prior to the inundations) to 1850. Critical evaluation of the maps was crucial here. Maps made at a high accuracy level proved to be far more reliable, and therefore useful for landscape reconstruction, than those made at lower accuracy levels.

The two series of maps clearly show the benefit of the combined geotechnical-geophysical and historical-geographical approach for paleolandscape reconstruction. The use of CPTs provides many opportunities for future research, especially since this method is very time-efficient. The historical maps also provided valuable information, especially the large–scale maps. Keeping in mind the positive results of the test case, we recommend applying these methods to other (coastal) regions as well, in order to enhance our knowledge of past landscapes.

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For further information on the project and to access the full Technical Report please go to www.archmanche.hwtma.org.uk/downloads

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3M.8 Case Study References

Adams, R., Vermeire, S., De Moor, G., Jacobs, P., Louwye, S. & Polfliet, T. 2002. *Toelichting bij de Quartairgeologische kaart, Kaartblad (15) Antwerpen Schaal 1:50 000.* Departement Leefmilieu, Natuur en Energie. Dienst Natuurlijke Rijkdommen.

Augustyn, B. 1977. Bijdrage tot het ontstaan en de vroegste geschiedenis van de Wase Polders - van de oudste tijden tot circa 1400. *Annalen van de Koninklijke Oudheidkundige Kring van het Land van Waas,* 80, 5-97.

Augustyn, B. 1985. De turfwinnersdorpen Kieldrecht en Verrebroek in 1394: twee stadia in de evolutie van een proto-industriële naar een agrarische produktiewijze. *Annalen van de Koninklijke oudheidkundige kring van het Land van Waas,* 88, 241-256.

Augustyn, B. 1999. *De veenontginning (12de-16de eeuw).* Beveren, Gemeente Beveren.

Bogemans, F. 1997. *Toelichting bij de Quartairgeologische kaart, Kaartblad (1-7) Essen - Kapellen Schaal 1:50 000.* Departement Leefmilieu, Natuur en Energie. Dienst Natuurlijke Rijkdommen.

Bogemans, F. 2005. *Quartairgeologische overzichtskaart van Vlaanderen 1:200 000*. Departement Leefmilieu, Natuur en Energie. Dienst Natuurlijke Rijkdommen.

Crombé, P. (ed.) 2005. *The last hunter-gatherer-fishermen in Sandy Flanders (NW Belgium); the Verrebroek and Doel excavation projects, Part 1: palaeo-environment, chronology and features.* Gent, Academia Press.

Crombé, P., Boudin, M. & Van Strydonck, M. 2011. Swifterbant pottery in the Scheldt basin and the emergence of the earliest indigenous pottery in the sandy lowlands of Belgium. *In:* HARTZ, S., LÜTH, F. & TERBERGER, T. (eds.) *Early Pottery in the Baltic – Dating, Origin and Social Context, International Workshop at Schleswig on 20-21 October 2006.* Frankfurt.

Crombé, P., Perdaen, Y. & Sergant, J. 2005. Features. *In:* CROMBÉ, P. (ed.) *The last hunter-gatherer-fishermen in Sandy Flanders (NW Belgium); the Verrebroek and Doel excavation projects, Part 1: palaeo-environment, chronology and features.* Gent, Academia Press.

Crombé, P., Sergant, J. & Perdaen, Y. 2009. The neolithisation of the Belgian lowlands: new evidence from the Scheldt Valley. *In:* Mccartan, S. B., Schulting, R., Warren, G. & Woodman, P. (eds.) *Mesolithic Horizons. Papers presented at the Seventh International Conference on the Mesolithic in Europe.* Oxford, Oxbow books.

De Clercq, W. 2009. Extrema Gallarium. Zeeland en Noorwest-Vlaanderen in het Imperium Romanum. *Zeeuws Tijdschrift,* 58(3-4), 6-34.

De Kraker, A. M. J. 2002. Zeeuws-Vlaanderen als strategisch manipuleerbaar landschap. *NEHA - Jaarboek,* 65, 32-48.

De Maeyer, P., De Vliegher, B.-M. & Brondeel, M. 2004. *De spiegel van de wereld: fundamenten van de cartografie.* Gent, Academia Press.

De Moor, G. & Van De Velde, D. 1995. *Toelichting bij de Quartairgeologische kaart Kaartblad (14) Lokeren Schaal 1:50 000.* Departement Leefmilieu, Natuur en Energie. Dienst Natuurlijke Rijkdommen.

Gelorini, V., Verleyen, E., Verbruggen, C. & Meersschaert, L. 2006. Paleo-ecologisch onderzoek van een Holocene sequentie uit het Deurganckdok te Doel (Wase Scheldepolders, Noord-België). *BELGEO,* 3, 243-264.

Gottschalk, M. K. E. 1955-1958. *Historische geografie van westelijk Zeeuws-Vlaanderen.* Assen, Van Gorcum.

Guns, P. 2008. *Historische evolutie van het polderlandschap langs de linker Scheldeoever: Waterbouwkunding laboratorium 1933-2008.* Waterbouwkundig Laboratorium, Borgerhout, Belgium, Digitale Drukkerij Vlaamse Overheid.

Hijma, M. P. & Cohen, K. M. 2010. Timing and magnitude of the sea-level jump preluding the 8200 yr event. *Geology,* 38, 275-278.

Jacobs, P., De Ceukelaire, M., De Breuck, W. & De Moor, G. 1993. *Toelichtingen bij de geologische kaart van België, Vlaams gewest, Kaartblad (14) Lokeren Schaal 1:50 000.* Departement Leefmilieu, Natuur en Energie. Dienst Natuurlijke Rijkdommen.

Jacobs, P., Polfliet, T., De Ceukelaire, M. & Moerkerke, G. 2010a. *Toelichtingen bij de geologische kaart van België, Vlaams gewest, Kaartblad (1-7) Essen - Kapellen Schaal 1:50 000.* Departement Leefmilieu, Natuur en Energie. Dienst Natuurlijke Rijkdommen.

Jacobs, P., Polfliet, T., De Ceukelaire, M. & Moerkerke, G. 2010b. *Toelichtingen bij de geologische kaart van België, Vlaams gewest, Kaartblad (15) Antwerpen Schaal 1:50 000.* Departement Leefmilieu, Natuur en Energie. Dienst Natuurlijke Rijkdommen.

Janssens, L. 2006. *Kaarten op bestelling. De beroepsgroep van land- en edificiemeters in het hertogdom Brabant en de landen van Overmaas (1685-1795).* KU Leuven.

Jongepier, I., Soens, T., Thoen, E., Eetvelde, V., Crombé, P. & Bats, M. 2011. The brown gold: a reappraisal of medieval peat marshes in Northern Flanders (Belgium). *Water History,* 3(2), 73-93.

Kiden, P. 1989. Holocene water level movements in the lower Scheldt perimarine area. *In:* BAETEMAN, C. (ed.) *Quaternary sea-level investigations from Belgium: a contribution to IGCP Project 200.* Brussels, Professional Paper Geological Survey of Belgium,.

Kiden, P. 2006. De evolutie van de Beneden-Schelde in België en Zuidwest-Nederland na de laatste ijstijd. *BELGEO,* 3, 279-294.

Kiden, P. & Verbruggen, C. 2001. Het verhaal van een rivier: de evolutie van de Schelde na de laatste ijstijd. *In:* Bourgeois, J., Crombé, P., De Mulder, G. & Rogge, M. (eds.) *Een in duik in het verleden. Schelde, Maas en Rijn in de pre- en protohistorie.* Publicaties van het Provinciaal Museum van Zuid-Oost-Vlaanderen-Site Velzeke.

Lunne, T., Robertson, P. K. & Powell, J. J. M. 1997. *Cone Penetration Testing in Geotechnical Practice.* London, Spon Press Taylor & Francis Group.

Mathys, M. 2009. *The Quaternary geological evolution of the Belgian Continental Shelf, southern North Sea.* Unpublished PhD-thesis, Ghent University, department Geology and Soil Science.

Robertson, P. K. & Cabal, K. L. 2012. *Guide to Cone Penetration Testing for Geotechnical Engineering (5th edition).* Signal Hill, Gregg Drilling & Testing, Inc.

Sergant, J., Perdean, Y. & Crombé, P. 2006. The Site of Doel "Deurganckdok" and the Neolithisation of the Sandy Lowland of Belgium. *In:* Guilaine, J. & Van Berg, J. P. (eds.) *La Neolithisation/The Neolithisation Process. Acts of the XIVth UISPP Congress, University of Ličge, Belgium, 2-8 September 2001.* Oxford, Archeopress.

Soens, T. 2013. The origins of the Western Scheldt. Environmental transformation, storm surges and human agency in the Flemish coastal plain (1250-1600). *In:* Thoen, E., Borger, G. J., De Kraker, A., Soens, T., Tys, D., Vervaet, L. & Weerts, H. J. T. (eds.) *Landscapes or seascapes? The history of the coastal environment in the North Sea area reconsidered.* Turnhout, Brepols.

Van De Plassche, O. 1982. Sea level change and water-level movements in the Netherlands during the Holocene. *Mededelingen Rijks Geologische Dienst,* 36-1, 1-93.

Van De Plassche, O., Makaske, B., Hoek, W. Z., Konert, M. & Van Der Plicht, J. 2010. Mid-Holocene water-level changes in the lower Rhine-Meuse delta (western Netherlands): implications for the reconstruction of relative mean sea-level rise, palaeoriver-gradients and coastal evolution. *Netherlands Journal of Geosciences - Geologie en Mijnbouw,* 89 - 1, 3-20.

Van Gerven, R. 1977. *De Scheldepolders van de Linkeroever (Land van Waas en Land van Beveren): bijdrage tot de geschiedenis van natuur, land, volk.* Beveren.

Van Strydonck, M. 2005. Radiocarbon dating. *In:* CROMBÉ, P. (ed.) *The last hunter-gatherer-fishermen in sandy Flanders (NW Belgium); the Verrebroek and Doel excavation projects, Part 1: palaeo-environment, chronology and features.* Gent, Academia Press.

Verbruggen, C., Denys, L. & Kiden, P. 1991. Paleo-ecologische en geomorfologische evolutie van Laag- en Midden-België tijdens het Laat-Kwartair. *De Aardrijkskunde,* 3, 357-376.

Vos, P. C. & Van Heeringen, R. M. 1997. Holocene geology and occupation history of the province of Zeeland. *In:* Fischer, M. M. (ed.) *Holocene evolution of Zeeland (SW Netherlands).* Haarlem, Netherlands Institute of Applied Geoscience TNO.

CASE STUDY 3N – SOUTHWESTERN NETHERLANDS

Case Study Area: Vergulde Hand West and Yangtze Harbor, Southwestern Netherlands

Main geomorphological types: Estuary, Tidal basin, Beaches, Dunes

Main coastal change processes: Natural erosion, Natural flooding, Breaching, Human induced

Primary Resources used: Archaeological/Palaeoenvironmental Data

Summary: In this case study, fieldwork results and analysis for two test sites, Vergulde Hand West and Yangtze Harbor are presented. Both areas are located in the Southwestern Netherlands. During the archaeological excavations in Vergulde Hand West geological research was carried out in order to reconstruct the palaeoenvironments of the periods during which man was present in the area. At Yangtze Harbor, the geogenetic approach (targeting the optimal locations for prehistoric settlements in the subsurface based on landscape reconstructions) to detect nowadays drowned archaeological sites in the transgressive palaeo-deltaic environment of the Holocene Rhine-Maas delta was applied.

Recommendations: The techniques used in this case study, could also be applied in other regions of interest. Especially the geogenetic approach, stepwise deployed, provided the insights needed to do targeted high-resolution research, at locations optimal for prehistoric habitation, and to select the best methods and techniques for mapping the palaeolandscape and proving human presence in it.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the technical report on the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

This case study report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented.The analysis of these results and the potential for demonstrating the scale and rate of coastal change are then presented. For further details about the project methodology see Section 2.

3N.1 Introduction to the Netherlands Study Area

In this study, fieldwork results and analysis for two test sites, Vergulde Hand West and Yangtze Harbor (Figure 3N1), are presented. The fieldwork has been conducted in several campaigns, and by several institutions, including the Port of Rotterdam and BOOR.

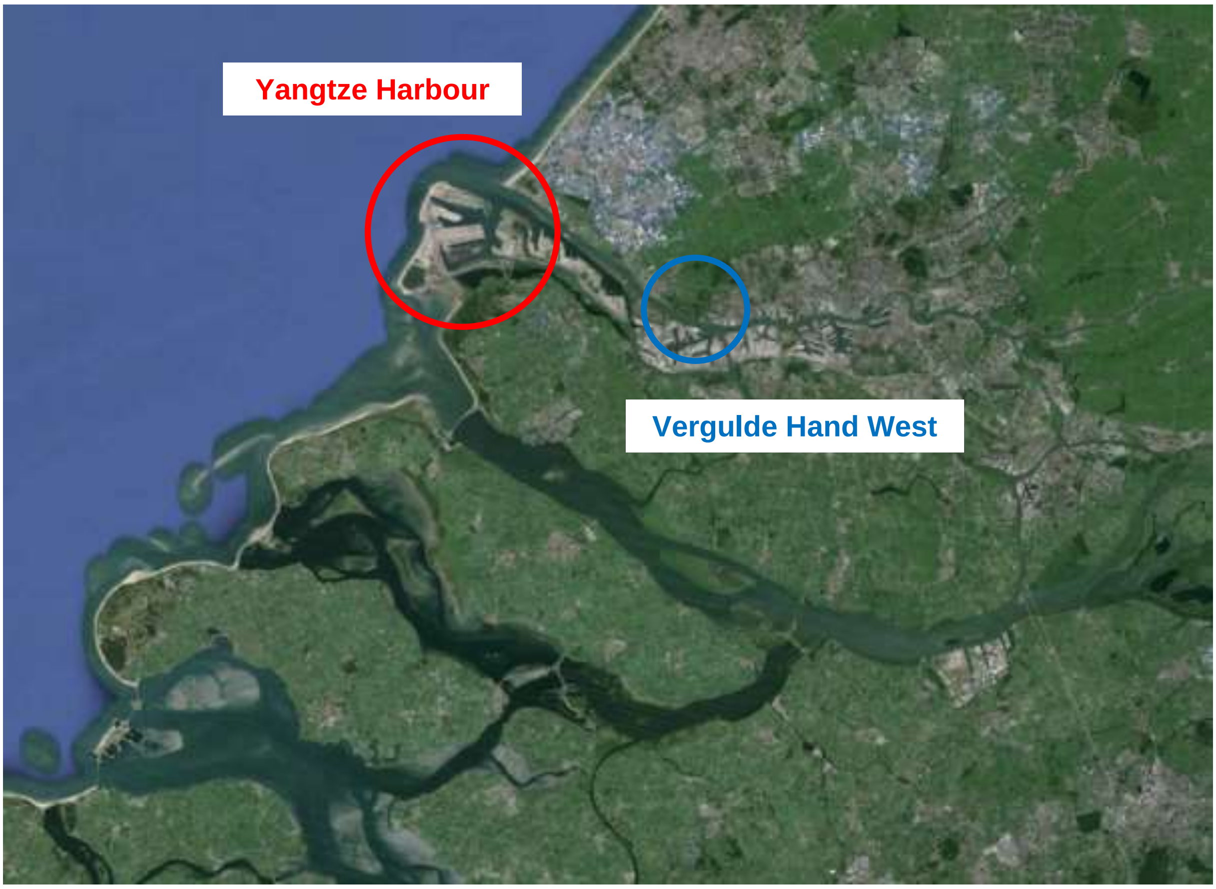


Figure 3N1: Rotterdam and surroundings with (rough) indication of the field study areas.

The first section of this study presents an overview of the paleogeographical and archeological evolutions in the Southwestern Netherlands, with a "zoom-in" on the Scheldt and Rijn-Meuse Delta´s. The report then goes on to describes the goals, methods and results of the fieldwork in the two test sites. After this, the results are analyzed, with a focus on paleolandscape reconstructions. Finally, the broader meaning of the two test cases is described.

3N.1.1 Geology and Geomorphology of the Southwestern Netherlands

During the first half of the Holocene the rise in sea level in particular was the driving force in the evolution of the coastal landscape. As a result of the rapid rise in sea level the major part of the southwestern Netherlands was drowned. About 5500 BC this area had been changed into an extended tidal landscape with tidal channels, mud flats, and salt marshes (Figure 3N3 and Figure 3N4, for the legend see Figure 3N2). The peat areas lay in the transition area between the tidal area and the higher Pleistocene sands in Brabant and Zeeuws-Vlaanderen and in the river delta of the Rhine and Meuse. Humans lived in this drowning coastal- and river landscape and occupied the higher dry-lying grounds such as the coastal barriers and the high river dunes (Pleistocene dunes) in the mouth of the Rhine-Meuse.

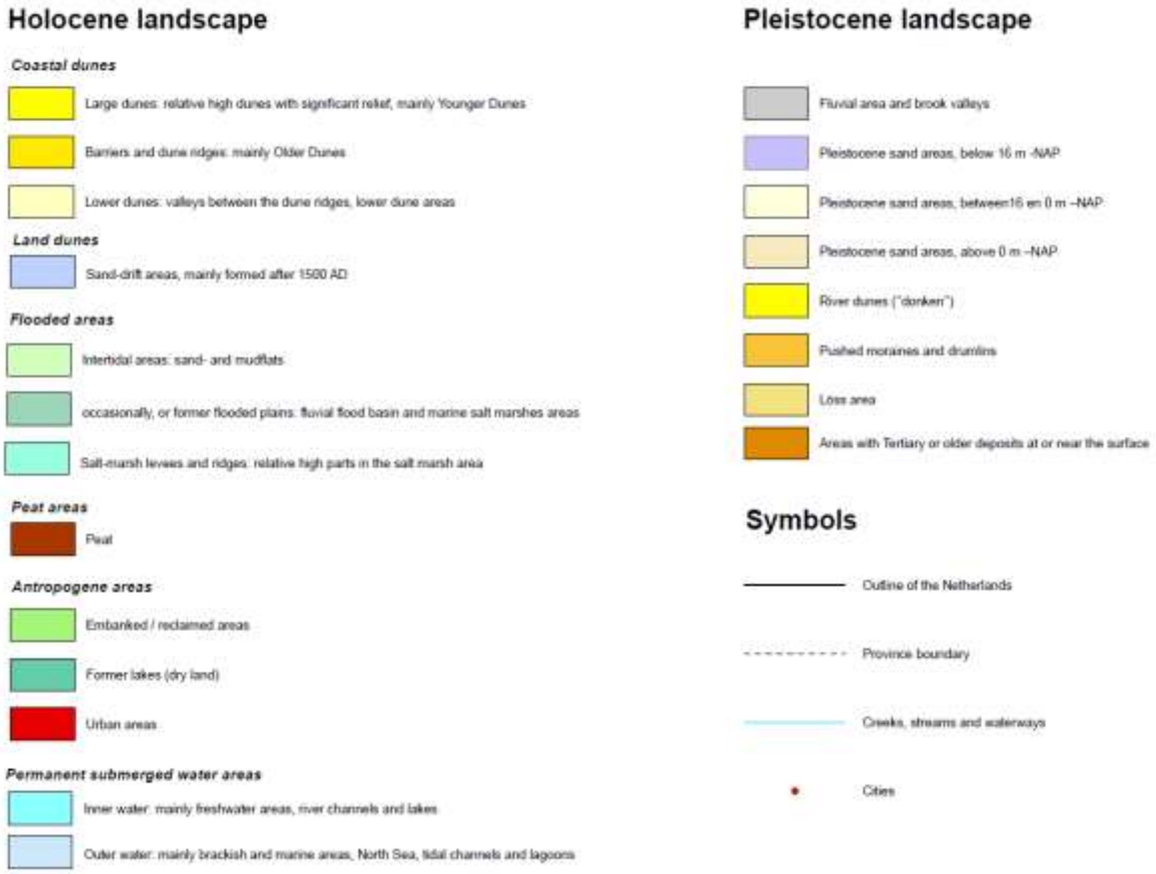


Figure 3N2: Legend for the palaeogeographical reconstructions.

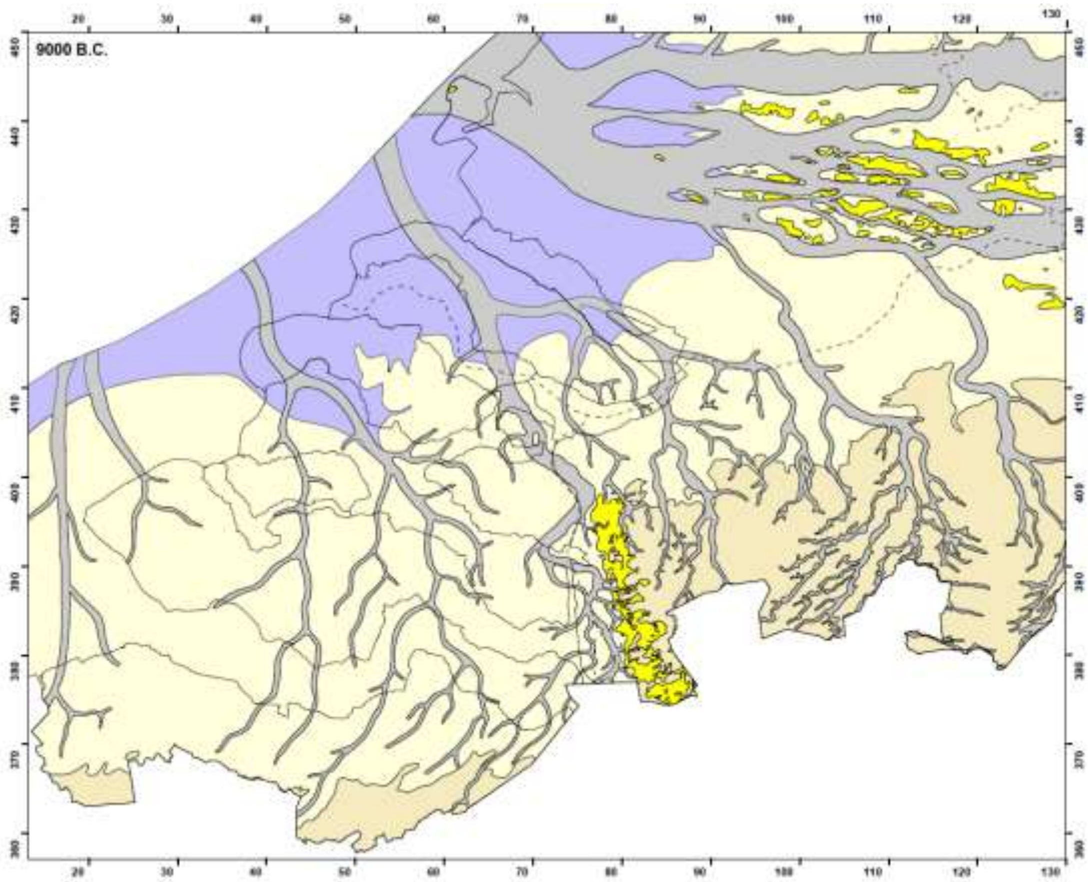


Figure 3N3: Palaeoegeographical reconstruction of the Southwestern Netherlands about 9000 BC.

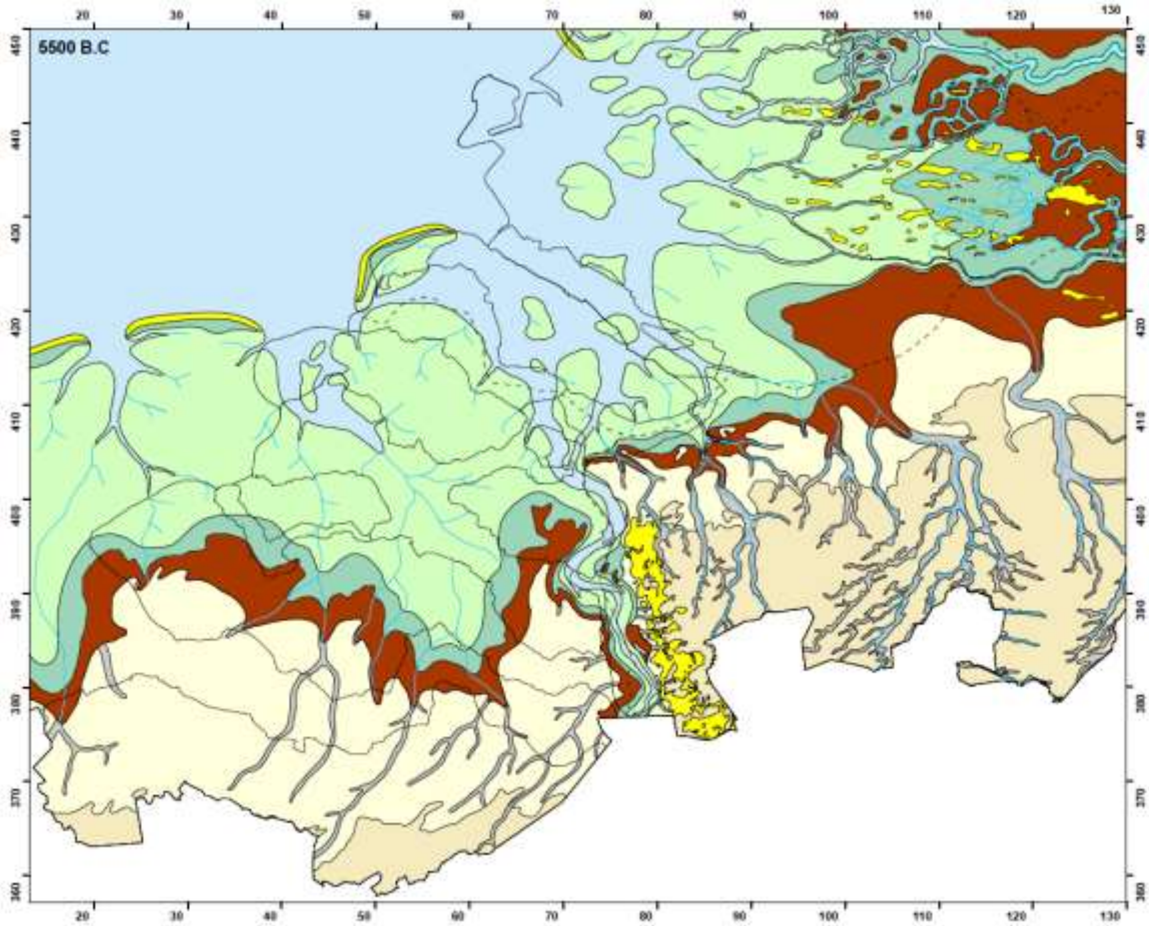


Figure 3N4: Palaeoegeographical reconstruction of the Southwestern Netherlands about 5500 BC.

From about 5000 BC onwards the rise in sea level slowed down and as a consequence sedimentation took over causing the coastal area to be raised. About 3850 BC this resulted in a strong silting-up of the tidal area enabling the intertidal-, supratidal- and peat areas to expand seaward (Figure 3N5) Man benefited from the silting up of the tidal areas by occupying -- besides the coastal barriers and the river dunes – the higher dry-lying parts of the mud flats (e.g. the Vlaardingen Culture). In the province of Zeeland, a few Neolithic sites on the top of the tidal deposits indicate human occupation in this period (Vos and van Heeringen 1997). The question of whether or not the tidal area was inhabited (permanently or seasonally) could not be answered on the basis of the loose finds. The fact that only a few Neolithic finds have been found until now might be explained by the relatively deep position of the tidal deposits (in general 1.5 m or more below surface level) and the relative minor building activity on land in this rural area.

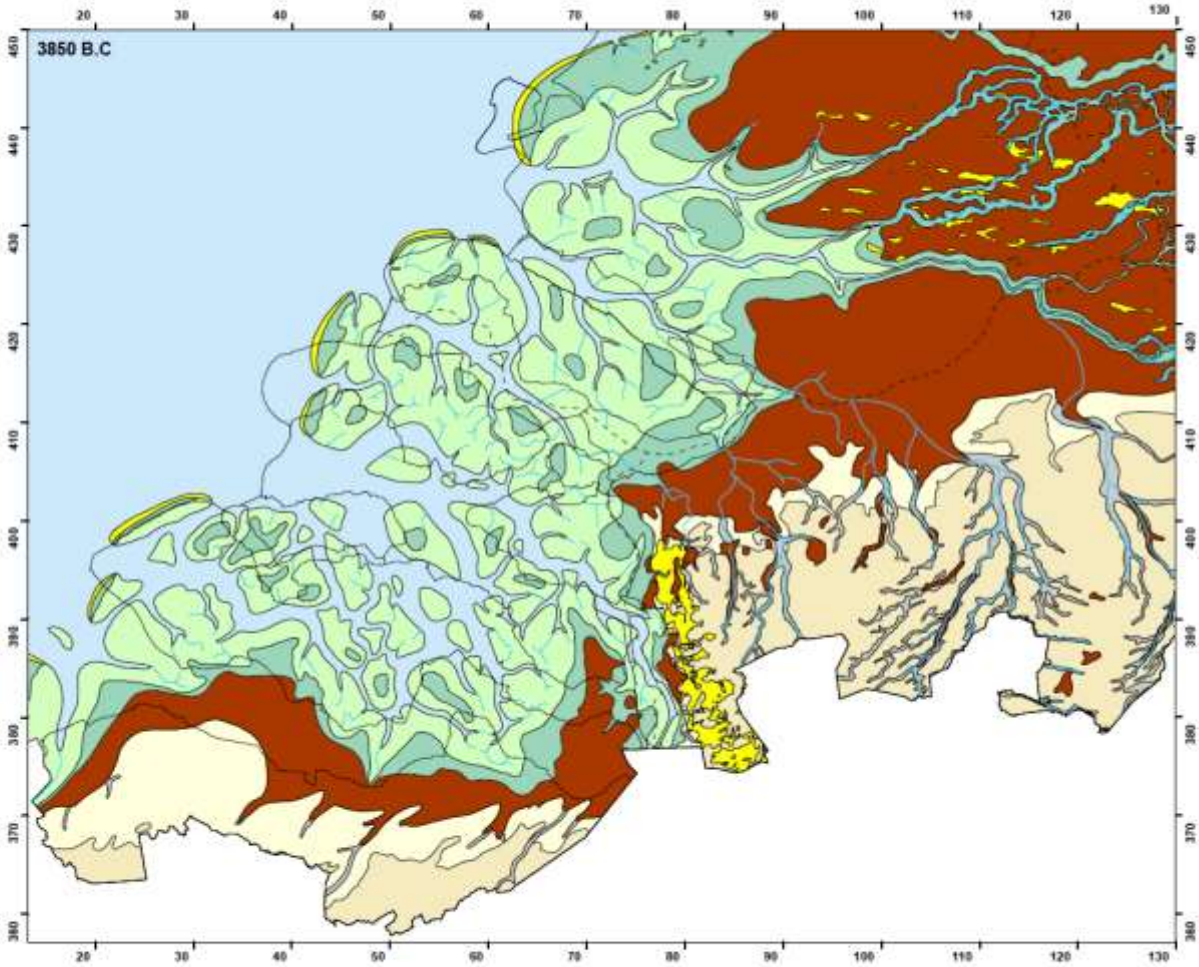


Figure 3N5: Palaeoegeographical reconstruction of the Southwestern Netherlands about 3850 BC.

Further sediment accretion led to considerable reductions in the tidal channels and the tidal outlets and extended coastal barriers and dunes were formed along the coastline. In the course of the next millennia these coastal barriers increasingly protected the tidal area in the hinterland from the sea. An almost closed coastline was formed with coastal barriers and dunes and a few outlets related to rivers such as the Rhine, Meuse and Scheldt (Figure 3N6). As a result the coastal area became isolated from the sea and the peat could expand. By about 2000 BC the higher mud flats became uninhabitable again due to poor drainage and peat growth (wetland). Still human occupation persevered, in particular on the tidal barriers and dunes, which were still dry, and the infilling river beds.

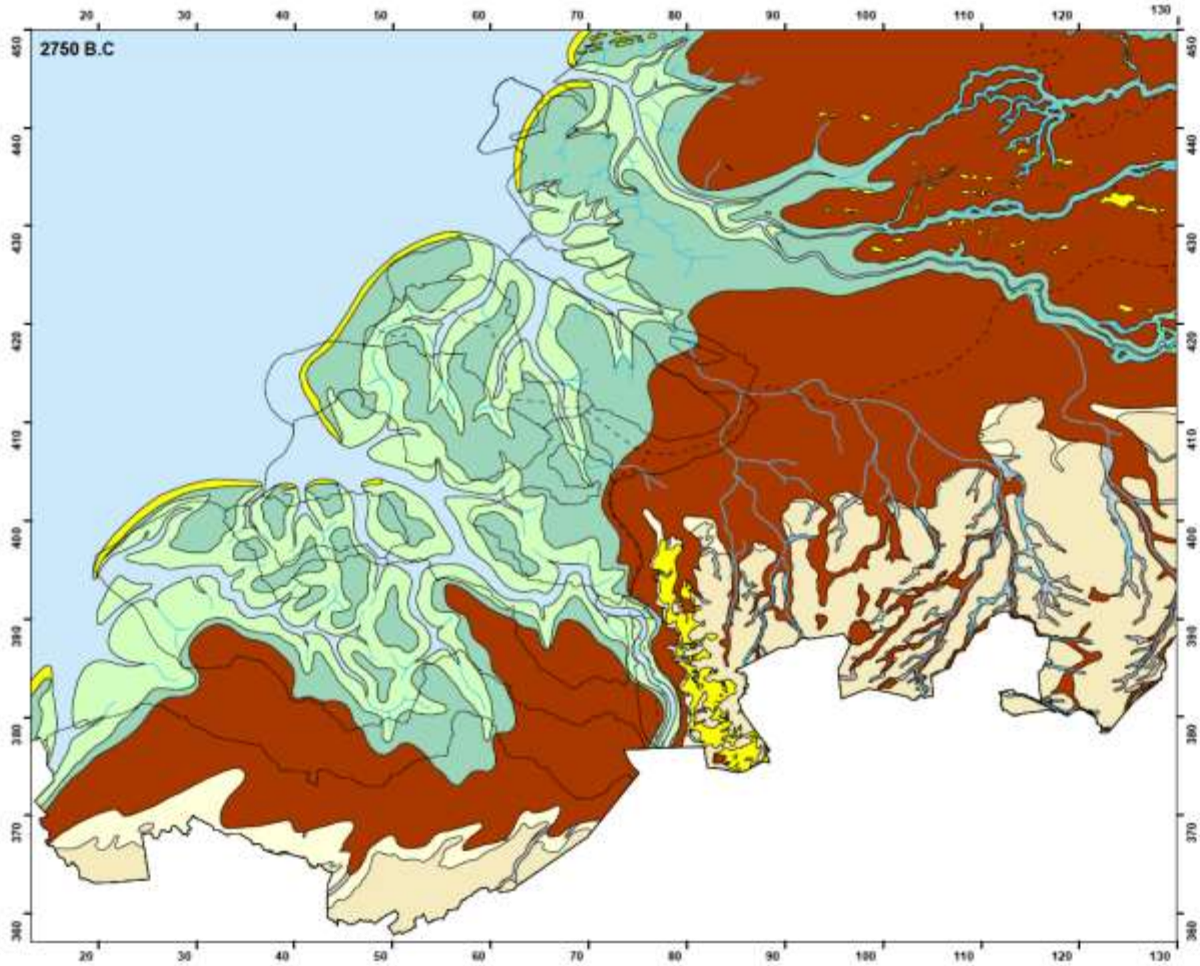


Figure 3N6: Palaeoegeographical reconstruction of the Southwestern Netherlands about 2750 BC.

The situation of an almost closed coastline with a couple of river outlets (Figure 3N7) remained until about 600 BC. Between 500 BC and the beginning of our era the coastal barriers and dunes off Zeeland slowly broke down and small inlets developed with “funnel-shaped” supratidal areas (Vos and van Heeringen, 1997) (Figure 3N8). This coastal erosion was due to a deficiency of sediment caused by changing tidal currents. The sea did not yet reach far inland because the peat in the hinterland had grown up to 1 m or more above the maximum storm surge level.

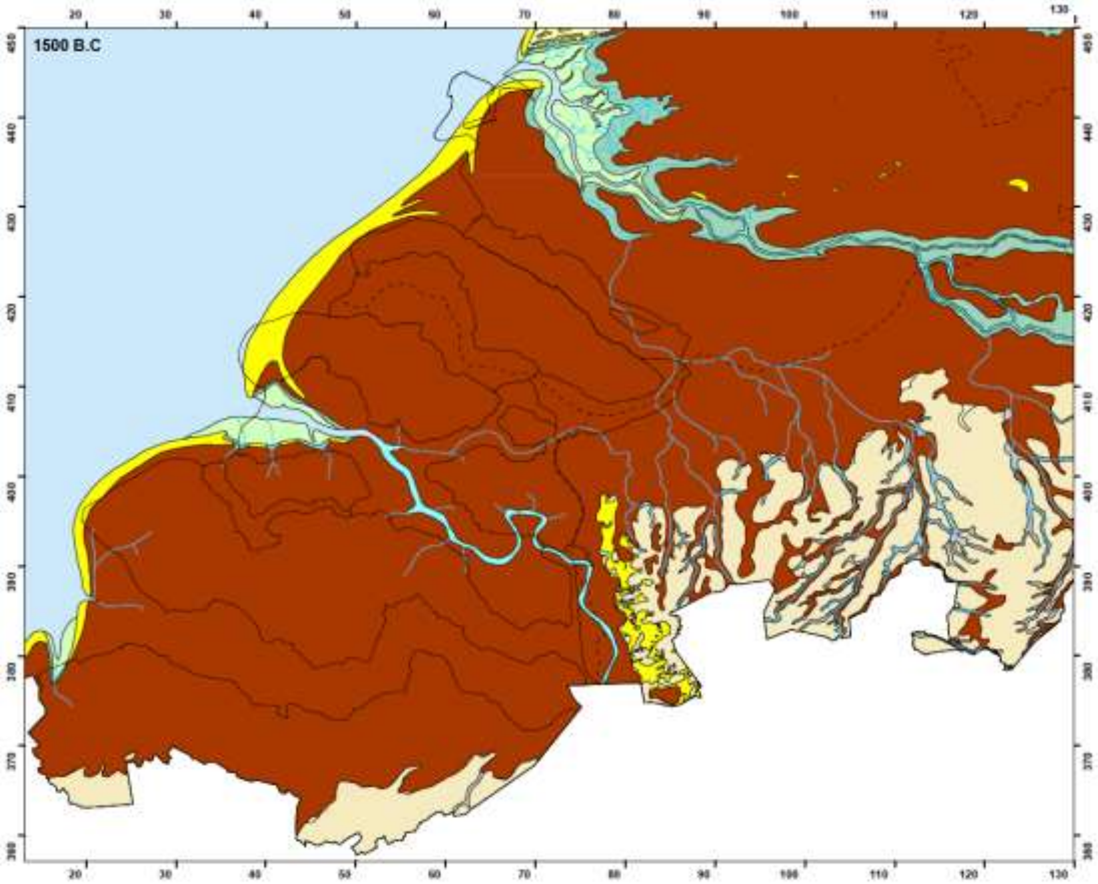


Figure 3N7: Palaeoegeographical reconstruction of the Southwestern Netherlands about 1500 BC.

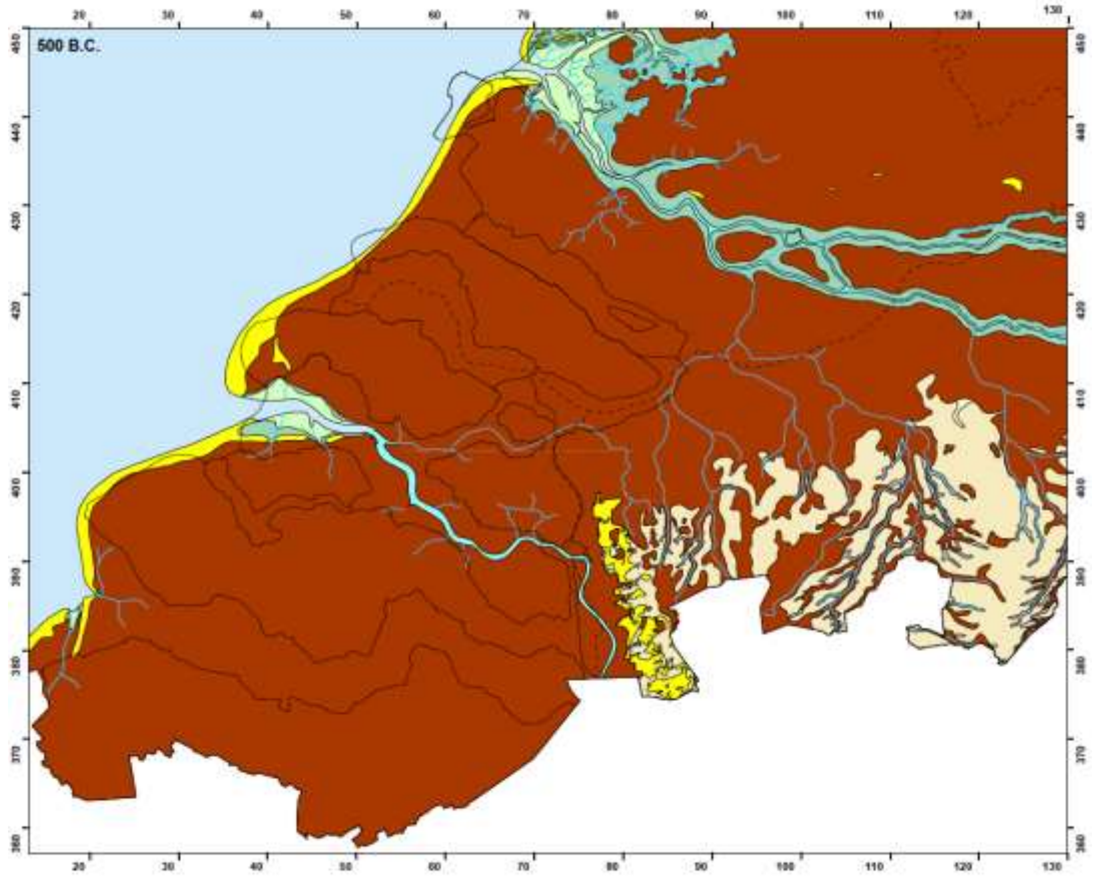


Figure 3N8: Palaeoegeographical reconstruction of the Southwestern Netherlands about 500 BC.

3N.1.2 Summary of the Archaeology and History of the Study Area

The Increasing role of humans on the landscape evolution
Humans took advantage of the new landscape in Zeeland. During the Iron Age, but in particular during Roman times the tidal channels that breached the coastal barriers were used to drain the high peat areas in the hinterland (Figure 3N9, Edelman (1958). Ditches and channels were connected to the tidal channels such that the higher elevated peat areas in the hinterland were drained and became habitable. The drained peat was also extracted at a large scale for industrial purposes (Van den Berg and W., 1986).

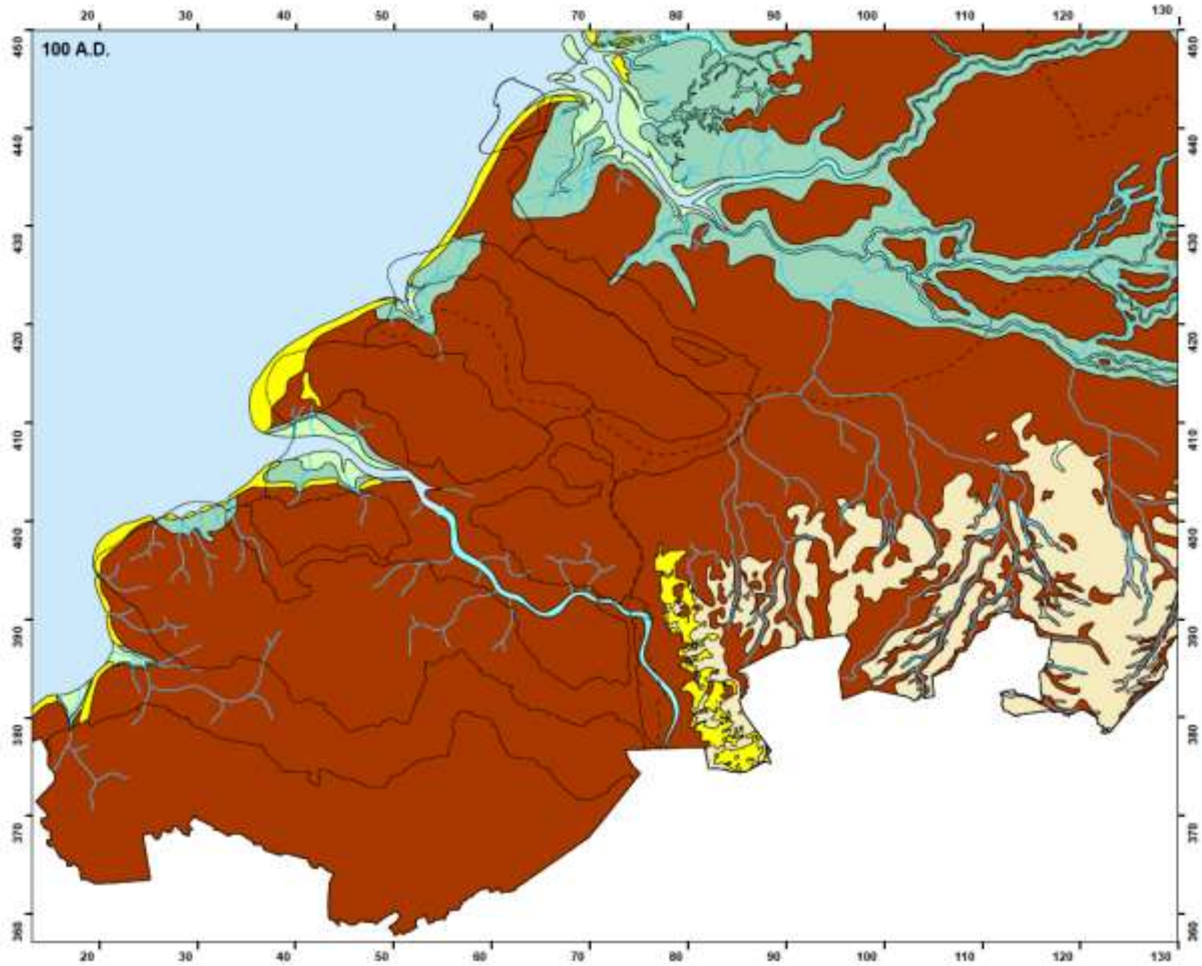


Figure 3N9: Palaeoegeographical reconstruction of the Southwestern Netherlands about 100 AD.

The consequences of these large-scale Roman peat extractions were disastrous. Because of lowering of the surface major parts of the peat areas were flooded and the tide storage area increased considerably. As a response the tidal channels increased strongly in size and also their erosive force, causing complete erosion of peat near the tidal outlets. This process of vanishing peat in its turn led to a further increase in the tidal storage capacity. About 270 AD a self-reinforcing process of peat erosion, lowering of the surface, increase in tidal storage capacity and expansion of tidal channels came into being causing the Roman peat excavation areas to be completely submerged by 350 AD such that habitation and peat excavation in those areas had become impossible. The process of drowning of peat areas continued there until about 800 AD when almost the whole of Zeeland was flooded (Figure 3N10; and the schematic profile reconstruction in Figure 3N11).

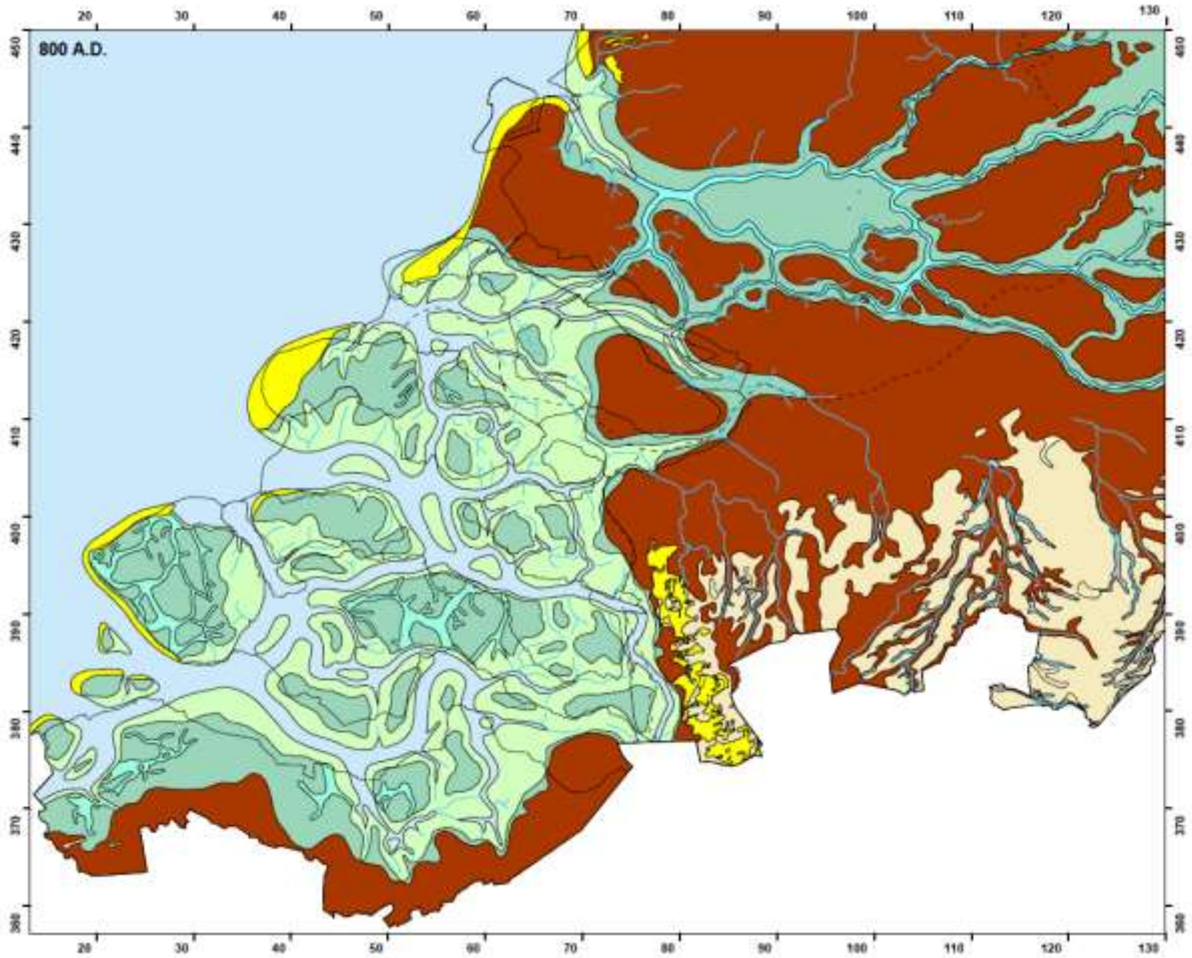


Figure 3N10: Palaeoegeographical reconstruction of the Southwestern Netherlands about 800 AD.

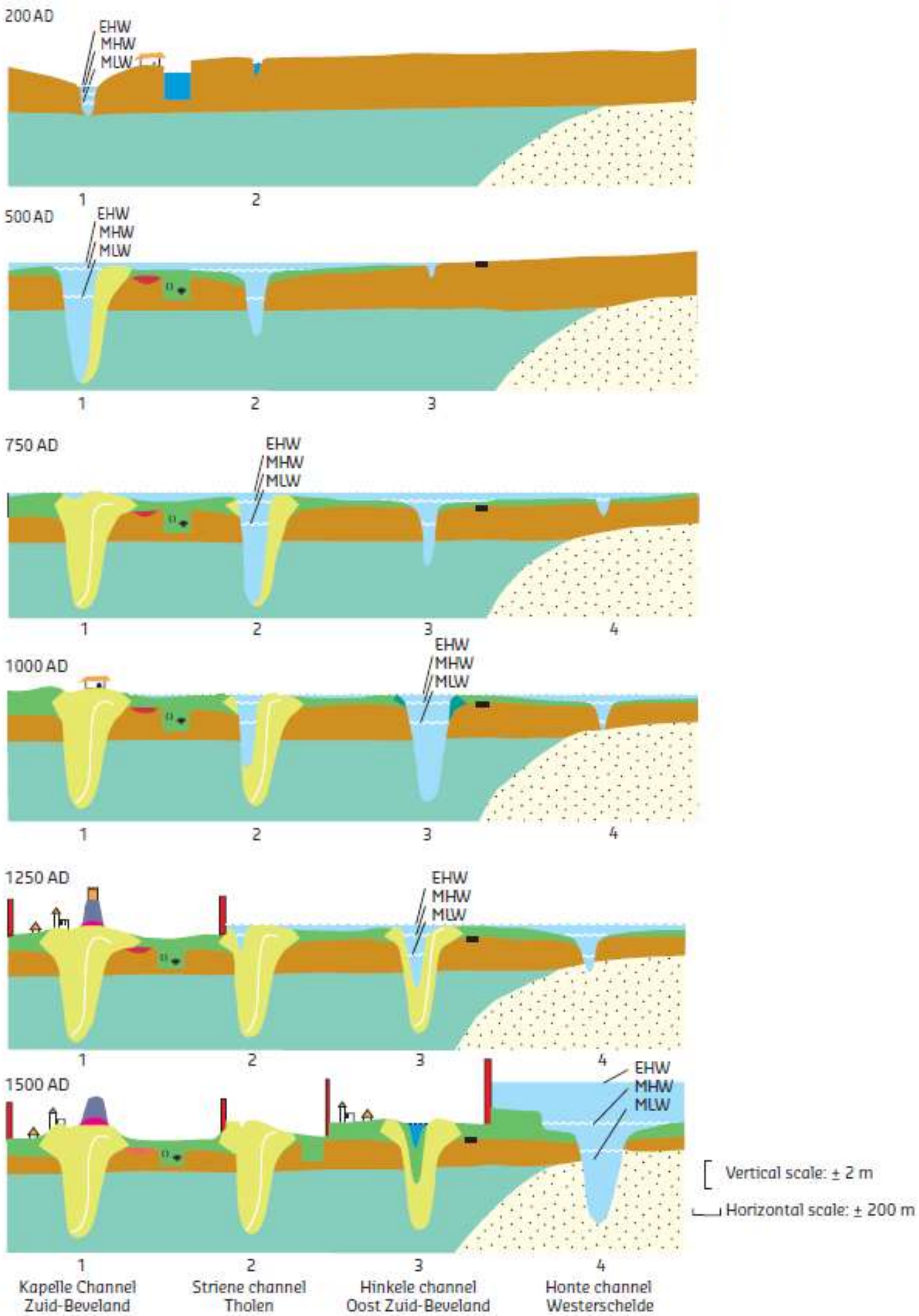


Figure 3N11: Schematic cross-section showing the development of four generations of channels, embankment, subsidence of the land surface and increase of the maximum tide levels in Zeeland.

Silting up and large-scale embankment of the landscape

After 800 AD a change occurred in the coastal evolution. Natural sedimentation (clay and sand) began to outweigh the process of lowering of the peat surface again. Consequently, the tidal area which had come into being between the third and eighth centuries AD started to gradually silt up again which led to the expansion of the salt marsh areas. As a consequence the mud flats which had risen by accretion were flooded less frequently. In the course of the tenth century parts of the newly formed salt marshes even fell dry permanently and *Flachsiedlungen* (non-raised dwellings) were built on the highly elevated mud flat deposits. Investigations of *mottes* (*châteaux à motte*) in Zeeland have revealed that during the 11th century the *Flachsiedlungen* – which are located below the dwelling mounds – were elevated by soil such that about 1 m high dwelling mounds were formed (Vos and van Heeringen, 1997). Also historical sources (Gottschalk, 1955-1958) indicate that in the coastal area of Belgium and Zeeuws Vlaanderen people lived on dwelling mounds (Locwirde, Commerswerve) during this period. During the 11th century the occupants were troubled more often by storm surges than during the 10th century (Dekker, 1971).

In the course of the 11th century humans locally began to dike in parts of the salt marshes in Zeeuws Vlaanderen. However, in the northerly located Zeeland area the systematic, large-scale impoldering of the major part of the salt marsh area took place during the 12th and 13th centuries (Figure 3N12, Dekker (1971). In addition to the favorable landscape situation (highly silted-up salt marsh areas) also social-economical factors were important to these large-scale diking-ins. The community was well organized owing to the rise of the churches and the region was prosperous due to the textile industry, in particular in Vlaanderen. The textile industry had a need for sheep wool which were kept on the salt marshes.

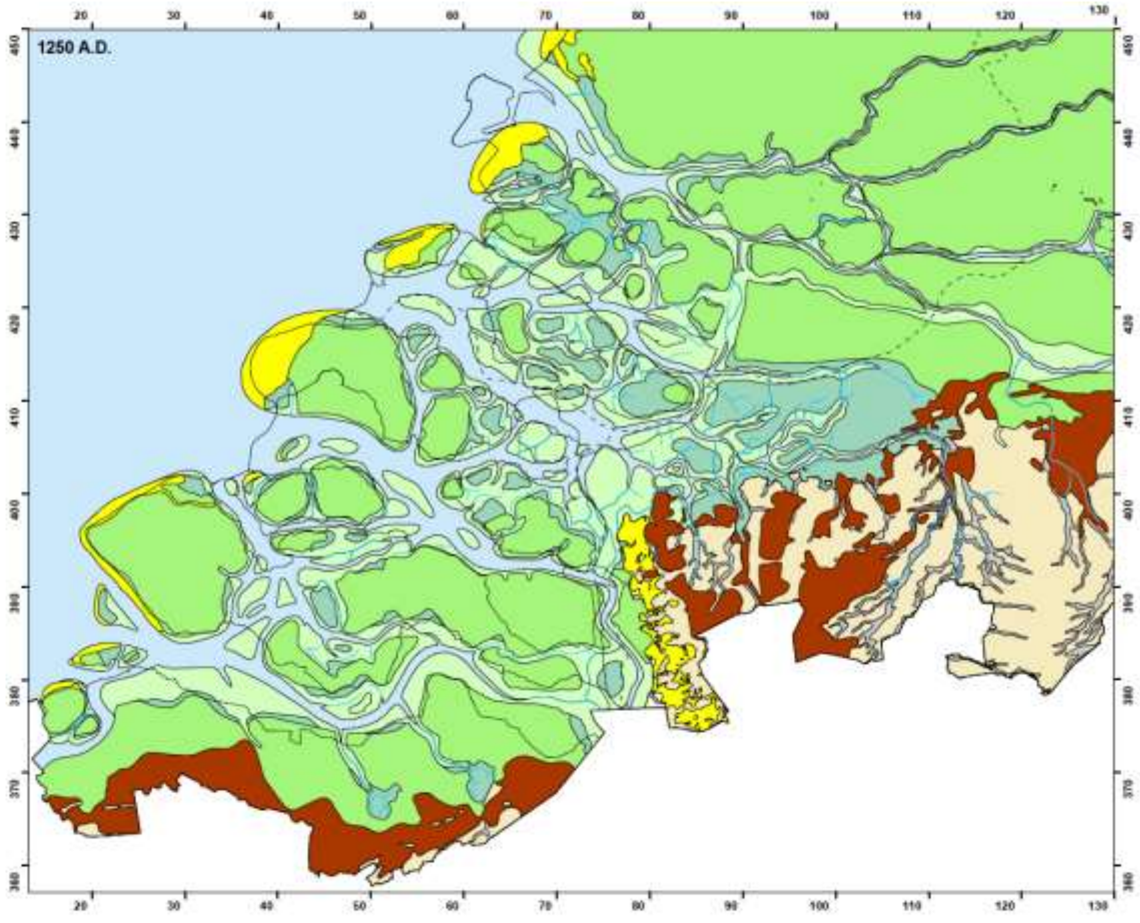


Figure 3N12: Palaeoegeographical reconstruction of the Southwestern Netherlands about 1250 AD.

The embankments had far-reaching consequences for the landscape and the tidal processes in the areas that were not diked-in. Because the major part of the salt-marsh area had been diked-in the seawater could not flow over these areas during storm surges. Since the water thus did not have an outlet anymore it was dammed up against the dikes, the result being that the storm surge level in the non diked-in tidal area was raised. The smaller the water storing capacity of the salt-marsh area, the higher the storm surge level and the higher the dikes had to be raised.

Flooding disasters

By building dikes in Zeeland humans created a landscape which was favorable for the occurrence of flooding disasters. Not only had the embankment of large parts of the salt-marsh areas caused the maximum storm surge levels to be raised considerably, but also the surface level of the diked-in polder areas was lowered due to human interference (a result of artificial drainage through sluice systems). The most significant lowering of the surface level occurred in those polders where the soil consisted mainly of peat (peat areas with a thin layer of clay). Also the excavations for the building of dikes and for salt production contributed to the artificial lowering of the surface. During the Late Medieval period large-scale salt extractions from peat drenched with seawater took place in the clay-on-peat areas (''*moernering''*). This technique of salt production, at which salt was extracted from peat by boiling, is called “selnering” (Figure 3N13).

Figure 3N13: Darinck delven or selnering (peat digging for salt extraction) in Zeeland around the 16/17th century. Pronk (1745, www.rijksmuseum.nl, 13/8/2014).

Thus humans created a large difference between the maximum storm-surge level in the open sea inlets and the surface level in the reclaimed polders (Figure 3N11). This difference in level could rise as much as several meters. When a dike breached (see dramatical depiction in Figure 3N14) this had catastrophic consequences: the seawater flowed violently into the lower lying polders. Since the inhabitants did not live on elevated dwelling mounds in the southwestern Netherlands this led to casualties and extensive damage.

Figure 3N14: Historic pictures of the catastrophic effect of a dike burst in 1651.

The flooding disasters which took place in the southwestern Netherlands have been brought into vision by means of a storm surge calendar (Figure 3N15) . This ''calendar'' distinguished between major disasters (inundation of large parts of the southwestern Netherlands) and minor ones (inundation of only one or a few polders) and also the military inundations are mentioned. The storm surge calendar shows that major disasters occurred in particular during the 14th to 17th centuries; afterwards they decreased in number. The high frequency of the occurrence of disasters during this period cannot be straightforwardly attributed to climate change; negligence of the dikes, insufficient coordination, incompetence, political circumstances, wars and economic crises all played important roles.

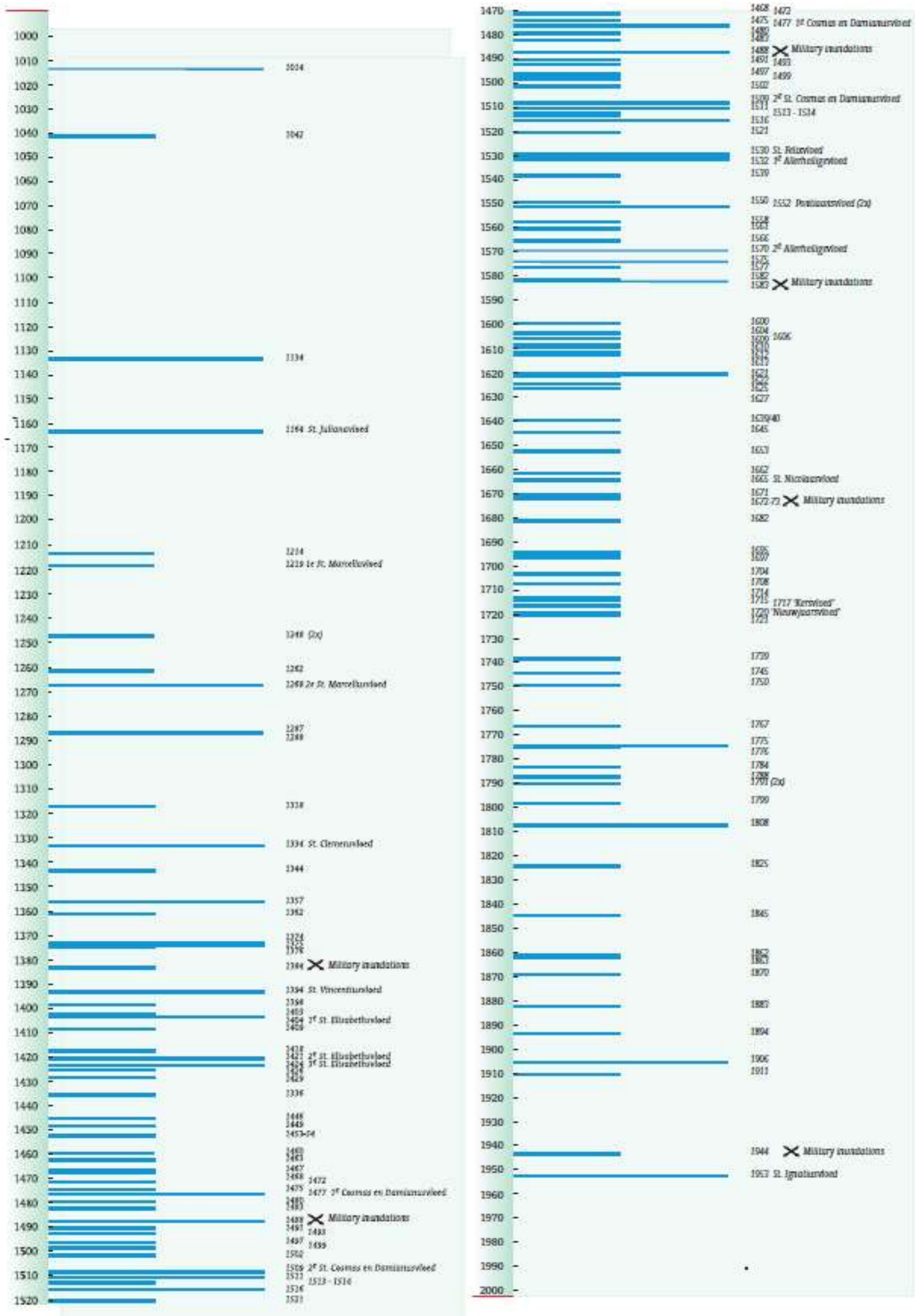


Figure 3N15: The storm surge calendar of the Southwestern Netherlands (made by F.D. Zeiler)

The floods have led to long-lasting and even permanent loss of land in certain parts of the southwestern Netherlands (compare Figure 3N12, Figure 3N16 and Figure 3N17). The area around the Braakman in the central part of Zeeuws Vlaanderen was inundated during the floodings of 1375/1376 and 1404 (St. Elisabeth Flood, see Gottschalk (1955-1958). It has taken 600 years for the area to be silted up sufficiently high such that it could be reclaimed completely. Areas which have been lost for a large part until present are the Verdronken Land van Zuid-Beveland and the Verdronken Land van Saeftinghe. The Verdronken Land van Zuid-Beveland was lost during the St. Felix Flood in 1530 (*St Felix quade saterdag*) and the storm surge of 1532 (Wilderom, 1964; Dekker, 1971; Leenders, 1986). As mentioned above, the loss of the Verdronken Land van Saeftinghe was due to military causes connected to the siege of Antwerp in 1585.

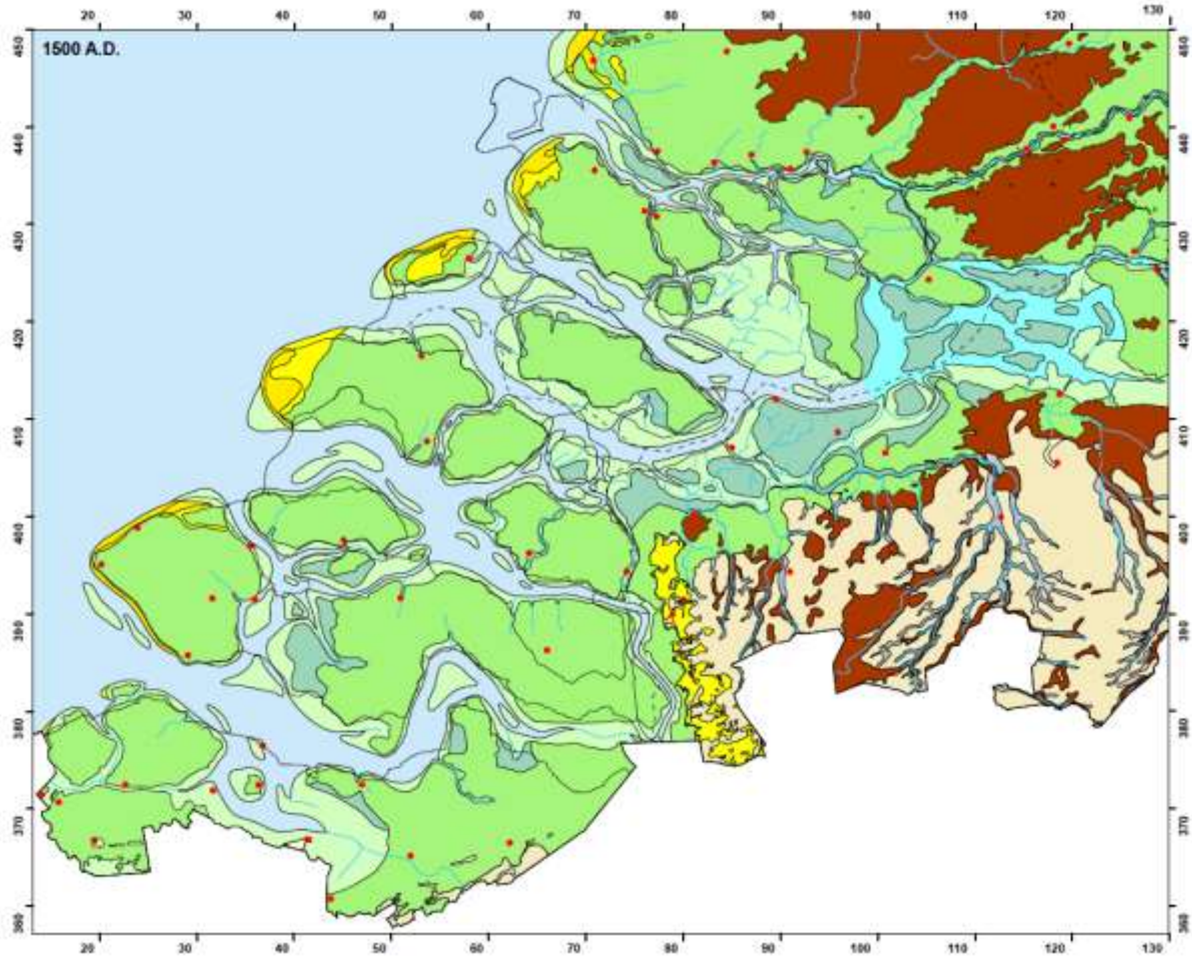


Figure 3N16: Palaeoegeographical reconstruction of the Southwestern Netherlands about 1500 AD.

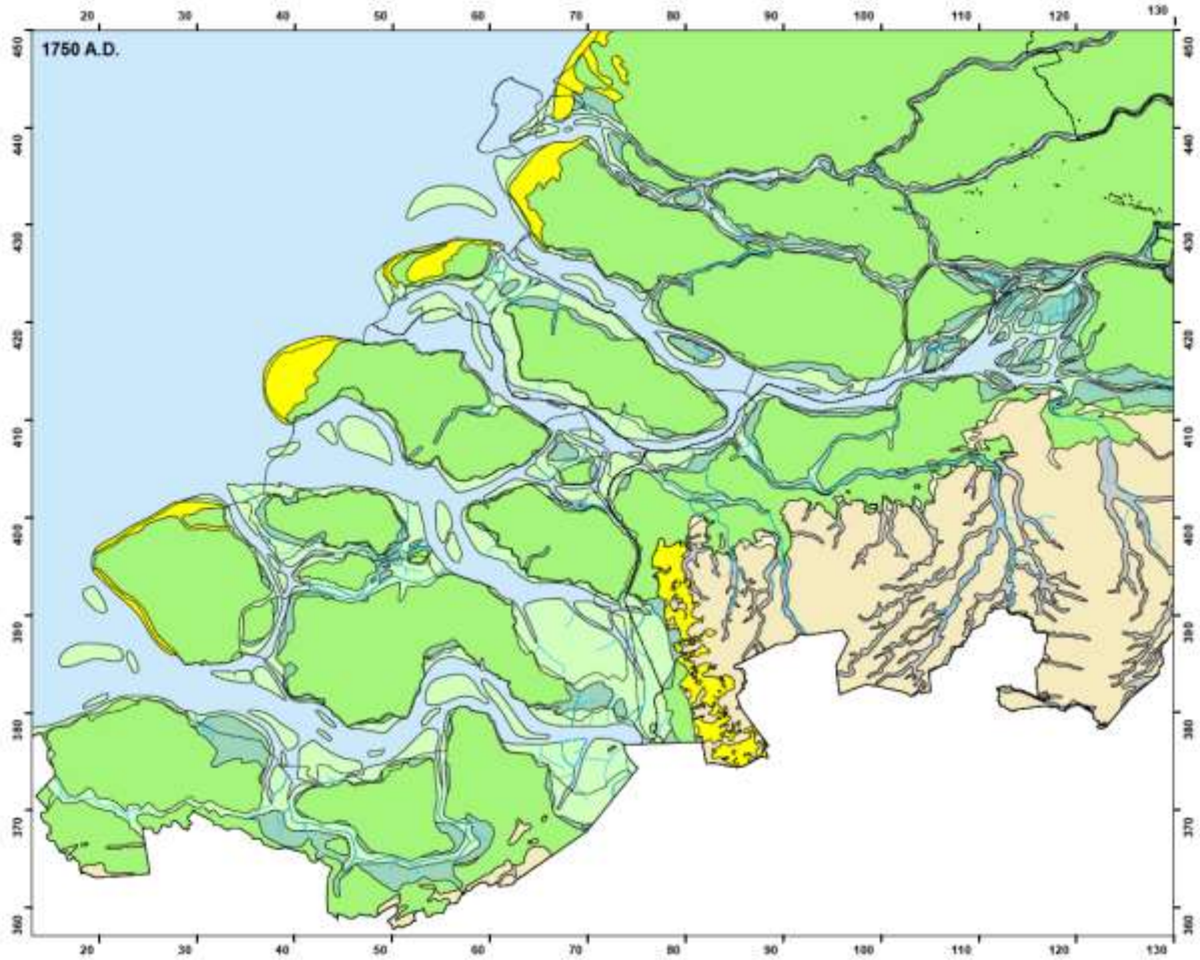


Figure 3N17: Palaeoegeographical reconstruction of the Southwestern Netherlands about 1750 AD.

The changing course of the river Scheldt

The course of river Scheldt and the mouth of the later Western Scheldt were separated at least until the Early Middle Ages, since north-west of the Verdronken Land van Saeftinge, a raised peat bog on top of the Pleistocene ridge was present. By then, the Eastern Scheldt formed the main outlet of the river. The connection between the Western Scheldt area and the river Scheldt east of Saeftinge, probably came into existence before 843 AD (Leenders, 1986). During the 10th century, the Honte was a relatively important sea branch because this connection was mentioned in historical sources as 'Mare' (Vlam, 1946; Gottschalk, 1971; Brand, 1983). The enlargement of the Honte was possibly the result of the floods of 1014, 1042 (Brand, 1983) and 1134 AD (Gottschalk, 1971; Brand, 1983). Notwithstanding the increase in size of the Honte connection, the Honte was not deep during the 13th century and could only be navigated during high water by shallow-drawing inland ships.

Around 1400, however, the Honte connection became increasingly important. The improved navigation conditions in the Honte were the result of inundations in the foreland of the Western Scheldt area (Denucé, 1933; Brand, 1983).

The storm surges of 1530 and 1532 had a decisive role for the final take-over by the Western Scheldt from the Eastern Scheldt as the main discharge of the river Scheldt (Brand, 1983). These inundations resulted in a shift of the watershed, which finally tipped the balance in favor of the Western Scheldt as the main outlet of the river Scheldt (Brand, 1983; Vlam, 1946).

Rijn-Maas Delta: The Striene connection

In the literature, a connection between the rivers Scheldt and Rijn-Maas is suggested already for the Roman Period (e.g. Hettema, 1951). The authors assumed - on the basis of a text by Julius Caesar - that the Roman Scheldt-Maas connection was the predecessor of the medieval Striene, a tidal channel which, during the 13th century, was silted up, blocked off and embanked (Wilderom, 1964). However this view is contested. The inferred Roman course of the Striene has always remained uncertain due to a lack of pedologic evidence (Kuipers, 1984; Steur and Ovaa, 1960). Also geological mapping in the 1990's has not been able to confirm the existence of a Roman Striene connection. Therefore, it is generally recognized now that the Striene was an Early Medieval connection between Scheldt and Maas. This connection came into existence after the Post-Roman inundation of the peat areas of Tholen, St. Philipsland and the area of the present-day Volkerak. Only southeast of Poortvliet (Tholen), the Striene tidal channel used the eastern part of the remnant channel of the Subboreal Scheldt meander.

Archaeology of the Rijn-Maas delta

Throughout the Holocene humans were present in the delta of the Rijn-Maas estuary. The drowning, and thus the appearance of the delta, began in this region in the Mesolithic around 7500–7000 BC at a depth of 22–20 m – NAP (Hijma et al., 2009; Hijma and Cohen, 2011; Cohen et al., 2012). At that time, especially the higher situated river dunes were inhabited.

When around 6500 BC the whole Maasvlakte area had come within the marine sphere of influence and the higher parts of the dune sites there disappeared completely by coastal erosion (Rieu et al., 2005), the occupation of higher lying dune locations shifted to the east. Mesolithic and Neolithic settlements on river dunes like those of Hardinxveld-Polderweg (ca. 5400 BC) and Molenaarsgraaf (Hazendonk, from about 4000 BC onwards) are examples of this. Also the wetlands were penetrated and encampments were built. The Mesolithic find location of Bergschenhoek around 4300 BC demonstrates these wetlands were used by humans (Louwe Kooijmans, 1985).

From the Neolithic (c. 5000 BC) onwards the area around the Vergulde Hand West was part of the higher silted-up clay–peat area to the north of the main courses of the Rhine–Maas rivers (deposition of layer 6; Figure 3N23). The oldest known sites in the Maas estuary region belong to the river dune settlements such as the Piet Heinplaats in Vlaardingen and the one of Schipluiden-Noordhoorn (3900–3500 BC; De Ridder (2000)). In the subsequent period (ca. 2900–1800 BC) also the adjacent tidal levees that had been formed along the tidal creeks were taken in use. The remains of the younger settlements of the Vlaardingen culture are located in this landscape. The most famous settlements of this culture are those of the Vlaardingen Westwijk and Hekelingen in Spijkenisse (Louwe Kooijmans, 1985).

Archaeological remains from the Bronze Age area are scarce in the Maas estuary region. In the Early Iron Age the bogs along the Maas were first inhabited. Although the region was not inhabited densely in this period, settlements with houses have been found at slightly elevated peat bogs (''*peat cushions*'') in Rotterdam, Spijkenisse and Vlaardingen (Van Trierum, 1992; Wind, 1973).

In Roman times the Maasmond was part of the Roman Empire. At that time the Rijn–Maas channel was an important waterway. In the first century AD the region became intensively inhabited again. The peak of the occupation phase was in the second century AD.

During the 3rd century AD habitation decreased strongly and up to 1250 AD little is known about the nature and distribution of the settlements and their positions in the landscape. This is mainly due to a lack of well-preserved remains of settlements from this period. In particular, insufficient light has been shed on the Early Medieval traces of habitation, partly because the sites are oxidized (peat area) or eroded (marine area).

3N.2 Archaeological and Palaeoenvironmental Fieldwork Methods and Results

The fieldwork carried out at the site of Vergulde Hand West is presented first, followed by the work carried out at Yangtze Harbour.

3N.2.1 Vergulde Hand West

Fieldwork Aims

The site 'Vergulde Hand West' (VHW) is located at the west side of the municipality of Vlaardingen, immediately north of the Nieuwe Waterweg (Figure 3N18). In 2005, large-scale excavations of archaeological remains from the time periods between the Middle Bronze Age and the Middle Ages were carried out at this site. The archaeological remains which occurred at a depth of approximately 2 m below ground level were threatened by the construction of a new industrial estate. During the archaeological excavations geological research was carried out in order to be able to reconstruct the palaeoenvironments of the periods during which humans were present in the area. The geological and palaeoenvironmental research has been published in a report by Deltares (Vos and Eijskoot, 2009). This report formed the basis for the palaeolandscape synthesis in the final archaeological publication (Eijskoot et al., 2011). In this part of the study, the geological and palaeolandscape research of the VHW is summarized and the main conclusions regarding the regional landscape development are discussed. We will examine a number of special post-sedimentary layer deformations which occurred in the area of the site VHW.

Figure 3N18: Location of the study area of Vergulde Hand West (VHW) in the Vlaardingen Township (province of Zuid-Holland; The Netherlands).

Fieldwork Methodology

The area of the excavation of the 'Vergulde Hand West' (VHW) site in the summer of 2005 was about 500 m by 500 m (approximately 25 ha). The excavations were led by the Vlaardings Archeologisch Archaeological Office. During the excavations, the site was divided into four sectors, namely the sectors East, West, Middle and Canoe (Figure 3N18 and Figure 3N19). From an archaeological point of view, the sector East was relevant in particular for the Early and Middle Iron Ages and the preceding period. In the sector Middle especially the layers from the Bronze Age, Middle Iron Age and Late Iron Age were important. In the sector West interesting archaeological material was found mainly in the deposits from the Roman period and the Middle Ages. In the research of the landscape in the sector Canoe the main question was how the canoe had ended up in older peat layers. An impression of excavation and the main archaeological features found in 2005 on the VHW location are presented in Figure 3N20.

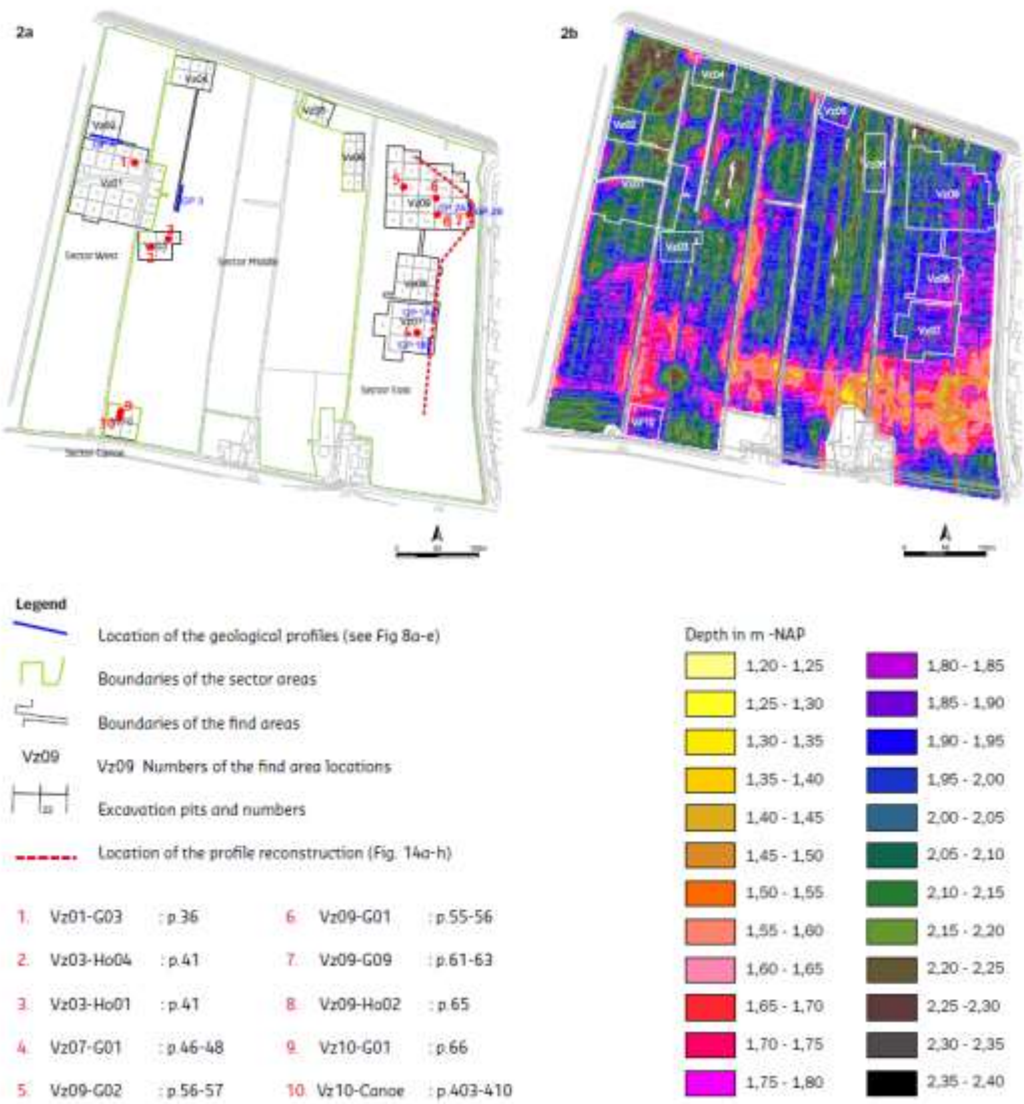


Figure 3N19: Map of the VHW study area with the location of the sectors West, Middle East and Canoe. Figure 3N19a. Topographical map with positions of the geological profiles (Figure 3N25) and main archaeological sites. Figure 3N19b. Lidar elevation map (AHN) of the VHW.

Figure 3N20: Impressions of the VHW excavation in 2005. Figure 3N20a. Excavation of find location area Vz09 in sector East (see also Fig. 2a); Figure 3N20b. Floor and house wall of branches from the Middle Iron Age (Vz09-G01; sector East); Figure 3N20c. Foundation posts of a granary from the Middle Iron Age in sector East (find location area Vz09 in sector East) Figure 3N20d. Foundation posts of a wooden structure dated around 992 AD (Vz02-Ho01 in sector West); the posts are struck in the preserved medieval peat layer (Hv-1, see Fig. 7); Figure 3N20e. Path of branches from the Middle / Late Iron Age (Vz09-P01; sector East); Figure 3N20f. Remains of wooden structure from the Middle Bronze Age at the base of the Spuipolder layer (Vz10-Ho01 in sector Canoe); Figure 3N20g. The 11 m long canoe made of oak (find location area Vz10, sector Canoe); Fig. 3h. Ditch from the 2nd century AD which was dig in the Binnenpolder layer of sector East (find location area Vz08, sector East).

The landscape history formed an important part of this archaeological study, because of its relevance to the understanding of the relationship between the development of this landscape and human activity in the area. Also the relationship with the surroundings, such as water connections, was part of this geogenetic and archaeo-landscape research. From the Neolithic onwards (period after 4000 BP) the area of the VHW was geographically part of the north side of the Rijn–Maas delta (Figure 3N4). During this period, the depositional environment of the VHW was above the palaeo-MHW level and the deposition of clay sedimentation and peat formation alternated. Landscape environments which occurred were brackish marsh deposits, freshwater tidal deposits, reed bogs, alnetum fens and oligotrophic peat bogs. The geological / palaeo-landscape research that was carried out had a strong chronological approach. For each of the sectors of the VHW a stratigraphic model of the layer units was composed (peat – clay) which have been formed from the Middle Bronze Age onwards (Figure 3N22, Figure 3N23 and Figure 3N24).

The lithological and archaeological layer units were dated by means of a large number of ^{14}C datings, more than 200 in total (Eijskoot et al., 2011). By using wiggle-match techniques and dendrochronological studies of oak and ash piles, datings of archaeological pole structures could be obtained with a 2-sigma reliability of less than 10 years (Eijskoot et al., 2011). Due to the high precision of the datings from amongst other Mid / Late Iron Age settlements also the drowning of these archaeological structures could be determined fairly accurately.

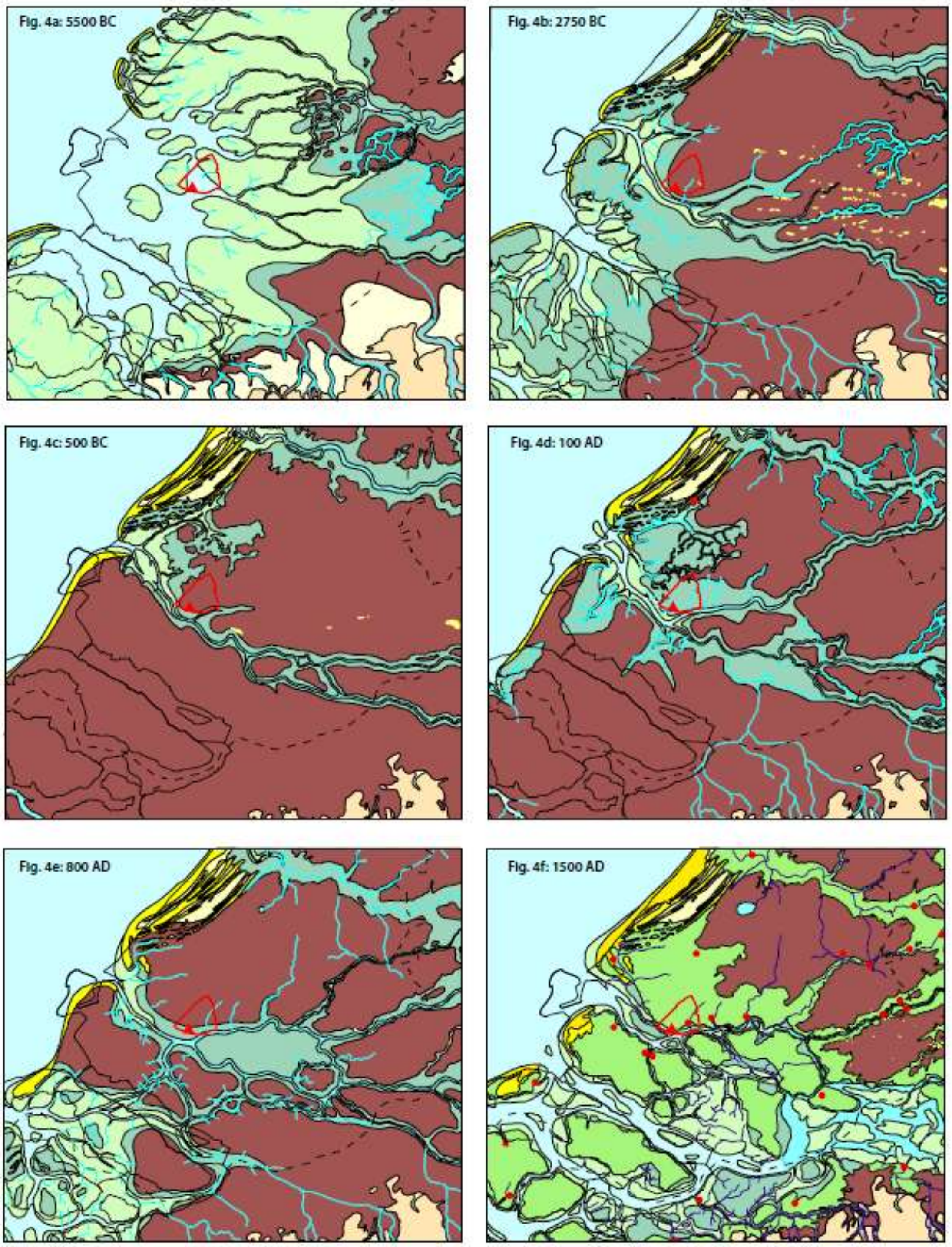


Figure 3N21: Regional landscape reconstruction of the Rijn-Maas delta during the Holocene: an excision from the palaeogeographical maps of the Netherlands for the Maasmond area, after Vos et al., 2011.

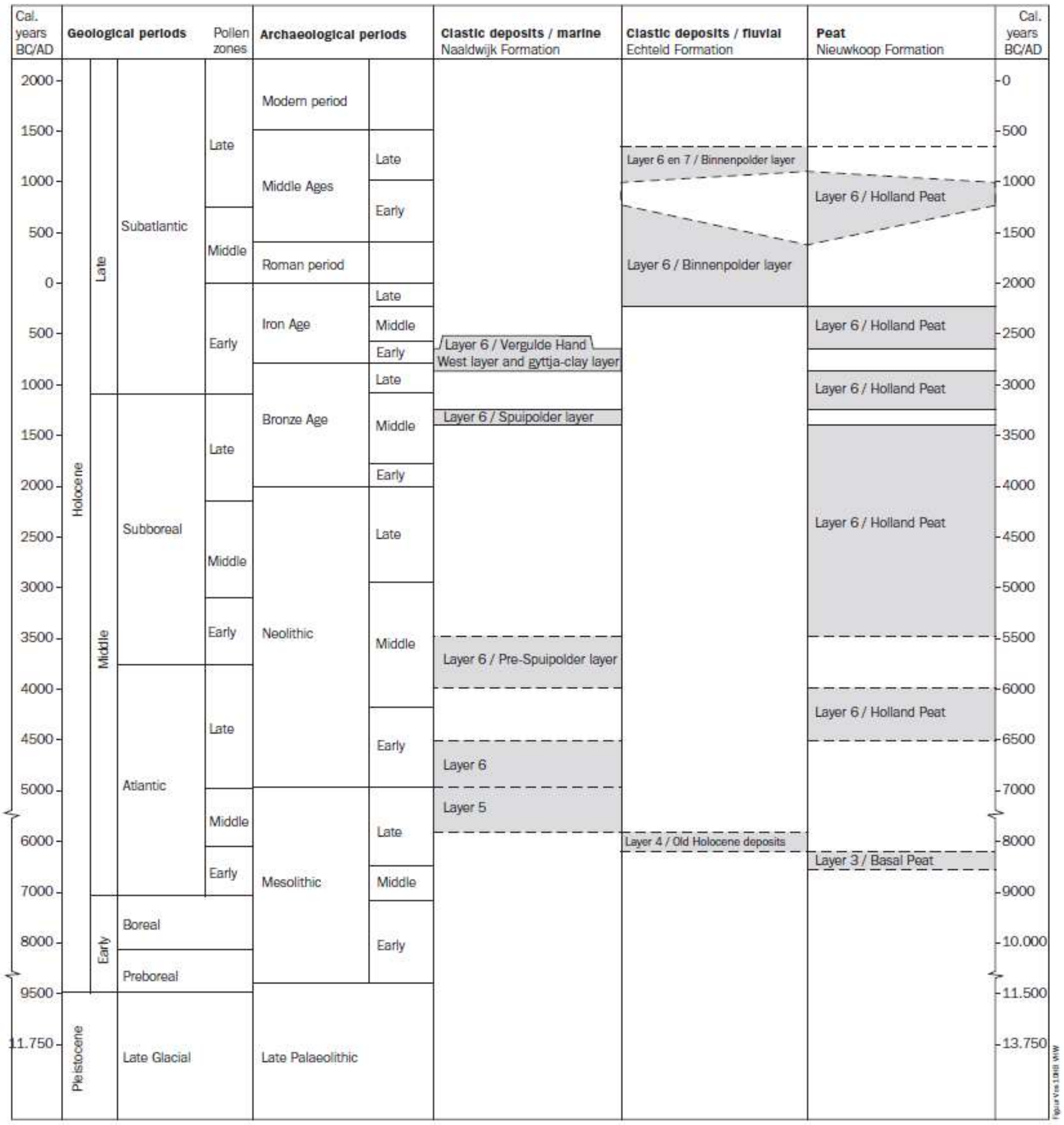


Figure 3N22: Geological and archaeological chronostratigraphical scheme of the Holocene with the regional lithostratigraphy in the area of the VHW (main layers 1 up to 7; see also Figure 3N23 and Figure 3N24).

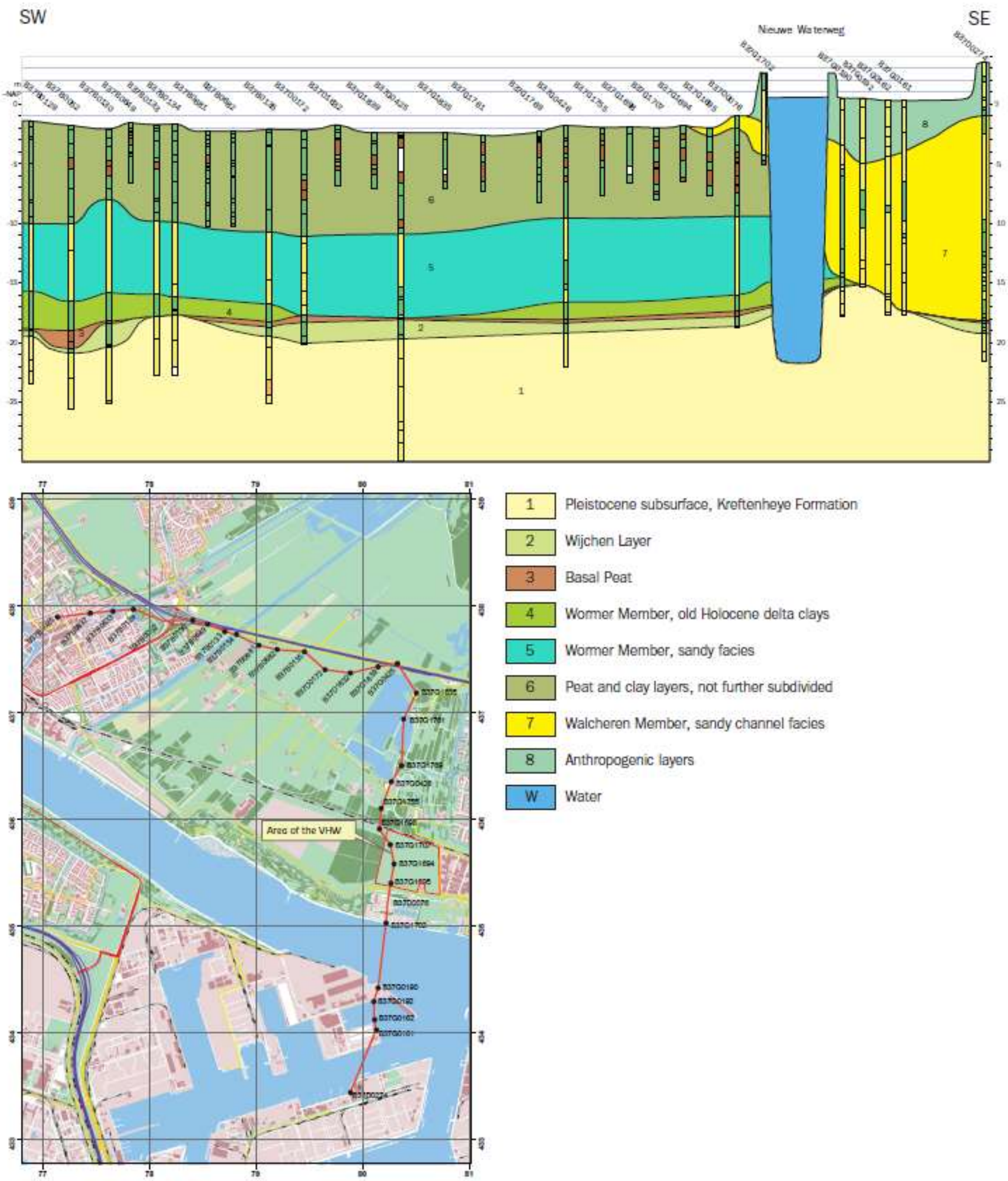


Figure 3N23: Location map and lithostratigraphic cross-section of the Holocene deposits of the VHW and surrounding area; for the chronostratigraphical classification of the layers, see Figure 3N22.

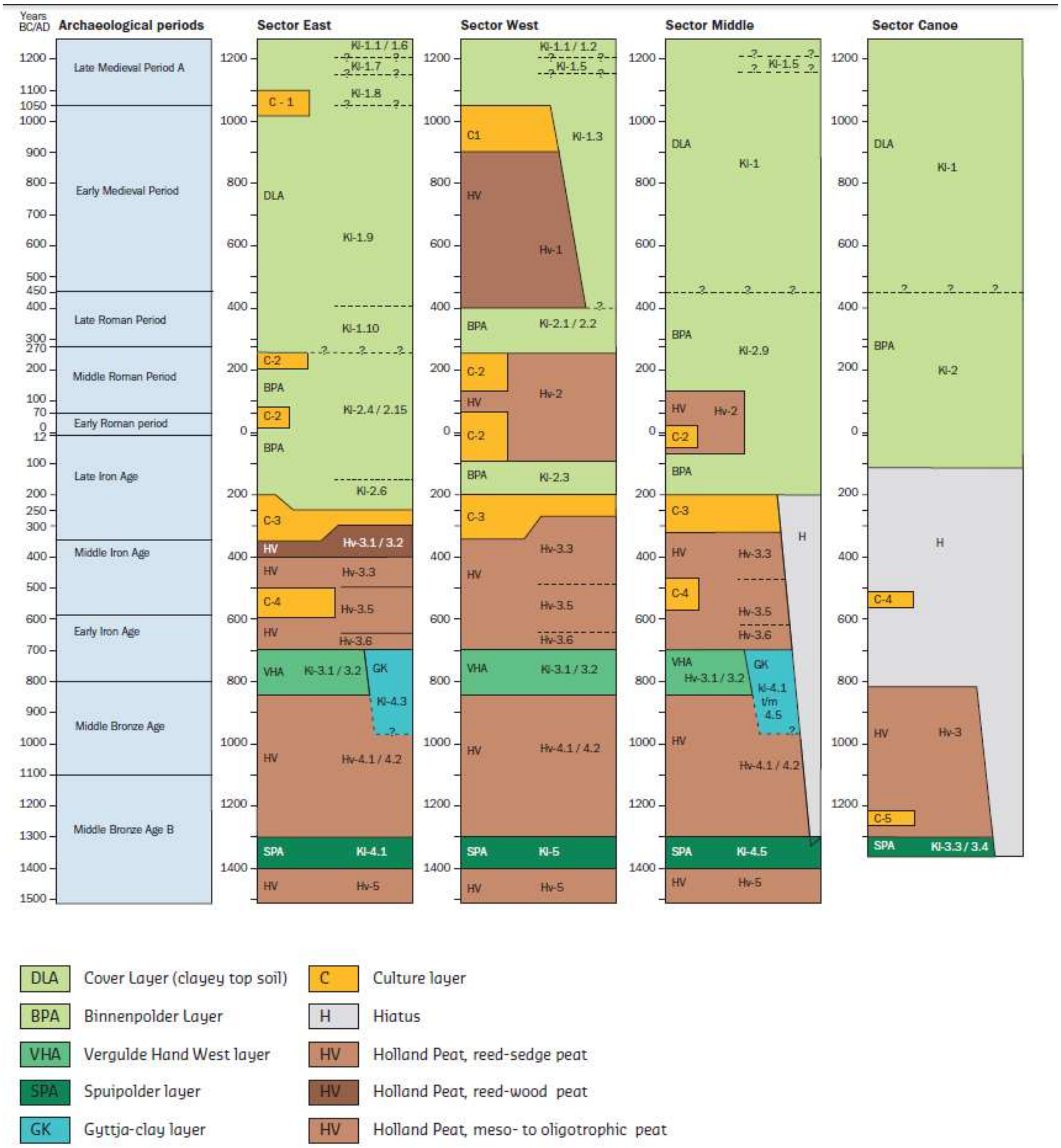


Figure 3N24: Stratigraphic scheme of the VHW location, in which the local lithological layers of the sectors East, West, Middle and Canoe are classified in time.

In order to be able to reconstruct the landscape evolution in detail for each sedimentation phase extensive multidisciplinary, palaeo-ecological research has been conducted on both the natural and the archaeological cultural layers. This research concerned pollen grains (pollen analysis), diatoms (silica algae), molluscs, botanical macro remains (larger plant litter; Vos and Eijskoot (2009)) and micromorphological research on sediment slices. In addition, from the archaeological cultural layers also mites, beetles and Chironomidae ("midges"), which provide information on the palaeoenvironment, were examined (Eijskoot et al., 2011).

The archaeological remains themselves also provide information about the palaeoenvironment. For instance, the presence of a Middle / Late Iron Age permanently inhabited settlement in a bog proves that this peat area was drained and the growth of peat had come to an end at that location. A constructed wood path of branches (Figure 3N20e) indicates that at the time when the path was used the peat was (periodically) swampy and difficult to access.

Holocene sequence or surroundings of the VHW
Holocene layer units which occur in the subsoil of the area around the Vergulde Hand West are shown in a geological overview profile of the site location and its immediate surroundings. From the profile (Figure 3N23)– based on 29 boreholes from the DINO database of Geological Survey of TNO Netherlands – it can be derived that the Pleistocene fluvial deposits, including the Layer of Wijchen, lie below a depth of approximately 18 m - NAP (layers 1 and 2). The Basal Peat and Early Holocene inundation clays lie at a depth of about 15–18 m - NAP (layers 3 and 4). These old Holocene deposits are covered with sandy, estuarine tidal deposits, which are counted among the Wormer Member (layer 5 in the overview profile). The top of the Wormer sands lies at a depth between 8 and 10 m - NAP. For the sediment facies of the older Holocene deposits in the area, see also the descriptions in the publication of the Blijdorp pit (Cohen and Hijma, 2008).

On top of the Wormer Member a sequence of clays and peat was formed (layer 6). These belong to the estuarine and fluvial delta deposits of the Rijn and Maas. In the profile of individual peat and clay, layers have not been stratigraphically subdivided any further because the sediment sequence at scale level of the profile is too complex. This is due among others to the presence of post-sedimentary deformations in the subsoil, such as the occurrence of *intrusion clays* (in Dutch: *oplichtingskleien* of *klapkleien*; in German *Klappkleis*; Behre (2005)) and local subsidence of clay soils in the peat by autocompaction

The Basal Peat in the surroundings area of the VHW has been dated to around 8500 cal. BP (Hijma et al., 2009); layer 3, at a depth of about 18 m - NAP). The basis of the clay–peat complex in the region has been dated between about 6500 and 7000 cal. BP (Hijma et al., 2009). Based on these datings the formation of the sandy tidal deposits (layer 5) has been placed in the Mid Atlantic (Figure 3N22). In the excavation pits of the VHW the peat–clay profile had been opened up to 1 to 2.5 m below ground level (approximately 2.5 to 4 m - NAP). The ages of the peat and clay layers exposed, have a time range that lies between the Mid Bronze Age and Late Middle Ages. At one particular location in sector East also deeper lying peat deposits from the Middle Neolithic have been sampled for age determination. This dated peat lay around 6 m - NAP and has been dated to about 5750 cal BP (GrA-34130 and GrA-33011, in Figure 3N25c).

Lithostratigraphy of the subsurface deposits of the VHW
The subsurface of the VHW *down* to a depth of 2.5 m – NAP, which had been exposed during the archaeological excavations, consisted of clay and peat layers. In the stratigraphic overview profile (Figure 3N23) all of these layers have been combined into a single layer, unit 6. Within the area of the VHW, these layers have been subdivided in further detail for the 4 sector areas (Figure 3N24 and 3NFigure 3N25). In the pictures of Figure 3N26 an impression is given of the litho-facies of the different stratigraphic layers.

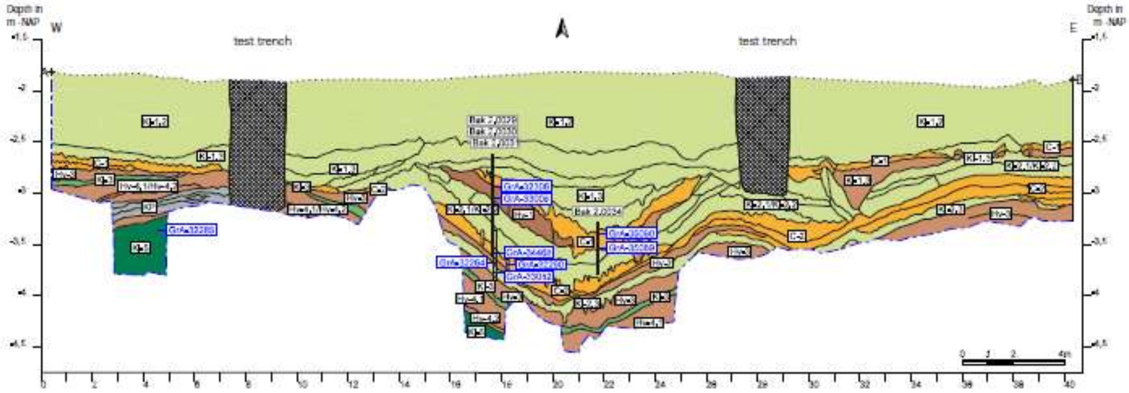


Fig. 8d. Geological profile 4

RD-/NAP coordinates (x-, y- and z-values)

A✦ 80,223/435,756, -1,80

✦B 80,273/435,748, -1,90

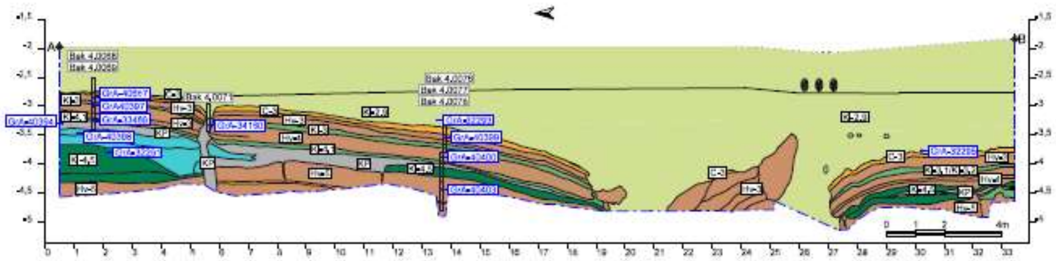


Fig. 8e. Geological profile 3

A✦ 80.346/435.695, -2,00

✦B 80.340/435.663, -1,85

^{14}C-dates of profile 8d

Groningen-code	BP	2σ date-range
GrA-35090	1150 ± 40	778-978 AD
GrA-35089	1380 ± 40	592-784 AD
GrA-32306	1820 ± 35	88-318 AD
GrA-33008	1705 ± 25	258-402 AD
GrA-34488	1950 ± 60	90 BC - 217 AD
GrA-32284	2095 ± 35	199-40 BC
GrA-32290	2035 ± 35	161 BC - 52 AD
GrA-33082	2180 ± 35	370-121 BC
GrA-32285	3080 ± 35	1420-1267 BC

^{14}C-dates of profile 8e

Groningen-code	BP	2σ date-range
GrA-34180	2145 ± 35	354-54 BC
GrA-32295	2215 ± 35	379-201 BC
GrA-32293	2240 ± 35	390-203 BC
GrA-40687	2250 ± 50	396-201 BC
GrA-40399	2255 ± 25	391-208 BC
GrA-40394	2255 ± 30	392-207 BC
GrA-33488	2500 ± 40	794-418 BC
GrA-40397	2540 ± 30	800-545 BC
GrA-40398	2630 ± 30	829-792 BC
GrA-40400	2915 ± 25	1203-1020 BC
GrA-32291	3080 ± 35	1420-1267 BC
GrA-40403	3410 ± 30	1880-1628 BC

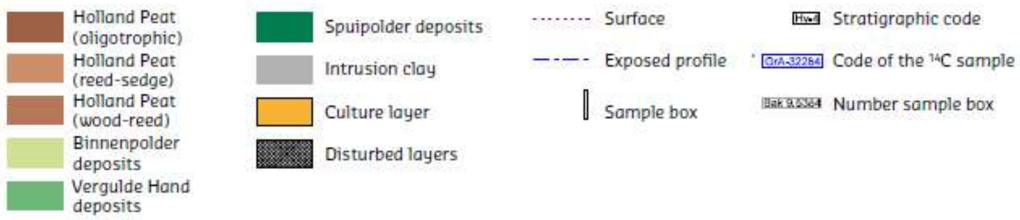


Figure 3N25: Lithostratigraphic cross-sections of the pit profiles of the sectors West, Middle and East. Figure 3N25a. Geological profile 1A in sector East; Figure 3N25b. Geological profile 2A and B in sector East; Figure 3N25c. Geological profile 1B in sector East; Figure 3N25d. Geological profile 4 in sector West; Figure 3N25e. Geological profile 3 in sector Middle. For the location of the profiles, see Figure 3N19; and explanation stratigraphic codes in the profiles, see Figure 3N24.

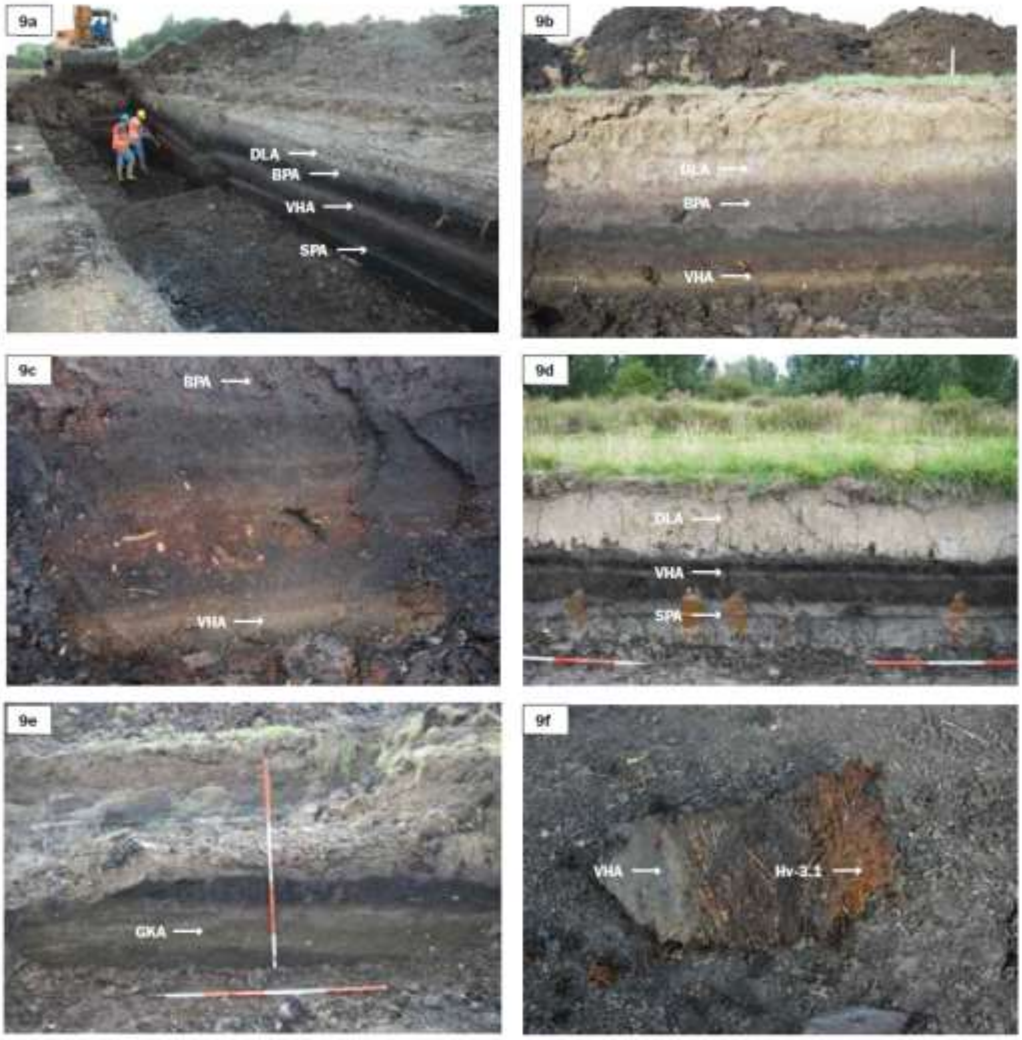


Figure 3N26: Pictures of the lithostratigraphical units exposed in the pit profiles of the VHW. See Figure 3N24 for the explanation of the stratigraphic codes of the sediment layers. Figure 3N26a. BPA, VHA and SPA layers embedded in peat, find location area Vz07 in sector East; Figure 3N26b. Peat layer (Hv-3) situated between the BPA and VHA layers, on top of the peat layer the Middle Iron Age soil disturbance is visible in the dark irregular layer (culture layer C3), find location area Vz07 in sector East; Figure 3N26c. Peat layer (Hv-3) situated between the BPA and VHA layers, in the peat layer - from the base to the top - the subunits Hv-3.6 (reed peat in a black matrix), Hv-3.5 (reed-sedge peat with alder wood), Hv-3.3 / C3 (dark brown mesotrophic peat, the top is disturbed by man) are exposed, find location area Vz08 in sector East; Figure 3N26d. BPA, VHA and SPA layers and intercalated peat layers (Hv-3 and 4), find location area Vz01 in sector West, in this sector the grey clay layer of the SPA unit relative thick. Figure 3N26e. Gyttja-clay deposits (GK) below the peat layer Hv-3, in find location area Vz06 in sector East. Figure 3N26f. Peat lump of the Hv-3 unit from a pit profile in find location area Vz09 in sector East, layers from left to right: VHA, HV-3.5/6 and Hv-3.3 (Sphagnum peat).

The estuarine deposits of the Rijn–Maas delta which were formed in a brackish to marine environment are counted among the Walcheren Member (part of the Formation of Naaldwijk). The fluvial delta deposits (river- and freshwater tidal deposits) are rated among the Formation of Echteld (Westerhof et al., 2003)). The distinction between the estuarine and fluvial deposits has been made on the basis of the presence of remains of trees in the river delta deposits. Here this concerns trunks, roots of wood and dispersed wood such as leaf matter (mainly 'alder swamp forest elements'). Another difference is that the fluvial delta deposits generally are richer in humus, and therefore more brownish in color. The estuarine clays consisted mainly of marsh deposits that were rooted by reed. All peat layers were counted among the Holland

Peat, which is part of the Formation of Nieuwkoop. Subsequently, at layer-level subunits were distinguished within these clastic and organic main units. These layers occur locally and for that reason have a stratigraphic significance only within the VHW site and immediate surroundings. The names of the clastic layer units (Binnenpolder-, Vergulde Hand-, Spuipolder deposits) have been derived from the topographical names from the surrounding area.

Within the investigated estuarine delta deposits of the VHW, two clastic layers have been distinguished:

1. Vergulde Hand deposits (VHA): Grey clays, usually strongly rooted by reed and slightly humic. The layer lies above the Spuipolder deposits and is separated from that layer by a layer of reed peat.
2. Spuipolder deposits (SPA): Grey clays similar to the Vergulde Hand deposits. These clays too are often rooted by reed.

The marine clastic layers under the Spuipolder layer (clay layer about 4 m below ground level) are called the pre-Spuipolder deposits. These deposits had been opened up only in sector East.

The fluvial clastic delta deposits consist of:
1. Gyttja-clay deposits (GK): Green-brown to grey-brown gyttja and strongly humic clays. These deposits contain much organic matter including detritus (fine and coarse), leaf litter and also wood. They are lake bottom sediments which occur only in sector Middle and the northwestern part of sector East.
2. Binnenpolder deposits (BPA): Grey to grey-brown clays, often humic to strongly humic, with wood and remains of roots of wood. Locally also reed fragments and roots of reed may occur in the clay. To the Binnenpolder deposits also belong the clays above the peat from the Mid- and the beginning of the Late Iron Age, which have been deposited in pools or depressions. Due to their very weight these clays have subsided into in the underlying peat layers (differential setting). Also the creek deposits, which were exposed in the profiles of the excavation pits of the sectors East, Middle and Canoe are counted among this layer unit.

The *intrusion clays (KP)* make a separate clastic layer unit because they have been deposited in cracks and fissures within the peat by buoyancy of the peat and therefore they are younger than the above- and underlying peat (Figure 3N27). The intrusion clays are associated with the first floods that marked the start of the deposition of the Binnenpolder layer. For that reason, the intrusion clays – in the peat – can observed as a part of the Binnenpolder layer.

Figure 3N27: Pictures of the intrusion clays in peat profiles of the VHW. Figure 3N27a. Horizontal view of a crack in the peat, filled in with intrusion clay, in find location area Vz07 in sector East. Figure 3N27b. Horizontal view of a crack in the peat filled in with intrusion clay, in find location area Vz07 in sector East. Figure 3N27c. xx; Vertical view of grey intrusion clays (Kp), through the HV-3, VHA and Hv-4 layers in find location area Vz07 in sector East. Figure 3N27d. Vertical view of grey intrusion clays (Kp), split up in several layers, through the HV-3, VHA and Hv-4 layers in find location area Vz07 in sector East (see also profile of Figure 3N25a). Figure 3N27e. Vertical view of grey intrusion clays (Kp), with the direct contact with the upper laying BPA layer, and breached out in the HV-3, VHA and Hv-4 layers, in find location area Vz04 in sector Middle (see also rofile of Fig 8a). Figure 3N27f. Peat blocks which are pushed against each other as a result of the floating of the peat in the period between 250 and 200 BC, in find location area Vz09 in sector East. Fig. 10f. Peat block which was drifted away during the floating of the peat between 250 and 200 BC and later filled in with intrusion clay (Kp) and Binnenpolder clay (BPA layer), in find location area Vz01 in sector West.

Also the *cover layer (DLA;* Figure 3N24*)* are a special unit because the characteristics of the unit are mainly determined by pedological processes and these processes alternate the oridional sediment structure. Therefore, the pedogenesis obscures the original geological features of the sediments in the cover layer. The DLA layer lies above the groundwater level and for that reason the clays have been oxidized and highly fragmented (crumbly because of many crimp- and swell cracks). Due to the oxidation the iron in the soil layer has a reddish brown color (rusty spots) and all (initially present) remains of plants have been decomposed. Originally peaty layers – and also the organic archaeological material – within the oxidation zone of the DLA layer have vanished completely. At the very most these organic levels in the covering layer are recognizable by the dark gray (humic) discoloration which resemble 'vegetation horizons'. Because of the differential subsidence and accretion of the layers, they are not lying on the same level everywhere. The relative high situated BPA and VHA layers may occur locally within the oxidation zone of the soil. In that case, these older clastic deposits cannot be distinguished - lithologically and stratigraphically - since the separating peat layer is missing. At those locations the older VHA clays are part of the DLA layer. Stratigraphically the DLA layer is counted as a part of the BPA layer because in terms of volume most of the sediment consists of fluvial / fresh water tidal deposits which belong to the Formation of Echteld.

In the stratigraphic table the clastic layers and intrusion layers are indicated by code Kl and Kp, respectively. In each sector, from top to bottom the layers have been assigned a serial number (Kl-1, 2 etc.) and each sublayer a second serial number. Thus, for example, a sublayer within the VHW layer in sector East, has been assigned a code Kl -3.2 (Figure 3N24). The various peat and cultural layers in the stratigraphic sequence are indicated by a code: Hv for peat layers and C for cultural layers. These layers too have been assigned serial numbers from top to bottom; for example, a peat layer in between the VHW and SPA layers in sector West has the code Hv -4.1 (Figure 3N24). It is emphasized that within the sectors the layer codes are not always synonymous. This is due to the fact that the assignments concerned a field coding where the peat layers were counted from top to bottom. In the sector Canoe, however, a peat layer was lacking. Therefore in this sector the numbering of the peat layer sequence differs from those in the sectors West, Middle and East, see Figure 3N24.

The peat in the subsoil of the VHW consisted generally of reed peat, reed peat with wood or brook peat consisting mainly of alder. Oligotrophic peat with a.o. heather twigs (*Ericaceae*) and peat moss (*Sphagnum*) has been found in sector East only (Hv 3.1 / 3.2).

In Figure 3N24 the lithostratigraphic layer units of the VHW have been placed in time on the basis of ^{14}C datings of the top and bottom of the peat layers and the archaeological datings of the cultural layers. The most important dates of the layers are shown in the pit profiles of the four sectors (see Figure 3N25; and references in Tables 3N1a–1d). The Pre-Spuipolder layer in sector East was formed about 3750 BC, the SPA layer between about 1400 and 1300 BC, the VHA layer between about 850 and 700 BC and the BPA was formed after about 225 BC. In the Roman Period and Early Middle Ages (400 – 1000 AD) peat formation occurred in the VHW area. Remnants of this peat have been preserved only in the sectors West and Middle because there parts of the peat are lying below the groundwater level. In the sectors East and Canoe the peat has vanished completely because there the peat had been raised to above the groundwater level and was therefore fully decomposed by oxidation. Remnants of this peat can only be recognized by the dark layer levels in the BPA layer.

Post-sedimentary layer deformations

During the geological investigation of the profile walls of the excavation pits in the four sectors it appeared that layers had been deformed after their deposition. Three post-sedimentary deformation processes can be distinguished:

- Formation or intrusion clays: fissuration in the peat because parts of the peat became buoyant / floating and therefore loose from the subsoil during periods of high water.

- Autocompaction: subsidence of peat layers in the subsurface as a result of (differential) gravitational forces of the covering clay layer.
- Peat oxidation, oxidation of the organic material of peaty deposits.

These three deformation processes changed the location and stratigraphic position of the layers, including the archaeological layers and features, in the shallow subsurface of the VHW. The causes of the deformation processes will be briefly discussed below.

Intrusion clays

In the natural depositional sequences, in general, younger sediments are found on top of the underlying older sediments. However, there are exceptions to this rule when the layers are displaced and turned around by large-scale tectonic movements. Also intrusion clays are an exception to the rule that younger deposits are found on top of older deposits because these clays are not formed on top but within a peat layer. An intrusion clay layer can be formed when a peat layer becomes submerged. Then the top of the peat layer can become buoyant and tear loose from the peat subsurface. The top of the peat can become buoyant when the gravity of the peat is lighter than the gravity overlying water. There are two reasons to explain why the top of the peat has a lower specific gravity than the flood water:

1. The flood water is salty and that is heavier than the fresh groundwater in the peat (Behre, 2005).
2. The top of the peat is drained and contains a lot of air which is encapsulated and does not escape immediately after flooding. The oxygen containing peat is similar to polystyrene (foam) which has big buoyancy.

At occasional high water levels that are higher than the surface of the peat, the relatively light top of the peat will not be submerged but become buoyant. Because of the upward force horizontal and vertical cracks are formed in the peat. Those parts of the peat that were torn loose will become buoyant peat islands at high tide. When the water levels are lowered the peat islands will subside and the peat will lie on the subsoil again. During the interim period between high and low tide intrusion clay was deposited under the peat island. When the flooding occurs frequently, the peat will go up and down and below the peat island a layer of intrusion clay of a few centimeters up to over a cm thick can be formed (Figure 3N27). The intrusion clay layers are characterized by sharp lower and upper limits and the lack of rooting. The clay is heavy and often layered on (flat) remnants of plants and on humus content. After the peat has lost its buoyancy and is no longer lifted up during floods, also the vertical peat cracks get filled with clay. This clay deposit is not layered.

In the area of VHW the intrusion clays in the peat were formed between 250 and 200 BC. Due to the archaeological finds that occurred in the top of the peat in sector East, the process of intrusion clay formation could be dated fairly accurately. On the basis of wiggle match datings it could be established that the latest farmhouse (Vz01 - G01) was occupied around 250 BC and must have been abandoned once and for all a decade later (Eijskoot et al., 2011).

It is very likely that man continued to live on the bog during the floating of the peat and the formation of the intrusion clay since a wood path of branches was built on top of a clay-filled fissure in the peat (Eijskoot et al., 2011). How long the occupation of the floating peat islands continued is unclear; it may have been a couple of years, but also a few decades. Because, due to the repeatedly going up and down, the peat continued to tear further, the living conditions became increasingly unfavorable. Also within the settlements and in the farm houses cracks filled with intrusion clay have been observed. An example is a settlement Vz03 - Ho04 which was pulled out of its joints by fissuring peat (Eijskoot et al., 2011).
Archaeological remains were deposited through the cracks and fissures in the intrusion layer under the peat surface. These remains concern settlement waste matter, a large amount of building wood and even a sheaf of flax, complete with seeds, capsules and stems. This sheaf

of flax indicates that in the period immediately before the cracking of the peat, arable farming was still practised in the area of the VHW. Another example of where cracks in the peat influenced the original deposition of archaeological remains is the location of the canoe. This canoe is found along a tidal creek in the peat marsh. By uplift and intrusion of the peat the canoe was carried from the creek side into the peat fissure (Eijskoot e.a., 2011; p. 403-410). For that reason the canoe, dated to the Early Iron Age, is younger than the below- and above-lying peat which was dated to the Bronze Age.

During the water-level changes the floating chunks of peat blocks went back and forth horizontally. In some places it has been observed that the peat chunks were pushed up against each other during high water periods (Figure 3N27) but also that they were dispersed and the resulting hole was filled with BPA clay (Figure 3N27). Around 200 BC the peat blocks lost their buoyancy permanently, probably because the oxygen content in the package had been reduced strongly.

In the situation of the VHW the greater specific gravity of the flood water will have played not more than a limited role in the buoyancy of the peat. The fact is, the intrusion clays and the overlying clays of the BPA layer were formed in a predominantly freshwater environment, causing the specific gravity of peat water to be close to that of the flood water. Probably humans played an important role in the aeration of the peat resulting from the drainage in the Middle / Late Iron Age. By digging trenches and connecting them to the natural drainage pattern on the south side of the VHW site, the peat area might have been drained. However, due to the strong compaction of the peat and later oxidation of parts of the peat, the expected shallow ditch-trench structures in the peat surface could not be demonstrated archaeologically. The fact that in the Iron Age farmhouses were built, indicates that during this occupation period the peat was drained and thus the peat soil must have contained oxygen at the time before the floods.

Autocompaction

After the peat surface had been flooded in the Late Iron Age and the BPA clay layer had been formed a different deformation process occurred: that of autocompaction (e.g. Long et al., 2006). When clay is deposited on a soft peat subsoil, the subsoil will subside as a result of the weights of the deposited clay and the overlying water column during the flooding. Most of the clay was deposited in the local depressions and along the edges of the natural creeks. Due to the low position more clay could be deposited in depressions and along the creeks as a result of which the subsidence due to the gravitational pressure there was enhanced (Figure 3N28a-d). Some depressions, particularly in sector East, were so deep that water remained in them. These ponds or small lakes still contained water at times when the higher lying surroundings fell dry. In one of these pools, a considerable amount of hand-made pottery was thrown in the 1st century AD (Van Heeringen, 2010). The process of autocompaction continued until the subsoil had settled sufficiently. The differential subsidence stopped therewith and in the next period the depression was filled up gradually.

Figure 3N28: Picture of differential subsidence of the BPA clay layer caused by autocompaction of the peat which was induced by gravitational forces during the clay deposition of the BPA layer. Figure 3N28a. Loading structure of the BPA clay. The Medieval peat (Hv-1), only found below the loading structure, is not affected by oxidation because the peat layer was come down below the groundwater level, in find location area Vz02 in sector West. Figure 3N28b. .Loading structure of the BPA clay on top of the Hv-3 peat layer. The BPA clays are the lateral deposits of a creek, in find location area Vz07 in sector East; Figure 3N28c. Loading structure of the BPA clay on top of the Hv-3 peat layer. The BPA cays are the lateral deposits of a creek, in find location area Vz09 in sector East. Figure 3N28d. Depression caused by loading of the BPA clay in the Hv-3 peat layer, in find location area Vz09 in sector East. Figure 3N28e. Subrecent loading of the BPA layer in the Hv-3 peat layer, after the removal of the central ground depot of the excavation in 2005, the maximum subsidence of the surface level was more than 1,5 m, in find location area Vz01 in sector West.

Peat oxidation

Peat decomposes or "oxidizes" when it is exposed to the air. This can also happen with peat layers in the soil which are lying above the local groundwater level are and where oxygen can penetrate through the cavities present in the soil. Thus, for a good preservation of peat (and other organic residues) a high water table is required. The rate of oxidation depends on the duration and the extent to which oxygen can penetrate into the soil. Due to anthropogenic draining, the oxidation of the peat surface already took place during the Middle and Late Iron Age, Early and Middle Roman period and in the Late Middle Ages. The oxidation (palaeo-soil formation) in the peat can be recognized by the dark brown to black colour, and the granular structure and amorphous characteristics of the peat. The remains of plants in the soil layers have been conserved less well.

Much more drastically than in prehistoric times was the oxidation that has taken place over the past few hundred years in the soil. Due to large-scale reclamations and lowering of the water levels in ditches and the associated lowering of groundwater levels the top of the peat surface – under the covering clay layer – has completely disappeared from the area of the VHW. In many places of the VHW the oxidation / reduction boundary in the soil has penetrated down to the level of the Iron Age. Relatively young peat layers – such as the Early Medieval peat layer – have been preserved only locally (Figure 3N28a), in those places where, due to differential subsidence, they have subsided to deeper levels in the soil. Also older peat layers (Iron Age) have vanished, if they were situated relatively high, and rose above the groundwater level. As a result, also many archaeological remains have decayed and / or passed down fragmentarily. The oxidation of the peat has – together with the subsidence of peat by drainage – led to a considerable drop in the level of the surface of the VHW area. Originally – before the medieval reclamations – the ground level lay more than 1m above NAP. In the time of the excavation campaign the surface of the area lay around 2 m - NAP. This means that the subsidence of the VHW site since the Middle Ages amounts to at least 3 m, and possibly 4 to 5 m.

3N.2.2 Yangtze Harbour

Fieldwork Aims

This part of the study presents the geogenetic approach to detect currently drowned archaeological sites in the transgressive palaeo-deltaic environment of the Holocene Rhine-Maas delta. A stepped and practical approach is advocated in which subsurface archeological predictions are based on geological mapping and palaeo-environmental reconstruction at the underwater location. The study area is located in the Maasvlakte harbour extension of the Port of Rotterdam, formerly a part of the North Sea. The dredging of a new harbour (Yangtzehaven) would disturb the subsurface to about -21 m below present mean sea level.

The stepped approach started with a desk study of existing data. During this phase, a first conceptual geological model was compiled, to indicate the depth of the geological layers which had the highest chance of finding late Palaeolithic / early Mesolithic artefacts. It defined the strategy of the investigations in the next phase, in which dredging was performed as part of the engineering work of the harbour, down to 17 m water depth. With the top layer of the younger sea sands removed, this improved the opportunities to survey the fluvial and deltaic layers of Mesolithic archaeological expectation exposed underwater.

A full-area site investigation was carried out using geophysics and corings. It allowed us to reconstruct the long-drowned former landscape, which included inland dune areas and local drainage systems that are regarded to have high archaeological potential as typical Mesolithic settling areas. Two such areas were selected for detailed investigation as part of the next phase. Again, but now at higher resolution, geophysics and corings were collected and palaeoenvironmental analysis performed, and the palaeolandscape model was detailed. Cores and large grab-samples from the selected inland dune area yielded the first in-situ evidence of early to middle Mesolithic occupation of this Early Holocene wetland region in the Netherlands and southern North Sea. Besides the roles in the prospection and sampling strategy leading to the discovery of the site - elaborated in the case study report - the palaeo-landscape context provided by the stepwise geogenetic approach is also of scientific value in the archaeological interpretation.

Methodology

The archaeological potential of the continental shelf has been recognized for a long time. Driven by large fluctuations in sea-level, palaeo-landscapes with prehistoric coastal archaeological sites are now submerged. Compared to land campaigns, underwater investigations are relatively challenging in terms of costs, failure risks and data uncertainties (Bailey, 2004). An underwater archaeological study will thus be carried out with substantially less sampling than an equivalent terrestrial study. Palaeogeographical reconstruction, i.e. the creation of 'paleo-landscape models' based on combined geological mapping, dating and palaeo-environmental research, is an essential method to determine areas with high archaeological potential, especially in tectonically subsiding areas that experienced sea level rise, such as the North Sea. Furthermore, the palaeo-landscape models are essential to place archaeological finds in their environmental context when discovered.

Site investigation with multiple techniques is key to the construction of palaeo-landscape models. Geophysical methods are commonly applied in offshore environments (e.g. Gaffney et al., 2007). Correlation of geophysical data with more rarely obtainable in-situ data such as corings, allows for the identification of relevant layers in the geophysical data. By constructing the palaeo-landscape models that combine Holocene sea-level rise data with palaeo-surface elevations and environmental conditions, the human settlement locations and trekking patterns can be understood (e.g.Dolukhanov et al., 2010; Veski et al., 2005). With such knowledge the archaeological potential of an area can be charted (archaeological prediction maps). Archaeological prospection and heritage management efforts can then be focused on the areas with the highest chance of finding archaeological objects; enabling systematic, efficient prospection of large areas and maximized recovery of archaeology.

This part of the study presents the outcomes of the design of an innovative, stepped method to predictive underwater mapping for the Yangtze harbour area (Port of Rotterdam). In describing not only the method but also the paleolandscape results, this case study report succeeds the earlier Vos et al. (2012) short publication. Understanding the geological sequence of the subsurface is the foundation of the approach. Importantly, the geogenetic approach addresses archaeological prospection at the level of these lithological units that together comprise the subsurface (Vos and Bazelmans, 2002). For each type of lithological layer that could be encountered, a palaeo-environmental assessment was made and the change in finding archaeology in these units elaborated.

To connect the Maasvlakte 2 new seaward harbour extension of the Port of Rotterdam (The Netherlands; Figure 3N29), to the existing Maasvlakte 1 area, the Yangtze harbour was extended and deepened. The Maasvlakte 1 area was built in the 1970s and early 1980ies. Maasvlakte 2 is the latest enlargement of the Port of Rotterdam, one of the largest and busiest harbours globally. The final cut-through occurred in 2012 (Figure 3N30).

Figure 3N29: Location of the Yangtze harbour within the Maasvlakte area (Port of Rotterdam, the Netherlands).

Figure 3N30: Aerial view of the Yangtze harbour aer the cut-through of ther hatbour between Maastvlakte 1 and 2 in 2013 (Foto's Port of Rotterdam).

Previous research in the Maasvlakte 1 area had shown that fluvial deposits of Pleistocene age in the area in places contained Stone Age archaeology. Palaeolithic and Mesolithic discoveries were found in dredged sand on the beach of the Maasvlakte 1 area in the 1970s and 1980s (Louwe Kooijmans, 1975; Louwe Kooijmans, 2005; Verhart, 1988; Verhart, 2005) The then dredged sands were mainly Late Pleistocene and Early Holocene fluvial deposits, originating from dredged harbours and offshore locations in the direct surrounding of the Maasvlakte and came from a depth of about 20 to 40 m –NAP (e.g. Hijma et al., 2012).

The area of investigation of the Yangtze harbour, the study area, is given in Figure 3N31 and Figure 3N32. As the geological framework in the approach, a lithological-geological layer model of the study area was constructed. Besides new collected data for this archaeological project, the layer model incorporated the site investigation and engineering data collected for the larger Maasvlakte 2 project, and archived data from earlier projects. The sedimentary environmental conditions represented by the various lithological units (lithofacies) were logged, mapped and described. Subsequently, an assessment was made of the time period in which each of the lithofacies was formed, based on regional insight in sea-level rise (e.g. Hijma & Cohen, 2010). With this information, a paleolandscape model was made, in which the archeologically most promising locations could be highlighted and next steps of surveying strategy could be determined.

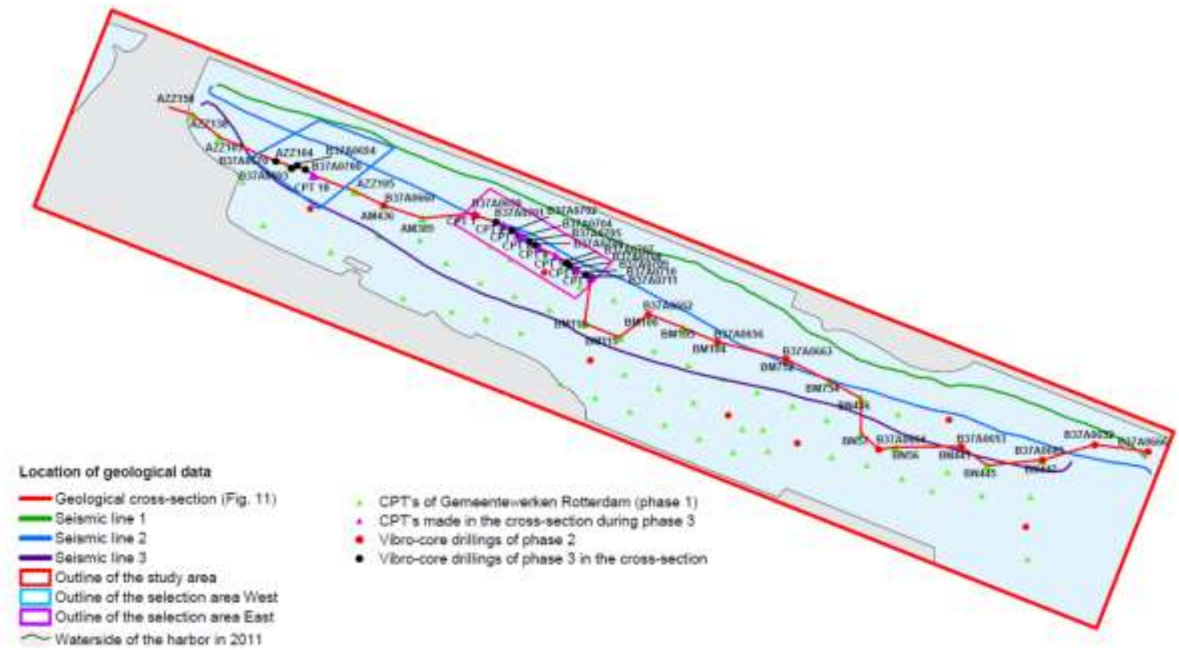


Figure 3N31: Location map of the Yangtze harbour study area.

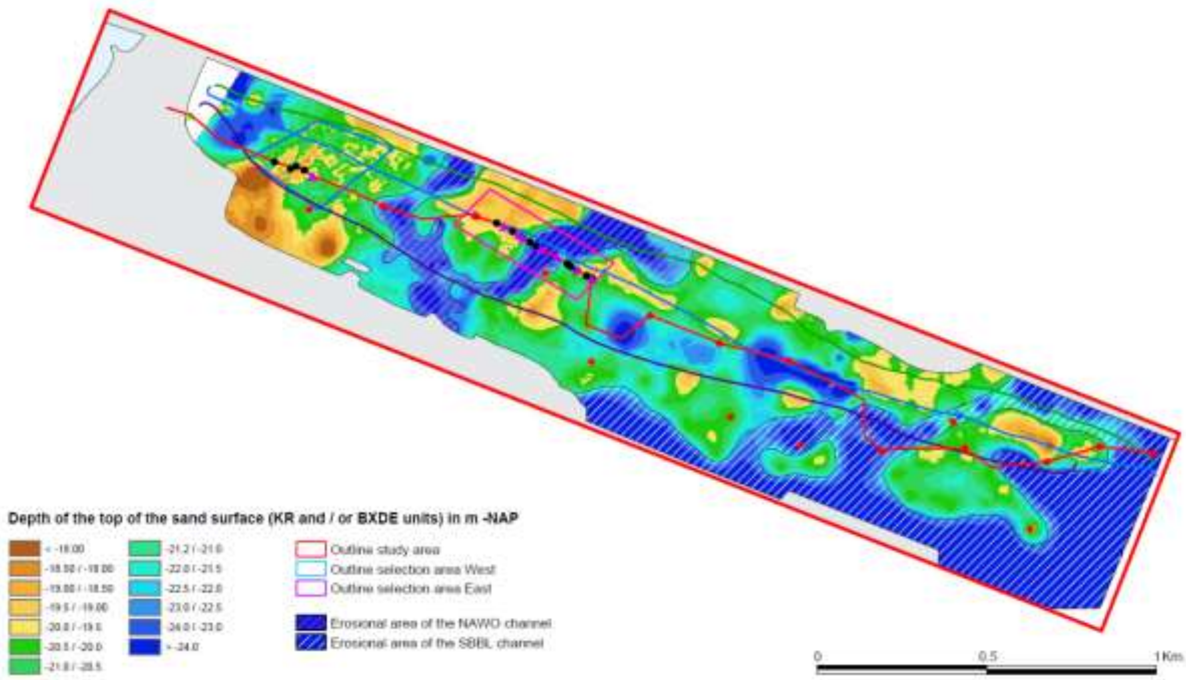


Figure 3N32 Map of the top of Late Pleistocene / early Holocene sand surface (top of the KR and BXDE units) of the Yangtze harbour study area.

For each lithological layer in the geological model, the archaeological expectation is evaluated and the likelihood of finding artefacts mentioned on the base on the palaeo-environmental conditions during and after the deposition of the sediment layer. The top of the Pleistocene substrate, from earlier studies was expected at about 20 to 22 m –NAP and to mark a buried valley floor of the end of the Last Glacial (Staalduinen, 1979), with inland aeolian dunes forming local highs (Hijma et al., 2009). These ‘river dunes’ are considered to be particularly promising as Mesolithic and Early Neolithic settling locations in past times of wetland environment (e.g. Louwe Kooijmans, 1980; Louwe Kooijmans, 1985; Louwe Kooijmans, 2005).

In the absence of direct dating, the age-model for the top of the fluvial sand included information on terrace stratigraphy (subtle elevation differences; lower is younger) and style of aeolian cover (sheet of coversand is older, isolated dunes is younger). Depth and thickness of floodplain overbank facies also gives age information. These sandy sediments are covered by deltaic peat and clay layers, from drowned Holocene landscapes. Their age-model includes information on post-glacial sea-level rise. These deposits are part of a transgressive sequence that culminated in the Rhine-Maas delta in the Middle and Late Holocene (landward shifting of the landscape zones depicted in Figure 3N33). This buried the valley landscape with the dunes that had persisted in the first millennia of the Holocene.

Over large areas of the harbour floor, an Early Holocene drowned landscape lies preserved from this time. At the time of the transition of the Boreal to the Atlantic (about 7000 BC) the study area still had fluvial landscape (conceptual model in Figure 3N34; analogue modern environment in Figure 3N35), with swampy floodbasins that received freshwater discharge from main channels of the Rhine and Maas river system (Hijma et al., 2009; Hijma & Cohen, 2011) and a river mouth to be found in further offshore areas downstream (Hijma et al., 2012; Sturt et al., 2013). In this landscape, local channel systems in the floodplain are assigned a higher likelihood to the presence of archaeology because it was assumed that humans would move through these waterways and would settle along the edges of these watercourses. Above this sequence, at a depth of about 17 m –NAP, former seafloor marine sands occur. Associated marine tidal channel structures have locally eroded the older sequence, and these zones were regarded of low stone-age archaeological priority.

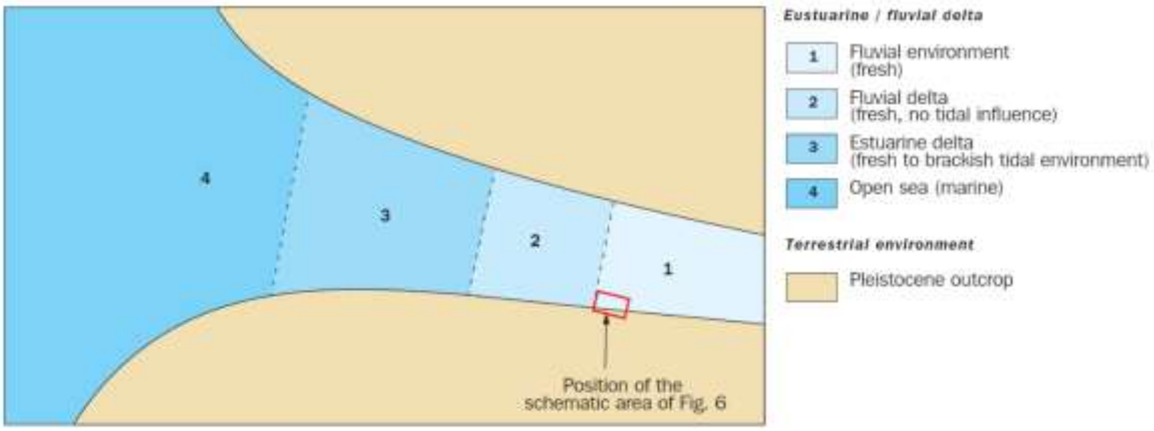


Figure 3N33: Schematic classification of the main landscape types within a funnel shaped river mouth. The position of the Yangtze harbour around 7000 BC in this schematic area is shown with a box (box in Figure 3N32).

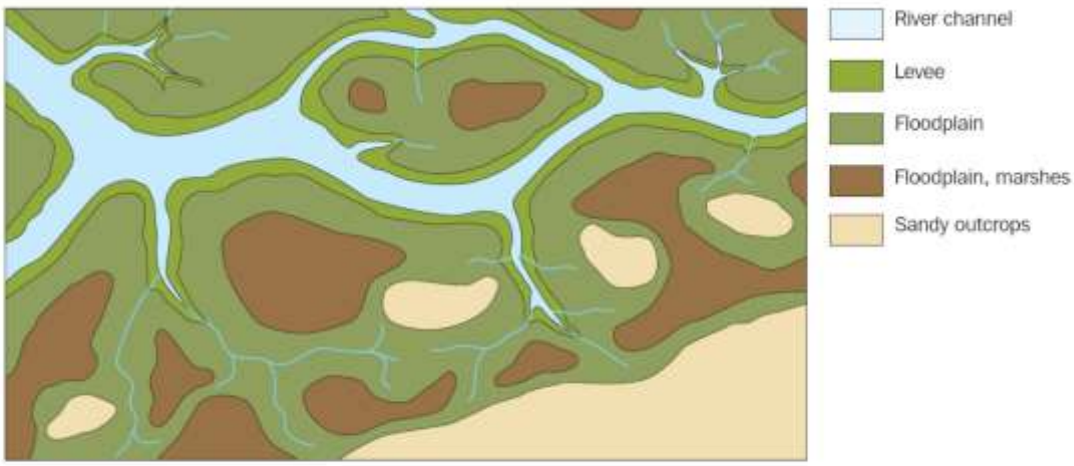


Figure 3N34: Schematic representation of the sedimentary environments in the Yangtze harbour area around 7000 BC.

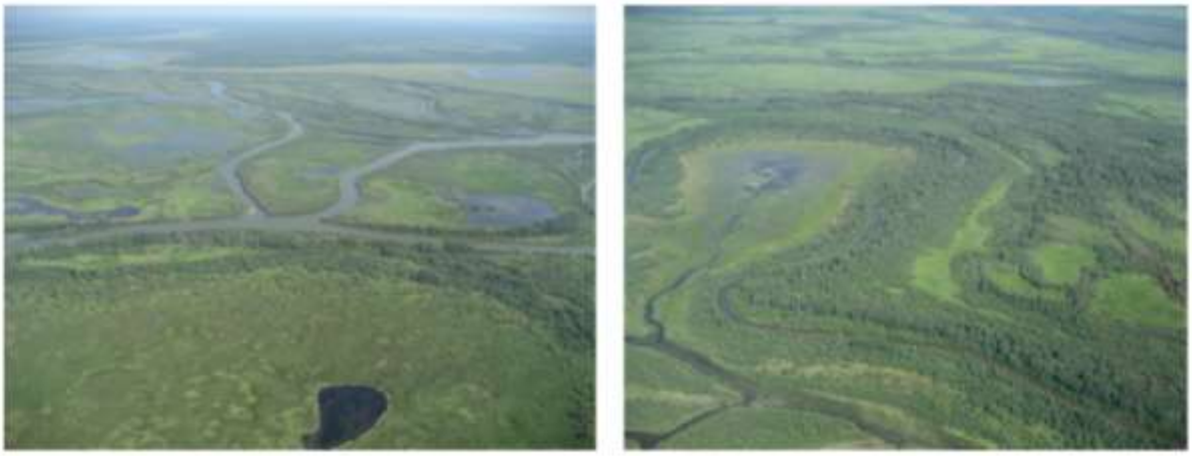


Figure 3N35: Contemporary airial view of the Cumberland Marshes in Canada, a representative picture of the landscape of the Yangtze harbour around 7000 BC.

The methodology used can be divided into four phases:

Phase 1: Desk study, intake and preparation existing geological data.
Antropogenic young overburden dredged away.
Survey design Phase 2

Phase 2: Implementation of the inventory field survey (survey and coring),
Reporting and analysis of the paleolandscape data
Decision on selection areas to densify the survey Phase 3

Phase 3: Detailed investigation in two selected areas (survey and coring),
Reporting and analysis of the paleolandscape data
Decision for archaeological excavation
Determining the locations for excavation

Phase 4: Execution of archaeological excavation (using a crane from a pontoon)
Completion of reporting paleolandscape results.
Integration of paleolandscape results with archeological results

Phase 1: Desktop study

The prospective investigation of the study area was a multi-phase research to trace the different depositional environments at a depth of 17 – 22 m –NAP and select the most promising archaeological locations for excavation (Vos et al., 2012; Figure 3N36):

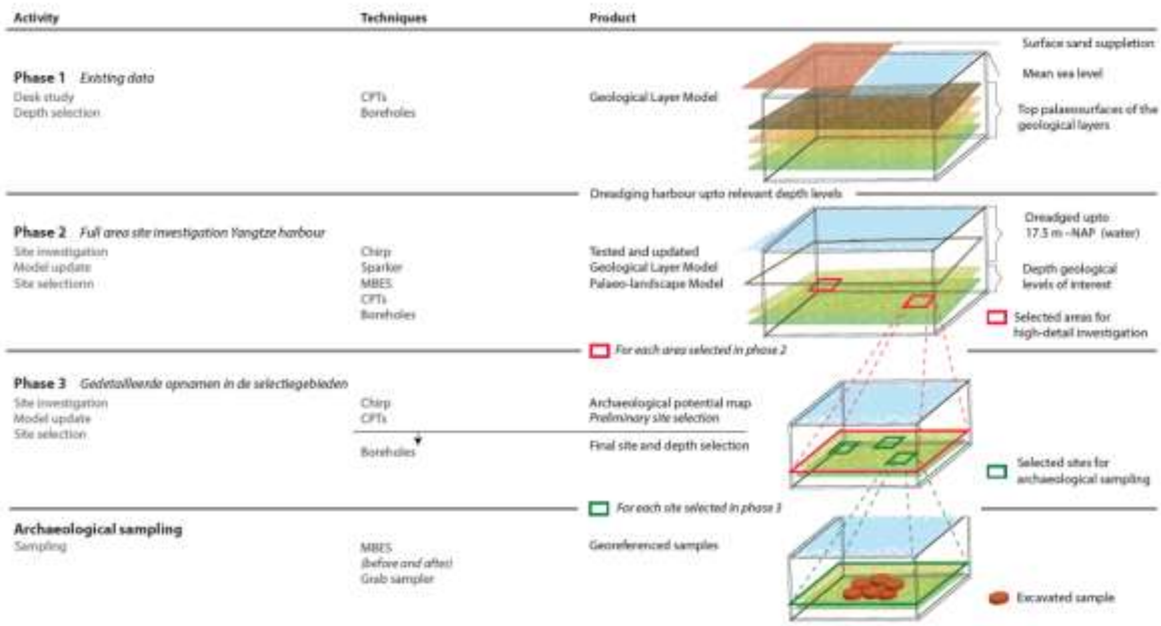


Figure 3N36: Geogenetic, stepped approach applied in the prospection study of the Yangtze harbour. For each phase, the activities carried out, the techniques used products delivered are mentioned.

In the first phase an estimate was made of the most likely depth of possible archaeological remains. Using existing data from CPTs and boreholes made for the construction of the harbour (by *Gemeentewerken Rotterdam*), a preliminary geological model of the study area was built. At this stage (2007), the surface area of the plan was still about 5 m +NAP. For the study area 133 CPTs were available (Figure 3N31 and Figure 3N32), of which eight were coupled to boreholes. Most of the CPTs penetrated down to the Pleistocene substrate, thus including the relevant layers. The cone resistance and friction parameters obtained with the CPTs were translated to lithological units (using correlation with boreholes) and subsequently grouped into a geological model. In the model, the palaeosurfaces of the top of the Pleistocene sand and the top of the deltaic deposits were interpolated between data points (using Kriging techniques) and manually adjusted for inconsistencies.

The surfaces in the palaeolandscape model of phase-1 represents the interfaces between different geological formations. As such, the model serves to draw the first hypotheses to localize the higher sand outcrops, the fluvio-deltaic environment and the complex or (Subatlantic) tidal channel incisions. This palaeo-landscape model was used to make the first rough estimate of the depth levels associated with the highest archaeological potential and to make a plan for the next step in the research, the fieldwork of the full site investigation of the study area.

Phase 2: In site investigations

Geophysical site investigation was carried out using an Edgetech X-Star Chirp Sub Bottom Profiler and a Geo-resources Sparker system. Position information was provided by a DGPS system. Both surveys were carried out at a speed of 2–3 knots. Shortly after the site investigation, a multibeam survey (MBES) was performed to accurately determine the bathymetry of the full Yangtze harbour. Seventeen boreholes were drilled from the seabed using a Vibrocore system, with a sampling core length of 5 m. As the Early Holocene clay deposits were very stiff, the core experienced high friction, yielding 2.2–4.5 m recovered sample length. From all the cores photographs were taken in the laboratory (Figure 3N37).

Figure 3N37: Image of the Yangtze harbour cores in sediment description laboratory of Deltares / TNO in Utrecht.

In the part of the harbour which had been dredged down to 17 m deep, three large west–east running lines of direction have been sailed (seismic lines 1 to 3, Figure 3N31 and Figure 3N32) which have been recorded using the above-mentioned seismic systems Chirp and Sparker. The records showed good results. The palaeosurfaces of the top of the Pleistocene fluvial sand (including the river dune sands) and the top of the organic and clayey delta deposits were clearly visible on the seismic reflection images. Also the tidal channel incisions were easy to recognize on these images and on the base of this the spatial distribution pattern of the palaeo-tidal channels could be reconstructed. In the western part of the study area a palaeo-dune topography was visible on the seismic profiles. These dunes had not been recognized as such in the CPT data used in phase 1. The reason was that the cones resistance was relatively low and variable. In phase 1 these sands were interpreted – wrongly - as a gully facies. Seventeen vibrocores were taken to yield high-quality information on the sedimentary characteristics of the lithological layers of interest between 17 and 22 m –NAP .

With the phase-2 results the geogenetic paleolandscape model was reiterated and improved. At this stage, three palaeosurfaces were modelled: the top of the sand surface (top of KR and BXDE unit), the top of the peat and clay layers (top of the combined unit of KRWY, NIBA, EC and NAWO) and the seafloor elevation in the harbour at the time of survey (spring 2011). The palaeosurface of the top of the sand surface of the study area was the main layer from the archaeological expectation point of view. This surface, generated from the 3D model, is depicted in Figure 3N32. In the western part of the study area a higher river dune area (elevation higher than 20 m –NAP; yellow-brownish colour) can be recognized and in the middle and south-eastern parts tidal channel incisions. The vibrocore data pointed out that the fill of the middle palaeochannel consisted of NAWO deposits and the south-eastern channel fills of SBBL deposits.

The sedimentary sequence of the harbour floor in 2011 is shown in a geological west–east cross-section. For the location of the used drilling- and probe data in the geological profile, see Figure 3N38. The top of the sand surface (KR and BXDE sand) ranges from circa 27.5 m –NAP within the eroded parts to 18.5 m –NAP at the highest parts of the river dune. The west–east channel incision in the middle part of the profile dates from the Atlantic (NAWO layer: green colour) and the channels in the eastern part from the Subatlantic (SBBL layer: yellow colour). The latter category is much sandier and has a larger grain size than the NAWO channel deposits which are laminated with fine sands and thin clay layers.

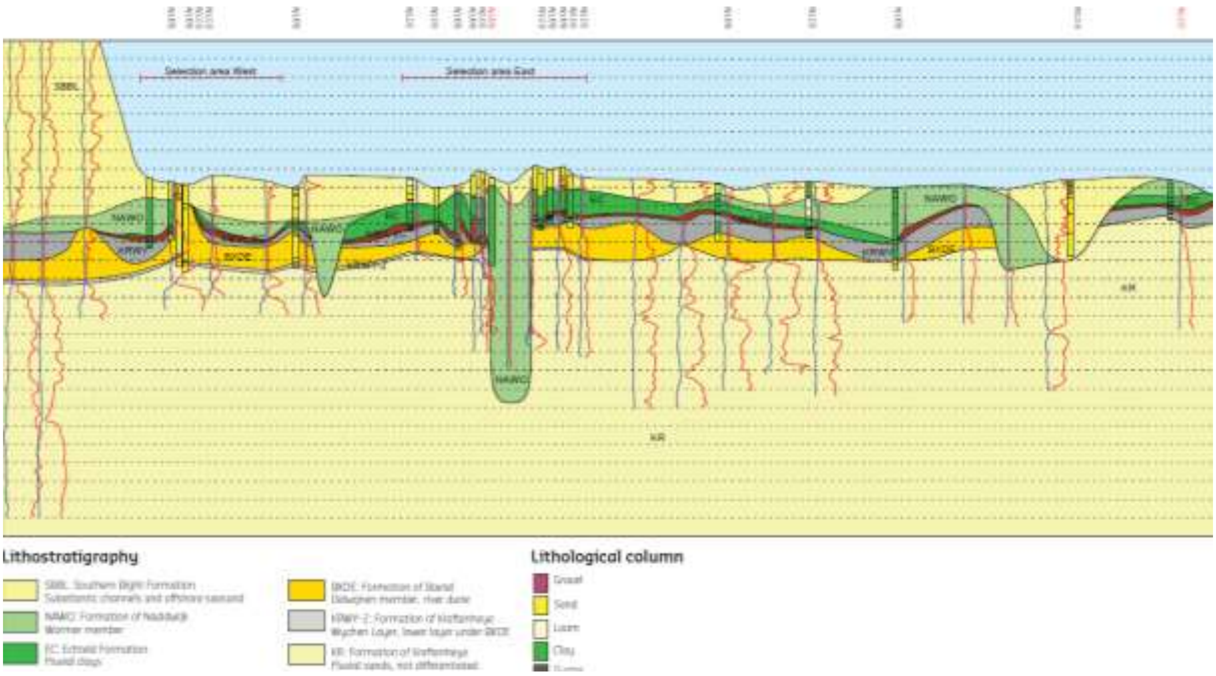
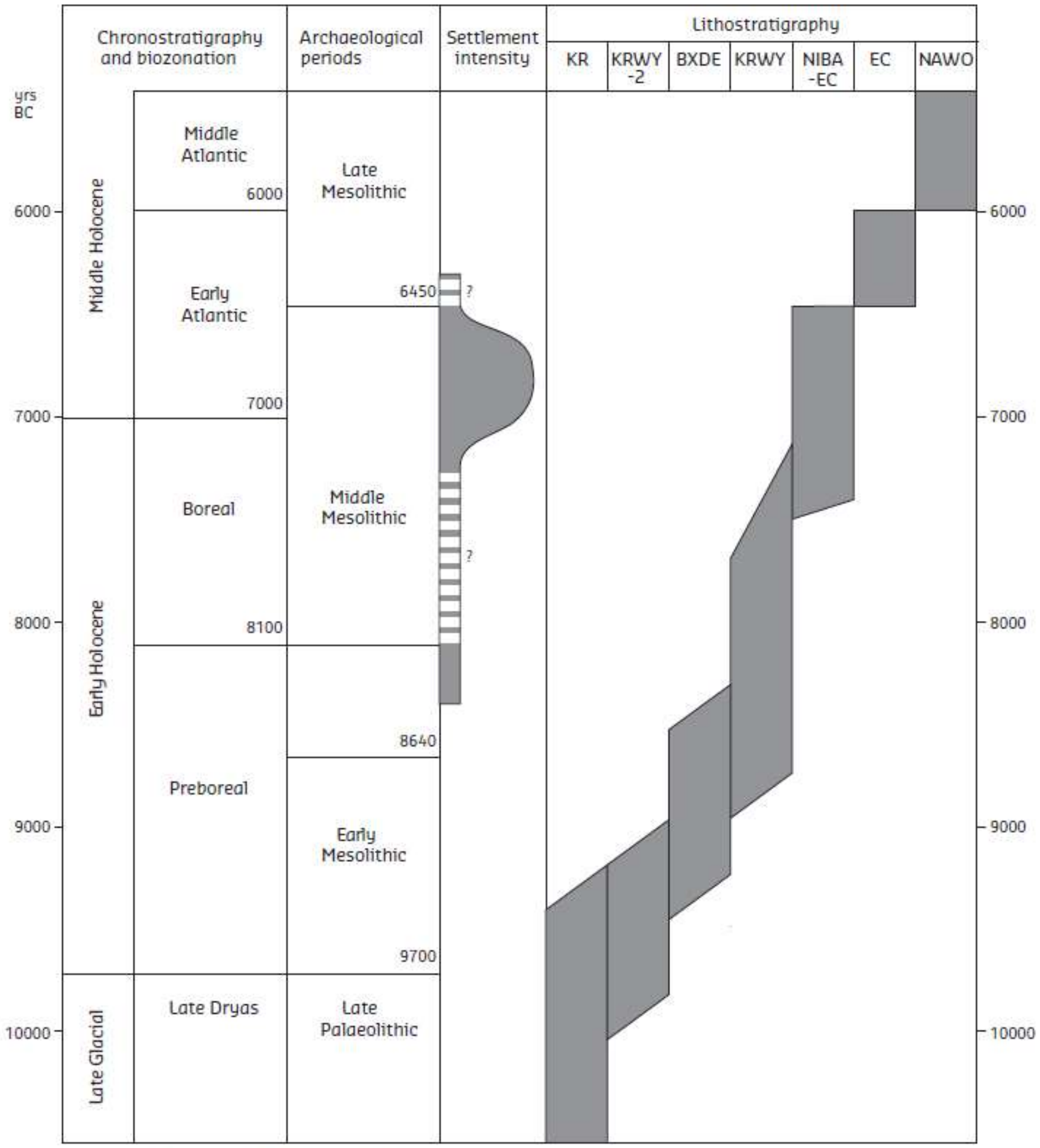


Figure 3N38: Geological west – east cross-section through the Late Pleistocene / early Holocene deposits of the study area. Location profile, see Figure 3N31 and3N Figure 3N32.

To obtain direct age-estimates for the lithostratigraphical units as encountered in the study area itself, a suite of radiocarbon (^{14}C) and optic stimulated luminescence (OSL) samples were obtained from the cores. Samples have also been taken from core material from the selection areas, collected during phase 3 (W and O sample codes). The ^{14}C-dating has been carried out by laboratories in Põznan (Poland; Poz nrs.) and Groningen (Netherlands; GrN nrs.) and are from organics in the KRWY, NIBA, and EC layers. The OSL dating has been carried out by the Netherlands Centre for Luminescence dating (NCL) in Delft (nowadays relocated to Wageningen), from river dune sands (BXDE).

By the end of Phase 2, a first batch of ^{14}C datings had returned from the lab, of use for planning Phase 3 and Phase 4 activities. In this case study report, we present the set in and age-attributions to the site lithological stratigraphy only in its final form (Figure 3N39).



KR: Fluvial sands of the Kreftenheye Formation
KRWY-2: Floodplain clayes of the lower Wijchen Layer
BXDE: Rivierdune sands of the Boxtel Formation
KRWY: Floodplain clayes of the (upper) Wijchen Layer
NIBA-EC: Basal peat, of the Nieuwkoop Formation, often clayey
EC: Deltaic deposits of the Echteld Formation
NAWO: Estuarine deltaic deposits of the Wormer Member

Figure 3N39: Stratigraphic table of the Early Holocene, with the time stratification of the lithological units of the study area.

Phase 3 and 4: High detail site investigation in selected areas

Selecting features for detailed archeological prospection

When the first Phase-2 radiocarbon dates had returned from the lab, and with the first cores scanned on palynological content and palaeo-environmental context, two selection areas (‘East’ and ‘West’; Figure 3N31 and Figure 3N32) were chosen to be subject of detailed geoarcheological research in Phase 3. The feature of most interest in Area East were the banks of a suspected palaeochannel, as Mesolithic humans might have settled here, using the channels for transport through backswamp area between the dry hinterland and the active river channel, in seasons most suitable for hunting and gathering in these respective environments. The feature of most interest in Area West was an inland dune complex. Inland dunes from areas further inland are known to be rich Mesolithic sites, and seem to have offered optimal places to settle because of the relative elevation of the dune above surrounding river plain wetlands.

Phase 3: High-resolution geophysics and dense coring

Areas East and West were subjected to further high-detail site investigation. At these locations high-detail geophysical surveys with a Chirp system were carried out and CPT measurements were made. The seismic lines in the selection areas were measured with an in-between distance of approximately 50 m, both in the longitudinal and the transverse direction (Figure 3N40 and Figure 3N41). Based on the initial results from this geophysical investigation supplementary borehole locations were chosen. Boreholes were again carried out with a Vibrocore system, yielding recovered samples of 2.3–5.0 m in length. For Area East this concerned 21 holes and for Area West 31 holes.

In Figure 3N42, the Chirp data set for Area East is shown together with the CPT and borehole data on the seismic line 38. This information forms the base of the geological profile of Figure 3N40. The incision of the channel structure is clearly visible.

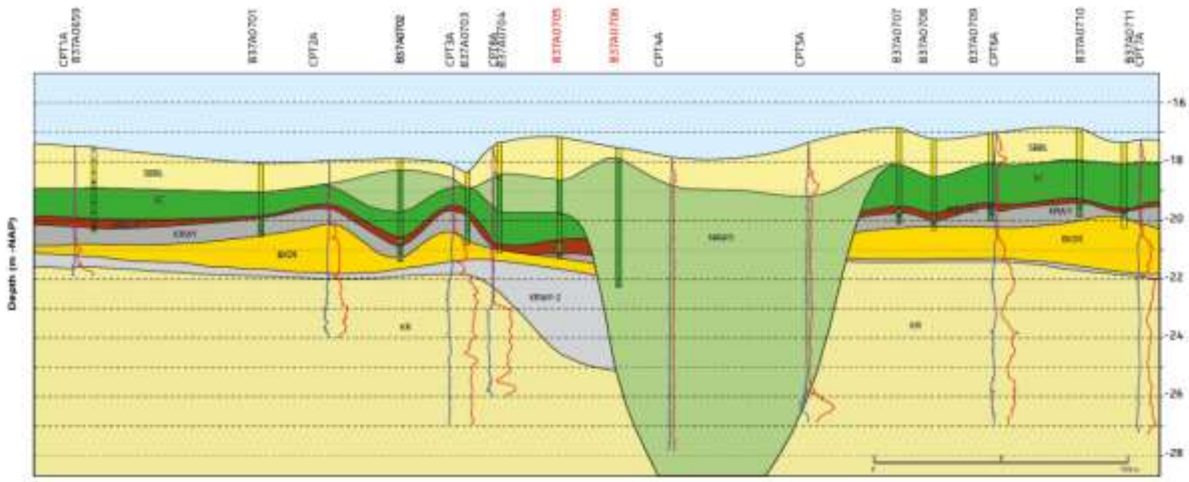


Figure 3N40: East-west cross-section of selection area East, geological interpretation based on the data presented in Figure 3N42. Legenda see Figure 3N38.

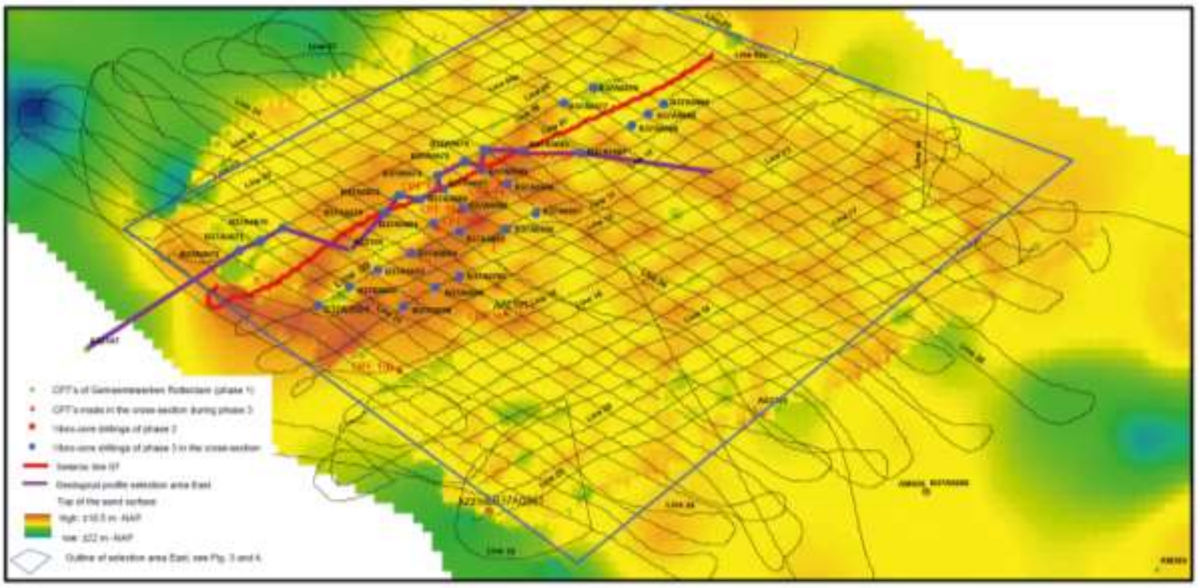


Figure 3N41: Map of the top sand surface of the Late Pleistocene / early Holocene deposits of selection area West (top of the KR and BXDE units) with the location of the boreholes and seismic lines.

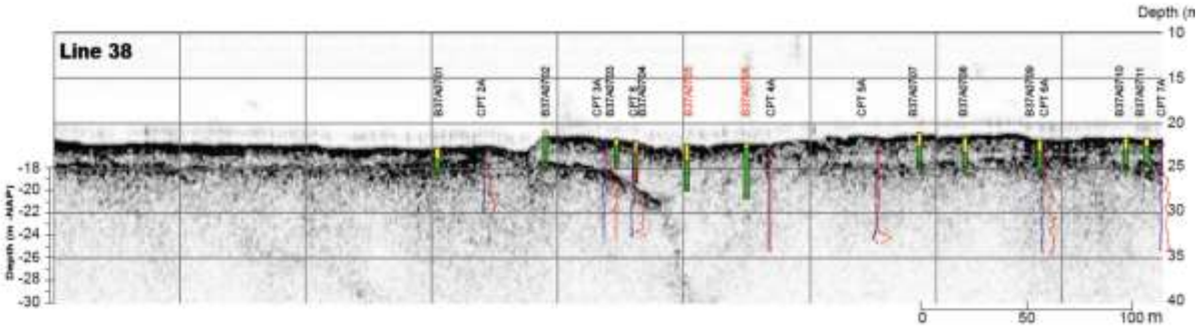


Figure 3N42: Results of the seismic survey of line 38 of selection area East, including CPT and bore hole data.

In Figure 3N43, Chirp data for Area West is shown together with the CPT and borehole data on the seismic line 07. The seismic reflections show a ‘’camel back’’ dune structure. The depression in between the two dune ridges (borehole B37A0680) is filled in with peat (NIBA) and clayey deposits (EC and NAWO). The geological sequence of the ‘’camel ridge’’ dune structure is depicted in Figure 3N44.

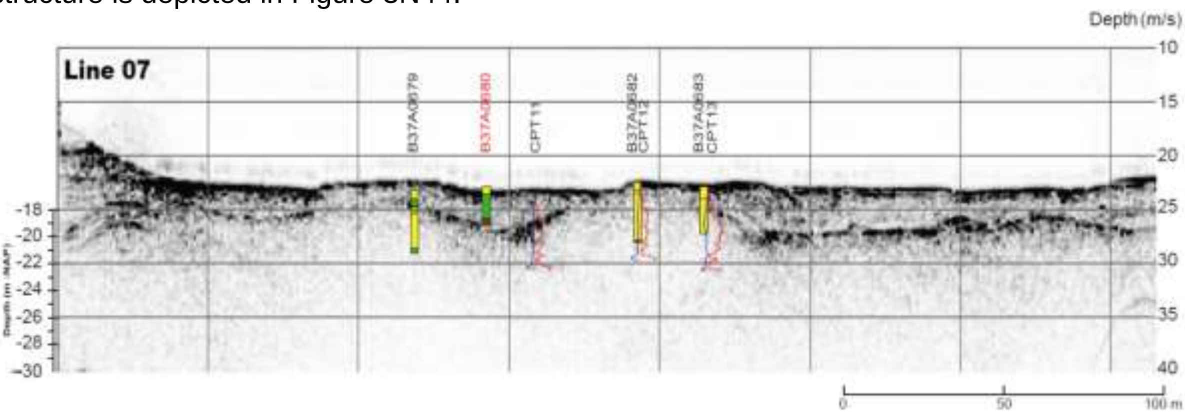


Figure 3N43: Results of the seismic survey of line 07 of selection area West, including CPT and bore hole data.

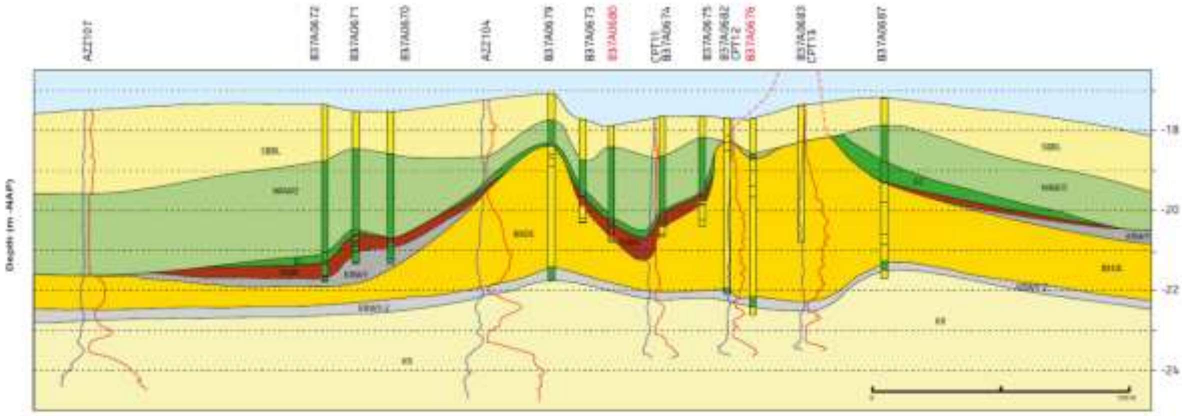


Figure 3N44: East-west cross-section of selection area West, geological interpretation based on the data presented in Figure 3N43. Legend, see Figure 3N38.

The sediments of 21 cores of Area East and 31 cores of Area West were examined on the presence of archaeological artifacts. A vibro-core with a core diameter of 10 cm was used for the archaeological sampling.. In Area West, 7 out of 31 cores contained archaeological evidence in the form of small flint artefacts and fine burned bone material in the top of the dune sands (Schiltmans, 2012). In cores B37A0673, B37A0675, B37A0676, B37A0696 and B37A0698 fine particles of burned bones and flint artefacts were found. On the base of these finds, it was decided that on these borehole locations the archaeological excavation with the crane should take place. In the cores of Area East no archaeological remains were found, no dig was executed.

Phase 4: Underwater archaeological dig using large grab samples

The archaeological underwater sampling was carried out with a pontoon crane (Figure 3N47a) at three find locations on the river dune of selection area West. Sample Pit 1 was dug out around the borehole locations of B37A0675 of B37A0676, Pit 2 around borehole B37A0673 and Pit 3 around borehole B37A0678. The third sampling Pit was carried out on the top of an eroded river dune, consisting of four separate parts of 2x3 m (Schiltmans, 2012).

Multibeam surveys were made of all three locations both before and after the excavation, allowing for accurate positioning of the acquired samples. Precise positioning is required to relate archaeological finds to the geological layer they come from. Knowing the position of in-situ finds in the local stratigraphy significantly increases the scientific value of the objects and enhances future investigation campaigns.

At the surface, on the pontoon, the samples were brought in a container. Each recovered sample was assessed by an archaeologist (Figure 3N47b). If a sample contained river dune sediments, it was preserved. For each sample, a small portion was taken for specialized research, while the bulk sediment was collected in big bags and subsequently sieved at a nearby site at the waterfront (Figure 3N47c). Sieving was carried out using high-capacity sieves with mesh widths of 10 mm and 2 mm. A total number of 46067 finds have been reported (Figure 3N47d), comprising mainly of charcoal, flint and fragments of animal bones. Both burnt and unburnt bone fragments have been found. The bones and sampled plant remains such as fruits and turnips gave a good impression of the food regime of the Mesolithic people who lived on the dune (Kubiak-Martens et al., 2013; Zeiler, 2012).

Additional sampling: Palaeo-environmental reconstruction

During phase 2, a total of 77 samples of the KRWY, NIBA-EC, EC and NAWO layers – derived from several borehole cores in the study area – were taken for pollen- and diatom research. The pollen and diatom slides were examined in a "scan research" and a global palaeoenvironmental interpretation of the investigated layers was accomplished. (Cremer and Bunnink, 2010). This preliminary interpretation was used for the palaeolandscape reconstruction of the archaeological expectation model of phase 3. In the last stage of the investigation, the final report, 41 pollen samples and 24 diatom samples were analysed (Cremer et al., 2013). Also, from eight new boreholes of the selection areas East and West (phase 3) 80 pollen and diatom samples were scanned on their palaeo-environmental significance. Twenty samples for each discipline were selected and analysed. A representative borehole in which the whole sequence or KRWY, NIBA-EC, EC and NAWO layers were investigated on pollen and diatoms, is B37A0705 from selection area East. The pollen and diatom diagrams are shown in Figure 3N45 and Figure 3N46.

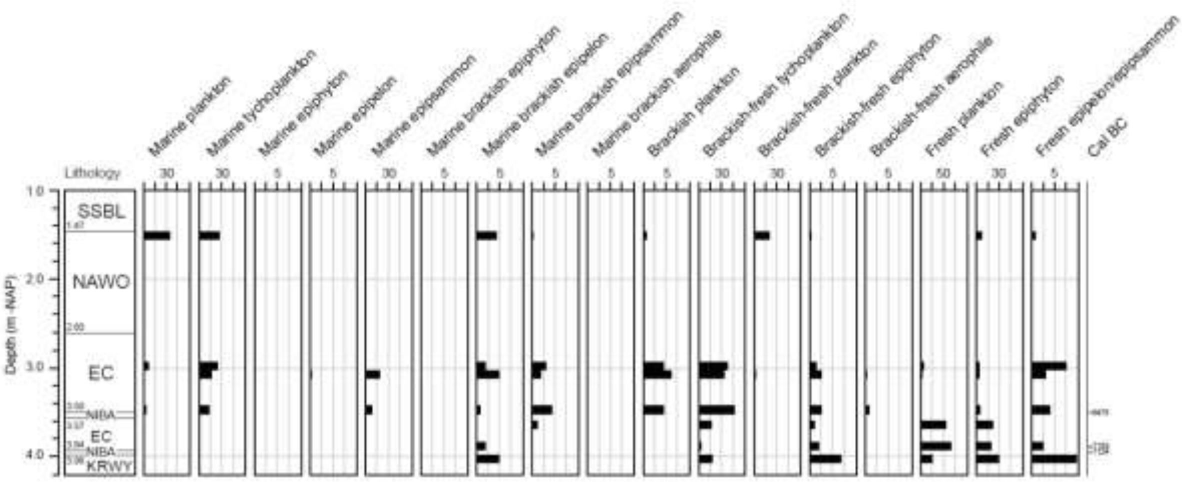


Figure 3N45: Diagram of percentages of the relative abundance of the ecological diatom assemblages (groups) analyzed in samples of dierent lithological units present in the cores of borehole B37A0705 (selection area East).

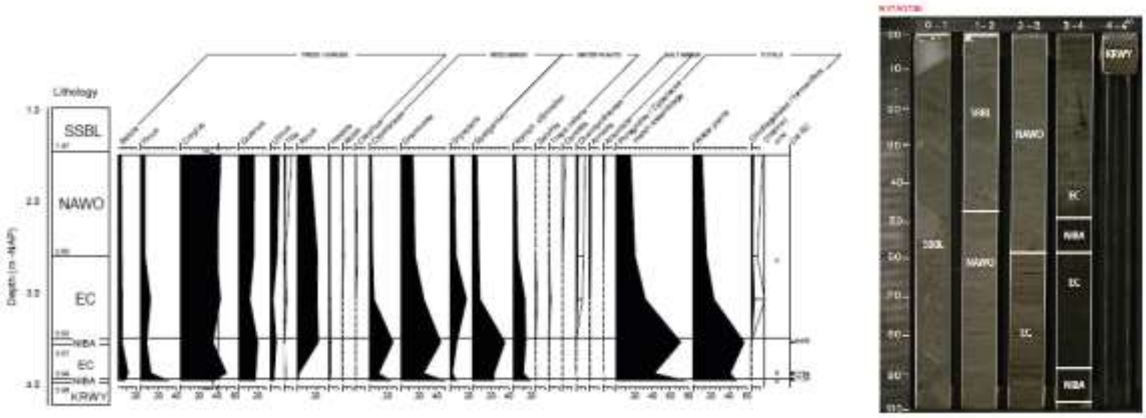


Figure 3N46: Diagram of the pollen assemblages analyzed in samples of different lithological units present in the cores of borehole B37A0705 (selection area East). Wedlands species are excluded from the pollen sum.

Figure 3N47: The underwater ''excavation'' recorded in pictures of the archaeological survey in 2012. Figure 3N47a: Computer controlled sampling with a crane; Figure 3N47b: Sampling en control of the digged up sediment; Figure 3N47c: Transport of the big bags samples to sieving location; Figure 3N47d: Sieving and archaeological selection of the sieved material.

The archaeological finds of the Yangtze harbour are the first in-situ scientific proof for Mesolithic hominin occupation in the lower part of Rijn-Maas delta sequence, west of the city of Rotterdam. In other parts of the country, mainly scattered remains of flint have been found; but the organic remains have been preserved as well as those found in the Yangtze harbour site. The preservation of these bones may have been favoured by the damp conditions at and around river dunes and the latter covered with sediment. The archaeological results will be published in 2014 in a special publication about the Yangtze harbour investigations.

3N.3 Analysis

3N.3.1 Vergulde Hand West: Landscape and occupation history

Due to the extensive geological, palaeoenvironmental and archaeological research the landscape and occupation history can be reconstructed in detail. The landscape history of the VHW has been visualized in a series of local palaeogeography maps (1600 BC – 1050 AD; Figure 3N48) and in a profile reconstruction (550 BC – 2000 AD; Figure 3N49). In Figure 3N50, a summary was made - in a schematic overview - of the observed activities by Man in the 4 sector areas of the VHW. This overview is based on all the archaeological finds and anthropogenic indications discovered in the samples of the studied proxies.

Figure 3N48: Landscape reconstruction of the VHW location (1600 BC – 1050 AD).

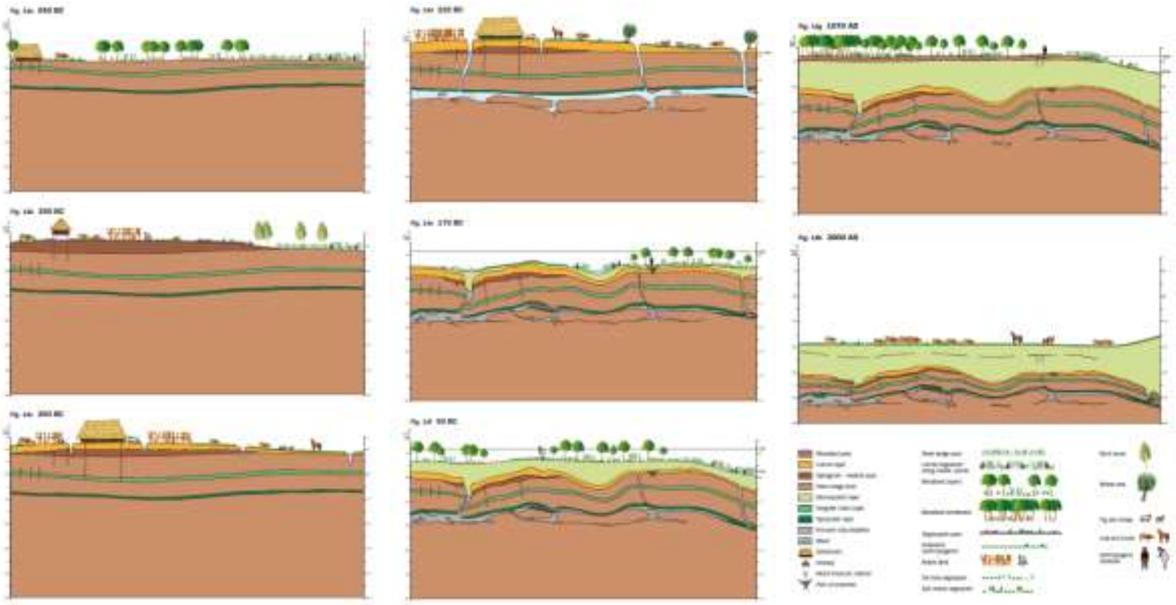


Figure 3N49: Profile reconstruction of the landscape in sector East between 550 BC –2000 AD. Location of the profile, see Figure 3N19.

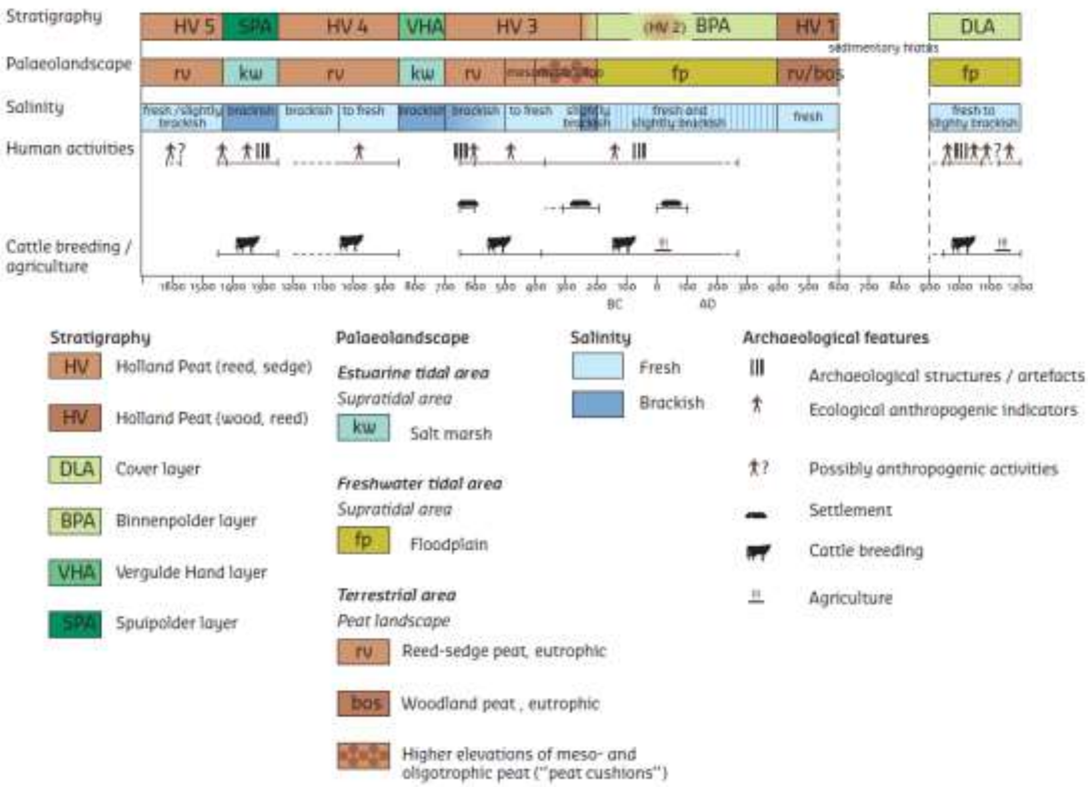


Figure 3N50: Summary of the archaeological indicators found in the peat and clay layers of the different sectors on the VHW location. See Figure 3N24, for the explanation of the stratigraphic codes.

The subsurface of the VHW - down to 5 m below the ground level - consists mainly of peat. In the peaty subsurface a number of clay layers have been formed. The deepest layer of clay which was exposed during the excavations, concerned the pre-Spuipolder layer in the sector East. This layer occurred at a depth of about 4.0–4.5 m below ground level (6.0–6.5 m - NAP) and was formed around 3650 BC. The environmental conditions in which this happened can be characterized as a brackish salt marsh environment in an estuary. The macro botanical remains from the clay layer do not rule out the possibility that people were present in the area at that time. Between about 3650 and 1400 BC predominantly reed peat grew in the area. This peat is eutrophic and in certain sections also clayey. This indicates that the peat was regularly flooded with nutrient-rich water. The peat was formed particularly in a fresh to slightly brackish water environment. The older peat (before around 1400 BC) has been insufficiently studied palaeoecologically for distinguishing specific phases or peat formation or for being able to pronounce on variations in salinity during the formation of the peat. During the last phase of the development of the peat, from about 1800 BC onwards, humans were present in the area and the vegetation was disturbed locally. Between about 1400 and 1300 BC the area was flooded repeatedly during high water. As a result, throughout the VHW a clay layer was deposited, the 'Spuipolder layer'. It is a salt-marsh clay, which was formed in a predominantly brackish water environment. Only in the sector Canoe there is palaeo-ecological evidence indicative of humans having been active in the area of the VHW.

Between about 1300 and 850 BC the area changed into a reed peat bog, rich in fern, in the supra- tidal zone of a freshwater tidal area which was occasionally flooded by the sea during periods of high water levels and storm surges. Furthermore, bank vegetation, grasslands, isolated bog-like vegetation and alnetum peat occurred. In the course of the development of the peat the marine influence increased. Humans were present in the area of the VHW at that time and has left his mark. Poles with cutting marks which have been pound in the sector Canoe are the strongest evidence of this, but also the palaeo-botanical and micromorphological data show anthropogenic effects on the landscape. This data indicate that human presence became more prominent in the Late Bronze Age. Between about 850 and 700 BC clay was deposited all over the area of the VHW. In the Middle part (sector Middle and the northwestern part of sector East), there was a shallow lake and along its edges marsh clay was deposited. This implies that at that time the area was frequently flooded by the sea during storm surges and was located in the sphere of influence of the estuary. These marsh clay deposits are rated among the 'Vergulde Hand depositions' and the sediments in the shallow lake are rated among the gyttja-clays. The granary (in Dutch: *'spieker'*) from around 650 BC. in the sector Canoe indicates human activities in the VHW during the deposition of the Vergulde Hand layer (Eijskoot et al., 2011). In the lake sediments rich in organic matter were formed, consisting of brown-gray clays and humic green-brown-gray gyttja's. Initially the depositional environment of the lake was still brackish, but at a later stage freshwater conditions were predominant in the shallow lake. The formation of these packages started in the Late Bronze Age. However, an accurate dating of gytjja from this early stage is not available and therefore the coming into existence of the lake cannot be determined with more precision.

Between about 700 and 500 BC another period of reed peat formation came. Around 700 BC (sectors West, Middle and East, layer Hv-3.6) there was still a limited amount of marine influence in the region (occasionally flooded during storm surges), but in the subsequent period the area became almost entirely fresh. Also the shallow lake turned to peat at that time. In the next phase (ca. 650 and 500 BC) alder trees grew locally in the peat (wood fragments in the reed peat) and there was no longer any marine influence (sectors West, Middle, East, layer Hv- 3.5). Locally, where the peat grew high, environmental conditions arose in the peat that were poorer in nutrition. In the phase during which the reed peat formation took place (750-500 BC) humans were present in the area. This is evident not only from the palaeo-ecological research, but also from the archaeological investigations. The archaeological traces include: a dugout wooden canoe of oak, a settlement and the remains of two off site buildings. Only in the settlement a macroscopically recognizable cultural layer formed during this phase. Between about 500 and 350 BC In the sector East the peat grew so high that it came to lie beyond the sphere of influence of the river and / or flooding by the sea. There mesotrophic (sector East, layer Hv-3.3) and oligotrophic peat (sector East, layers Hv-3.2 and Hv-3.1) developed. In the other parts of the VHW such peat development seems not to have come about. Here nutrient-rich environmental conditions were dominant. Throughout this phase, people were active in the area and between 400 and 350 BC the first buildings were erected in the sector East.

Between about 350 and 200 BC people lived and worked on the relatively high and dry lying peat. Remains of settlements from this period have been found in the sectors East, Middle and West. Field weeds, cultivated plants and a possible ploughshare, which were found in the cultural layer, indicate that agriculture was practised on the peat. In addition, livestock was bred. Cultural layers from this period have been found in the sectors East, Middle and West. In the areas which were inhabited, the peat must have been drained. At the residences and in the immediate vicinity of these locations the peat formation stopped. Due to tillage, treading and drainage a cultural layer came into existence there. In the vicinity of the dugout canoe the cultural layer of the Middle Iron Age was missing because the top layer of the peat (with the cultural layer) was gone by erosion from the adjacent creek.

Between about 250 and 200 BC periods of high water levels occurred repeatedly in the area of the VHW. The high water levels of predominantly fresh to slightly brackish water indicate periodically large river discharges at that time. Initially the top of the peat did not drown but became buoyant. The buoyant peat blocks (*"peat islands"*) tore loose from the underlying peat/clay subsoil and in these cracks and fissures clay was deposited, the intrusion clay. In the early stages these buoyant peat islands were still suitable for habitation. However, since due to repeatedly going up and down the peat tore more and more, the habitational conditions became less and less favourable. Also within the settlements and in the farmhouses cracks filled with intrusion clay have been observed. How long the occupation of the buoyant peat islands still continued is unclear; it may have been a couple of years but also 2 to 5 decades.

Around 200 BC the peat blocks lost their buoyancy. As a result the peat was flooded during high water periods and a clay layer was deposited on the peat (the so-called 'Binnenpolder deposits'). The flooding began along the edges of the creek in the southern and Middle parts of the VHW. After 200 BC the entire area was gradually flooded. The depositional environment of the clay was still predominantly fresh. Occasionally the area of the VHW could become brackish temporarily during major storms; the allochthonous coastal marine diatoms which occur in the clay are indicative of this. Over the whole year, the freshwater conditions dominated; the alders which could grow in the BLA layer show this. Archaeological traces show that in the beginning of the flood stage people were still bustling in the area. Also clay was trodden into the top of the peat on a large scale. However, the intensity of human presence decreased rapidly, and for the remainder of the flood stage in the 2nd century BC only micromorphological research still points to the possibility that people were active in the area.

The deposition of the clay layer on the relatively soft peat subsoil led to a process of autocompaction and differential subsidence. At those places where a strong subsidence occurred the organic archaeological remains have been preserved best because they are lying below the (current) groundwater level. Therefore, these residues have not exposed to the air and the organic archaeological material has not decayed.

The freshwater tidal depositions of the Binnenpolder clay continued until about Birth of Christ. Archaeological traces show that in the 1st century BC man was active again in all of the area. A second phase of activities with archaeological remains would follow in the 1st century AD. During this phase there was a settlement in the sector West and in the sectors Middle and East off site activities took place which have left behind archaeological traces The third and final phase of activities with archaeological traces was in the 2nd and 3rd centuries AD. By then the sectors East and West had been parcelled with two large ditch systems. During these phases of activity in the VHW, largely the same vegetation types and environmental conditions occurred as those in the 2nd century BC. The area remained part of the supra- tidal zone of the freshwater area. Also, occasionally the area was flooded during which brackish water was brought in. Given the nature of the archaeological traces, in the Roman Ages, the frequency and intensity of floods decreased. The sedimentation of clay – during high water periods – in a tidal freshwater environment continued until approximately 400 AD. Possibly, also the creek in the centre and south of the VHW was still active. However, geological dating evidence for this is lacking. The increasing wet conditions seem to be unfavourable for the human presence in the area. After about 250 AD, no anthropogenic traces have been found which explicitly indicate human activity in the area of the VHW decreased.

Between 300 and 900 AD another period of peat formation occurred within the area of the VHW. However, a lot of the original peat has disappeared by oxidation. Only in sector West the peat has remained well preserved due to subsidence of the peat by autocompaction. By the lowering of the peat, the peat has become below the oxidation – reduction level in soil, so that it was not oxidized. The preserved peat mainly concerned a brook peat with much alder wood. This indicates that the peat was formed beyond the direct marine influence. Possibly, this peat bog was still visited by people during its formation; however, the indications thereof are not in the least univocal.

In the 10th century the brook peat was brought into cultivation and a cultural layer developed which was almost fully formed due to human influence. On the cultural layer remains of timber have been found dating around 991 AD. This cultural layer too, like layer Hv-1, has only been preserved in sector West. However, in sector East remains of buildings actually have been found. These have been dated around 1072 AD.

In the 12th century, the area of the VHW was diked-in and cultivated on a large scale. Due to the strong drainage, compaction and oxidation of the peat, the area subsided strongly in the following centuries and the ground level came to lie below sea level (deeper than 2 m - NAP). The peat – including the organic archaeological remains – which lay in the soil above oxidation level / groundwater level decayed between the 13th century and this day. Little is left of the post-Roman peat. Also the pre-Roman peat which locally lay relatively high (and above groundwater level) has disappeared completely. The old pre- and post-Roman peat has only preserved at those places where it lay below the oxidation / groundwater level.

In the cover layer (DLA) humus horizons occurred. Due to the lack of plant remains these layers could not be dated. The genesis of these humus layers in the DLA layer remains unclear. It cannot be ruled out that the remains belonged to former peat layers which fully decayed later on.

3N.3.2 Yangtze harbor

Groundwater and sea-level rise

The main driver for the accumulation of the Early Holocene deposits burying the valley floor and the inland dunes was the rise of the groundwater table, for which sea-level rise in areas downstream of the study area was the main driving factor. In the very beginning of the Holocene (ca. 9.500 BC) the mean sea-level had still been low, about 35 to 40 m in the southern North Sea (Kiden et al., 2002; Sturt et al., 2013). The area of the central part of the North Sea were still dry land and England was connected with the European continent at that time. As post-glacial eustatic sea-level rise proceeded, the southern North Sea drowned and the palaeo-coastline approached the present-day coastline (e.g. Beets and Van der Spek, 2000).

The results from Phase 2 (further confirmed and scrutinized using data from Phase 3) show the study area became part of the deltaic wetlands that are the landward boundary of base level rise at the river mouth from about 7500 BC onwards. At 20.8 m –NAP Basal Peat began accumulating ca. 7250 BC, at 19.0 m –NAP about 6650 BC. The contact of the Basal Peat with freshwater tidal muds (EC) dates to 6500 BC based on samples from the top of the Basal Peat. This environment persisted until ca. 6000 BC, after which the area was clearly subaqueous shallow marine. The time frame 7500 BC to 7000 BC appears to have seen steady, still relatively slow rise of the groundwater table, by 7250 BC positioned at a depth of 21.0 to

20.5 m – NAP. Thereafter the groundwater rise seems to have accelerated a little, due to continued sea-level rise and the coast line / river mouth approaching the study area as part of transgressive processes. Around 6500 BC, peats encroached the river dune flank to a height of approximately 18.75 m –NAP. In the period between 7250 and 6500 the rise of the groundwater table was about 30 cm / century (Figure 3N51). In the most distal groundwater-locked places, organic deposits accumulated, while in equally wet areas that received more fine sediments during floods, humic clays dominated. This explains why the Basal Peat stratigraphic level in the area (our NIBA-EC unit) is an intercalation of true peats (NIBA) and fluvial humic clays (EC). So, the sea-level rise stimulated (indirect) the accumulation of organic and clastic deposits between 7250 and 6500 BC in the study area. If areas closer to the main Rhine channel of the time to the North of the study area are also included (Hijma and Cohen, 2010; Hijma and Cohen, 2011), peat formation can be considered to have started 7500 BC.

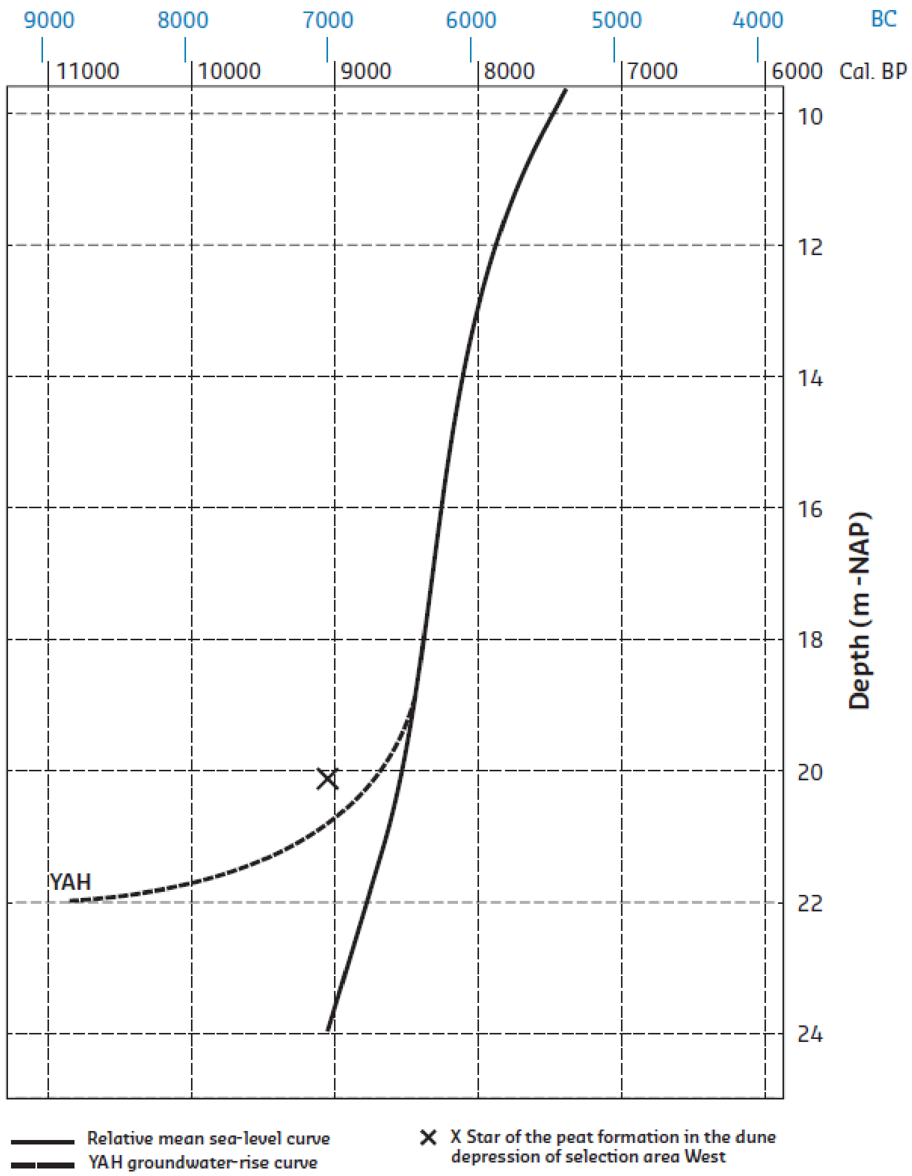


Figure 3N51: Time –depth curves of the Early Holocene sea-lever and groundwater table rise. Afer Hijma & Cohen, 2010 and data of the Yangtze harbour area (groundwater curve).

At ca. 6500 BC, a marked change in deposition occurred in the study area. This had been postulated from dates and sea-level index points obtained 30 km upstream (Hijma and Cohen, 2010) and attributed to an event of accelerated sea-level rise (Figure 3N51). The collected data for the top of the Basal Peat in the study area reproduces the 6500 BC age multiple times and confirmed the event-like timing of the drowning. Just as sea level had been rising before the 6500 BC 'jump', it also continued to rise after at a rate decelerating from 1 m/century to dm/century. This made that waters continued to deepen for millennia after. The region transformed into an estuarine delta and eventually became offshore area (Van Heteren et al., 2002; Rieu et al., 2005; Hijma et al., 2010). These transgressive developments based on sedimentary-geological mapping and dating of organics, can be further detailed using the palaeo-environmental information contained in pollen and diatom palynology.

Landscape reconstructions

With the help of the geological and palaeo-environmental data, the Early Holocene landscape evolution of the study could be reconstructed in relative high detail. Around 9000 BC the study area was situated in a mostly dry river plain of the rivers Rijn and Maas.The lower parts (below 22 m –NAP) were occasionally flooded during periods of extremely high water and a thin layer of silty clay was formed (KRWY-2 layer) there. Vegetation in the river plain was still scarce and as regards the pollen, it is dominated by pine. The floodplain lay dry for long periods of the year. Locally sand drifts occurred, the inland dunes to form. By 8400 BC, the dune in Area West is estimated to have reached a height of 15 m –NAP (6 meters above the surrounding plain). Absence of palaeosol B-horizons in the core of the dune complex below the younger marine truncation surface, indicate at least 1 m of dune top to have been eroded. The estimate for the top of the dune is a projection of similar dune morphologies of better preserved examples more inland in the delta plain. The highest occurences of a clay cover on the dune flank indicate (one or two dm thick; KRWY at highest encountered positions) occasional high water levels in the delta plain, due to floods of the river. The time span of this unit is long, more than 1000 years (i.e. sedimentation rates less than 1mm per year) and also its pedogenic ripening indicates the floodplain to have been dry land, and suitable for occupation, for most time of the time year round. With this respect, the Phase 3 and 4 findings confirmed the presence of such a landscape at the time of the early Mesolithic and early middle Mesolithic age, that had been the reason to do detailed investigations in Area East. An archeological site, however could not be confirmed in Area East.

The landscape situation changed after 7250 BC, when a large part of the area became wetland. Assuming that Mesolithic man did not stop visiting the study area but altered its use of it to the wetland situation, this palaeogeographical change would predict the potential area where archeological sites (e.g. places where fire was used) to have shrunk and find concentrations to have increased in the remaining suitable zone.

As evidenced by the Basal Peat, the water table rose at rate of 0.2 to 0.3 m per century (7250 to 6500 BC). Peat formation and distal clay sedimentation together could generally keep pace with the provision of accommodation space by the groundwater rise, but local lakes formed in the places receiving too little sediment and not able to grow enough organic matter. The landscape diversified greatly. Shallow ponds and lakes developed reed-sedge marsh rims. The higher river dune area maintained terrestrial and with woody vegetation cover. The tree vegetation on top of the dune shows the immigration of broad leaved tree species around 7000 BC, marking the Boreal / Atlantic transition. The proportion of *Pinus* reduced strongly and the thermophilic tree species such as *Alnus*, *Corylus*, *Quercus* and *Ulmus* increased greatly in numbers. Around the dune reed-sedge marsh vegetation, riparian vegetation and open water vegetation gain importance from this time. Around 6500 BC, with wetland sedimentation up to 18.75 m –NAP, the habitable area on the dune was at its smallest.

The hydrological and palaeo-environmental changes in the river plain mean that, while dry habitable areas became smaller and smaller, conditions for hunting and gathering may have diversified and improved. The new environment of the late boreal and earliest Atlantic of the area improved the pallet of food resources available in the direct surroundings. Therefore, at remaining high-and-dry locations in the wetland, one may consider the odds of encountering Mesolithic archaeology to have been raised relative to earlier situations.

In Figure 3N52 and Figure 3N53 the drowning history of Area West is visualized in a map and profile reconstruction. The figures show both the run up to the 6500 BC drowning of the area, and the aftermath. At the critical moment, the drowning was very fast (sea-level jumping, in a few months or a year, possibly in two events of about a meter each (Hijma and Cohen, 2010) and thereafter drowning and deepening continued.

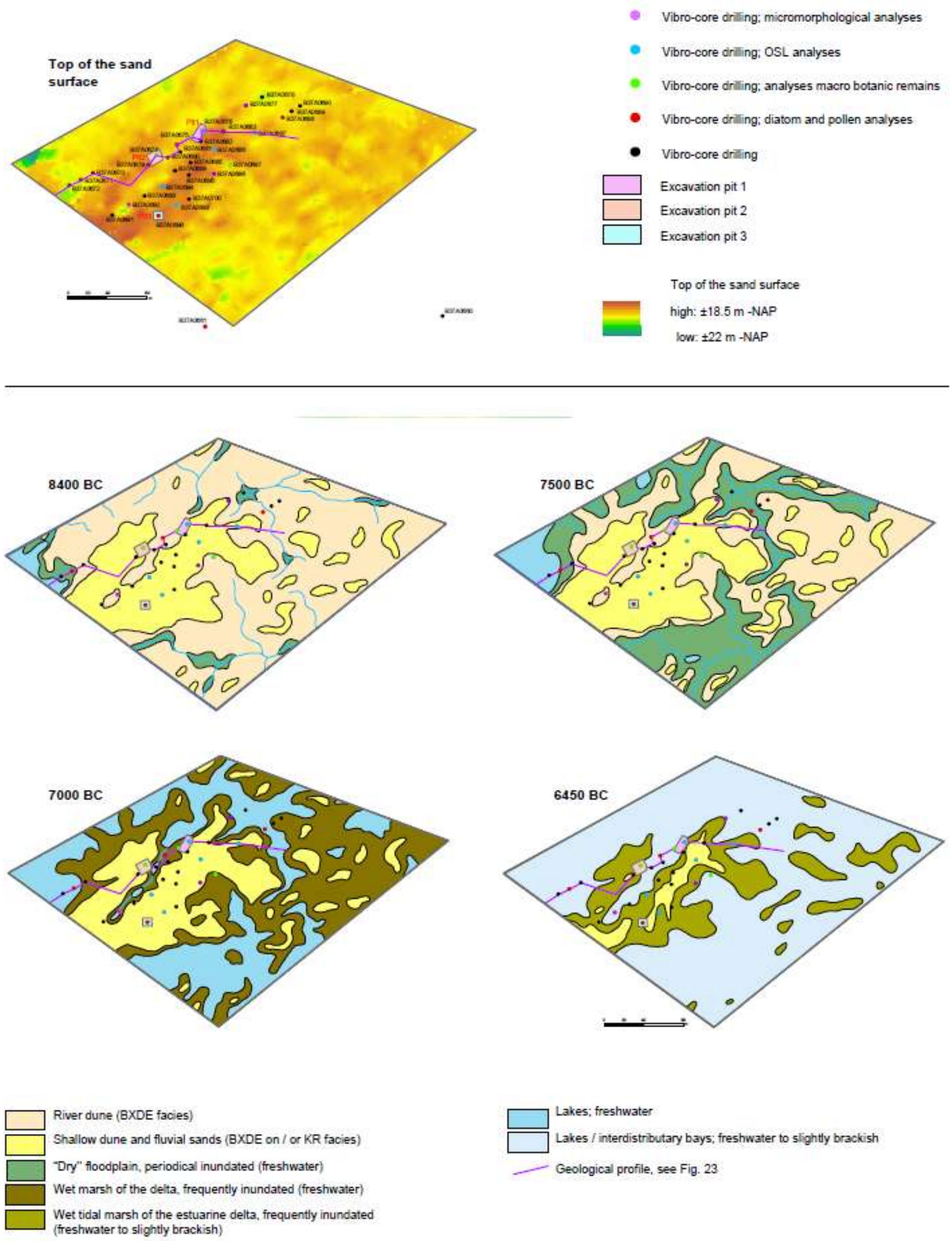


Figure 3N52: Map reconstruction of the drowning of the landscape of selection area West for the time steps: 8400, 7500, 7000 and 6450 BC

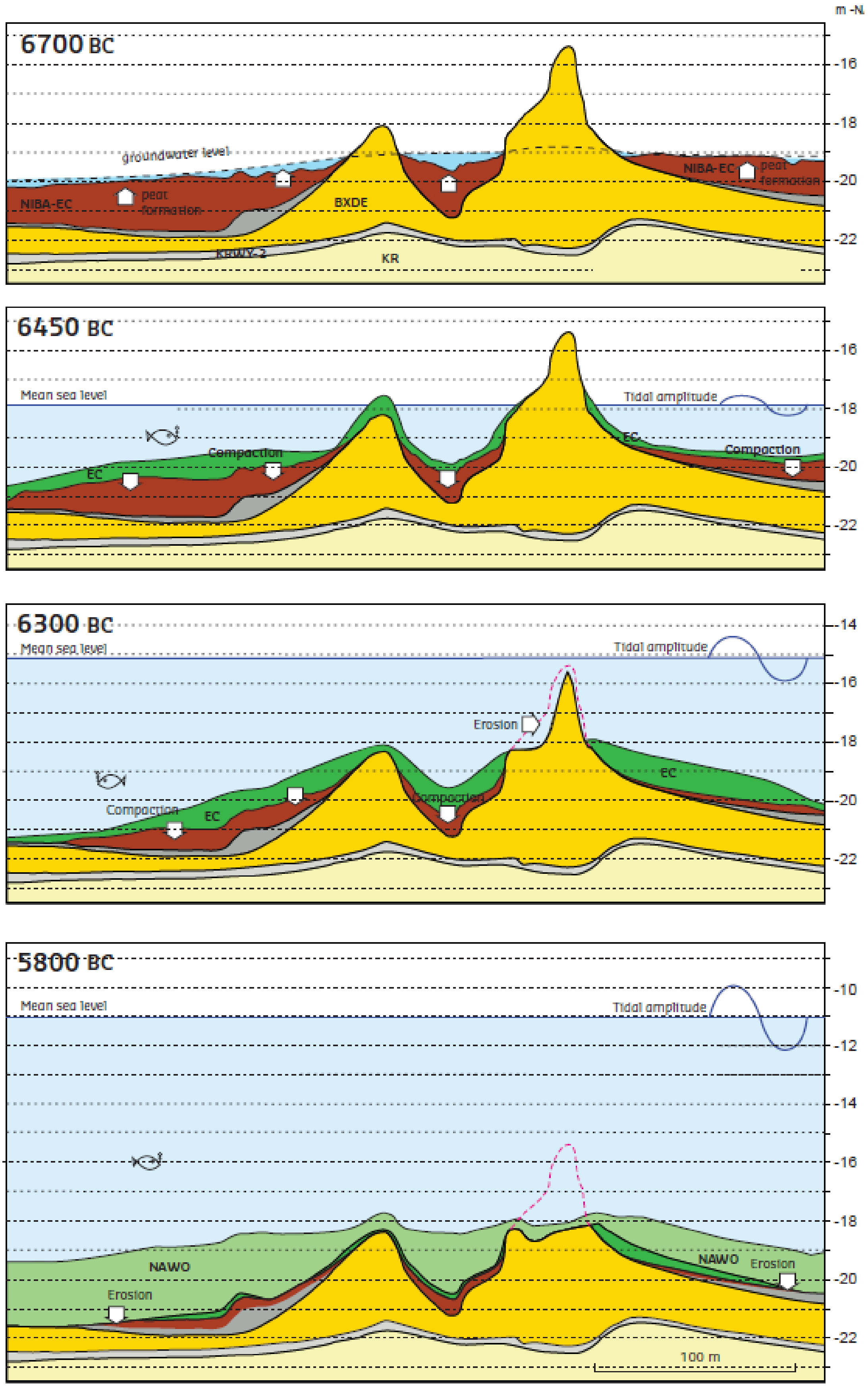


Figure 3N53: Profile reconstruction of the drowning of the landscape of selection area West for the time steps: 6700, 6450, 6300 and 5800 BC. Legend profile see Figure 3N38.

The 6500 BC event transformed the river plain wetland (zone 1 in Figure 3N33) into shallow subaqueous river mouth wetlands (zone 2 in Figure 3N33): 'upper-estuarine' or 'fluvial deltaic' freshwater floodbasin environment, part subtidal and part intertidal. Thereafter the environment became brackish, deepened further and became subtidal everywhere, and eventually became saline. In this environment the top of the dune was drowned and washed out by marine erosion. The would-be dune top at 15 m –NAP would have beend drowned at 6300 BC, based on sea-level data collected 20-30 km inland (Hijma and Cohen, 2010).

Coincidently and conveniently, the 6500 BC transgressive event matches the boundary between the Middle and Late Mesolithic in archaeological time division as has been used on inland sites (Louwe Kooijmans, 2005). In the coastal Netherlands, the transgressive event(s) of 6500-6300 BC may have been instrumental in causing a change in Mesolithic site patterns. From 6500 BC, the dune site Yangtze Harbour West rapidly became inhabitable. Successors of Middle Mesolithic people that had been visiting the area for its specific resources and hunting habitats, would have find these environments shifted to more inland positions (e.g. Rotterdam and Alblasserwaard), where indeed Late Mesolithic occupation is present and was exploited (Louwe Kooijmans, 2005; Brouwer-Burg, 2013). From a palaeogeographical perspective, we recommend detailed archeological intercomparison of these deltaic Late Mesolithic sites and the submerged Middle Mesolithic equivalents. In such comparisons and evaluations, it should be considered that the inland shifting of environments not only considers fluvial and estuarine wetlands, but also (embryonic) coastal barrier and spit systems at the estuary mouth (at the boundary of zones 3 and 4 in Figure 3N33). These environments may have been part of the Mesolithic land use strategies too, but these structures are not preserved because of coastal erosion.

3N. 4 Conclusions and Recommendations

3N.4.1 Vergulde Hand West: Regional significance of the VHW in the landscape reconstruction

The area of the VHW belongs to the best-studied geo-archaeological sites in the Rijn-Maas delta area of the Maasmond. This case study puts the history of this region over the last 3500 years in a different light. On the base of the VHW study data, the regional paleogeographic maps from 2008 and 2011 (Vos and Zeiler, 2008; Vos et al., 2011) have been adjusted significantly as compared to those from 2002 (Vos, 2002). The changes regards the peat distribution and the courses of the main drainage channels in the delta in the map reconstructions.

An important regional signal, which was derived from the VHW research, was that after 250 BC a large influx of fresh river water occurred from the hinterland of Rijn and Maas. The increase of the river discharge is indicated by extreme high flood water levels in the VHW area. The increase of the water level during floods did not directly led to the drowning of the peat area of the VHW location. Initially the upper part of the peat of the VHW was not submerged during periods of extreme high water levels because the upper part of peat became buoyant and tear loose of the peat in the deeper part of the subsurface. The alder vegetation in the peat and clay layer on top indicated that at that period of drowning the water was predominantly fresh; however, the diatoms examined in the intrusion clays and cover layer indicate that there was tidal influence in the area (influx of coastal allochthonous diatoms). The combination of alder vegetation and marine diatoms in the clays indicate that between 250 and 1 BC, the VHW location had become part of a freshwater tidal area.

The increase of discharge of freshwater from the hinterland is explained by the formation of new tributaries of the Rijn towards the Maasmond area. This interpretation implicates that the channel migration of the river Rijn - from the Oude Rijn area towards the Maasmond area - was older than those described by (Berendsen and Stouthamer, 2001) which dated these Rijn avulsions in the Roman period. After the time that Maasmond area became the main outlet of the Rijn - Maas river system (again), this Oude Rijn estuary lost gradually their discharge function and diminished in size from the Roman period onwards (Van Dinter, 2013).

Another interesting feature which was observed on the VHW location, was the expansion of the Early Medieval peat, of which the existence was proven in the peat depressions of sector West (Figure 3N28a), whereas the main channel of the Rijn-Maas system was located immediately south of the VHW area (Nieuwe Maas channel). The expansion of the peat – immediately along the main channel, indicates that the flow rate of this channel had been reduced. This is remarkable because in that period of the Oude Rijn decreased more and more and the discharge through the IJssel only began to play an important role after 800 AD (Makaske et al., 2008). From this observation at the VHW site it has been concluded that other southern channels took over the discharge of the Oude Maas. In the map reconstruction of 800 AD has been assumed that those were the channels of the later Hollandsch Diep, Bernisse and Binnenbedijkte Maas / Oud-Beijerlandsche Kreek. These watercourses could find a shorter route to the sea because after 350 BC the peat areas of Zeeland and the islands of Zuid-Holland Holland were flooded and new openings to the sea were created in this area (e.g. Vos and van Heeringen, 1997).

3N.4.2 Yangtze Harbor

From findings in the Western Netherlands (Louwe Kooijmans, 2005), and also from offshore dredged sands used to further extend made land of the Maasvlakte, the presence of Mesolithic archaeology in the region had been known (e.g. Louwe Kooijmans, 1975; Verhart, 1988; Verhart, 2005). It was reason to dedicate archaeological prospection efforts to surfaces from the Mesolithic period in the Yangtze Harbour area in the Port of Rotterdam too, which was carried out using ‘the geogenetic approach’.

As a result, this case study report can present the relation between 1) early and middle Holocene landscape development, 2) potential Mesolithic use of the reconstructed landscapes and 3) understanding what localities in the landscape would have the highest chance to find the archaeological proof for human presence. For the Yangtze Harbour area, the insights are:

1. Up to 7250 BC the whole floodplain and inland dune complex in it was suitable for (seasonal) settlement (i.e. make use of fire to cook food, make tools). Locations along local drainage are regarded to have been frequented most, but in the rest of the floodplain suitable locations will have existed too. It is hard to differentiate and chances of actually finding archaeology are to be considered low.

2. Between 7250 and 6500 BC, the area suitable for settlement was reduced to the higher parts of the inland dunes. The surrounding wetlands (swamps, marshes, lakes) were part of the rich habitat, but not good settlement location. It is easy to differentiate and the chances of finding archaeology on the top of the dune sediment is large. Chances are equally high on the dune foot and the fringe of swampland surrounding dunes. The state of preservation and the opportunities to also collect contextual palaeo-environmental information are even better. Finds at the dune foot may have been colluvially been displaced a few meters.

3. After 6500 BC, the study area had submerged. No Mesolithic archaeological sites are expected, also because of further sea level rise of many meters in later millennia.

The contrast between the period before and after 7250 BC is the result of the connection between the drowning due to groundwater rise (in advance of sea-level rise) and habitat changes with the altered hydrology (besides climatic developments and vegetation succession). In combination, this creates a Mesolithic ‘prospection optimum’ centred on inland dunes that have wetland deposits capping their feet. For the study area, this relation is visualized in Figure 3N54, together with trend lines of groundwater and sea-level rise, decline of available land.

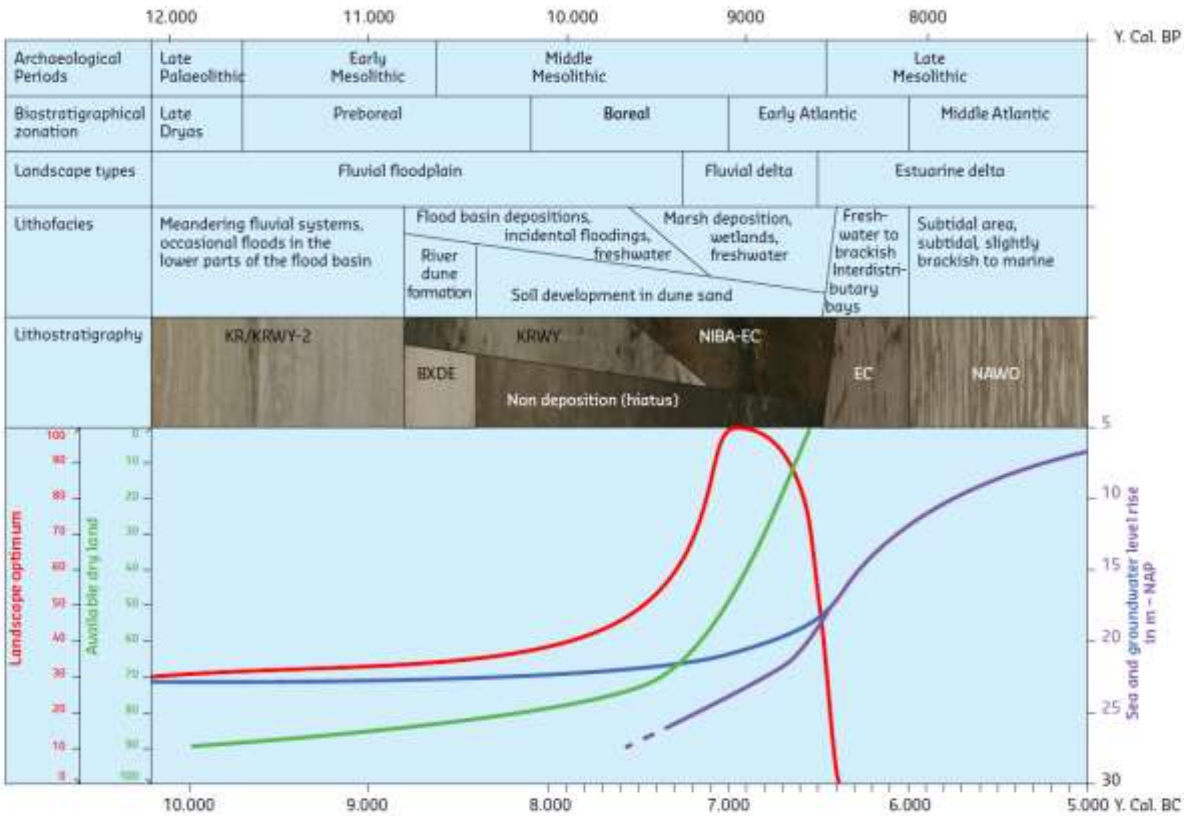


Figure 3N54: Synthesis of the lithostratigraphy, sedimentary environments, and dry / ''optimal'' land surface in time, related to ground- and sea-level rise. Stratigraphy, Figure 3N38, Figure 3N39 and Figure 3N44; sea- and groundwater-level curves, see Figure 3N51; salinity reconstruction, Figure 3N45 and Figure 3N46; available dry land / ''landscape optimum'' reconstruction, see Figure 3N52.

The geogenetic approach (targeting specific sediment layers and surface contacts), stepwise deployed, provided the insights needed to do targeted high-resolution research, at locations optimal for prehistoric habitation, and to select the best methods and techniques for mapping the palaeolandscape and proofing human presence in it. Suitable habitats for hunting and gathering in the fluvial delta were widespread. At site Yangtze Harbour West, archaeology of this period was indeed found at depth of 18,5 – 20 m -NAP. It shows that an extensive drilling program in inland dune sands will have a large change of success in finding archaeological proof by sieving the sediments of the sampled cores. The geogenetic approach also makes sure that sufficient material is collected to support detailed palaeo-environmental reconstructions to place excavated archeological sites in context. The geogenetic approach also makes sure that the obtained results feed back to the regional paleogeographical knowledge.

The stepped geogenetic approach can be applied in comparable underwater areas elsewhere in the world where large engineering projects are taken place. It is difficult to proof the effectiveness of the methodology on the single case of this study, but at least future underwater archaeological investigations can base their approach on ours. Especially for underwater areas where thick sediment layers cover up the palaeolandscapes – which is the case in the coastal zones of many of the world's present-day deltas, it is a promising approach. In this study, the information after each phase of the survey was used for planning the next phase. The stepped strategy makes anticipating, flexible project planning within the larger engineering operations feasible, and made adjustments to the outset concept of the project possible (methods, disciplines to consult specialist from). The stepped strategy also is more efficient than an overall project plan in which the budgets for the various activities (in time and money) are allocated in advance.

The geoarchaeological investigation benefited of the geotechnical data of the engineering work. The reverse can also be the case: an improved geological model, made for archaeological reasons, can be valuable for the design of the infrastructural work and the operation activities. In the case of the Yangtze harbour project, during phase 1 (desk study) the geotechnical CPT data constituted the base of the first conceptual geological model. During phases 2 – 4, the geoarcheological field survey had much benefit that the – from a (prehistoric) archaeological point of view - irrelevant sea sand deposits up to 17 m – NAP were dredged away, so that the relevant deltaic deposits were much easier to investigate with geophysical and coring technics. Because the geoarchaeological investigations were incorporated, the overall impact on the harbour engineering works itself was negligible and the cost for the archaeological research reduced.

One may wonder if the here deployed methods were the most optimal ones. A better alternative method to proof the presence of archaeology in floodplain deposits such as in Area West and Area East, could have been to take large ''bulk samples'' instead of corings ' already in Phase 3 instead of Phase 4. Such methods have been piloted for palaeolithic and paleontological (e.g. Mammoth bones) surveys of sand nourishments to beaches.

Like other elements of the geogenetic approach, bulk sampling can be fit in to the works that engineers are executing anyway to deepen the harbour, i.e. 'controlled dredging'. The means exist to obtain large grab samples for which it can be confidently known from which geological layer they were coming (the eventual Phase 4 archaeological dig has demonstrated this). After Phase 2, optimal locations for taking bulk samples can be decided on, and part of the coring activities in Phase 3 can be replaced by bulk grab sampling. For age control and palaeo-environmental control and geological context, cores will have to be taken prior to the dredging. Especially for the non-cohesive units such as dune sands and tidal silt-laminated clays and sands, in grab samples the sedimentary sequence will be disturbed when the slush is brought to the surface for inspection. Surely, bulk sampling is a 'rough' way of underwater archaeological prospection (and / or excavation). However, for the North Sea area in most cases there is no alternative considering the depth and cost of the investigation. Important is that before the sampling of the seafloor subsurface the geology of area is investigated with geophysical techniques and boreholes and the palaeo-environment of the area of investigation can be determinate.

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3N.5 Annexe: description of the samples.

KRWY layer: 4.10–3.98 m below HB (Harbour Bottom during springtime 2011. (21.26–21.14 m –NAP)

Diatoms:

The diatoms in this layer are particularly dominated by four ecological groups (Vos & De Wolf, 1993): freshwater epiphytes, freshwater plankton, brackish- and freshwater tychoplankton and freshwater epipelon / epipsammon. At the species level, the following freshwater species have been found most commonly: *Epithemia adnata* (epiphyton), *Aulacoseira crenulata*, *Aulacoseira subarctica* (both plankton), *Staurosira venter*, *Pseudostaurosira brevistriata* (both tychoplankton), *Cocconeis placentula* (epiphyton) and *Amphora pediculus* (epipelon). The only marine-brackish diatom species which occurs is a small number of *Gyrosigma attenuatum* which, however, also tolerates freshwater conditions. Marine diatoms are not present.

Pollen

The pollen sample from this layer belongs to pollen Zone A. This zone is characterized by high values of the *Pinus* pollen. Apart from *Pinus* small percentages of pollen of thermophilic species such as *Corylus*, *Quercus*, *Ulmus* and *Tilia* are present. In addition, pollen of marsh vegetation (reed-sedge vegetation) and a number of pollen from freshwater plants occur. A common type of spores in this zone is *Ophioglossum vulgatum*, a small species of fern which during the Early Holocene often occurred in relatively high percentages in near coastal sediments. Currently, this species is found mainly in wet dune valleys. Marine indicators such as pollen of salt-tolerant plants, dinoflagellates and foraminifera are absent. The high values of *Pinus* and the still relatively low values of the thermophilic species indicate a Boreal age of the KRWY layer.

Palaeo-environment

The KRWY layer in borehole B37A0705 lies relatively low and along the edge of a trench-like depression (palaeo-brook system). The humid conditions account for the fact that the diatoms have been preserved relatively well there. In higher-level samples of the same KRWY layer of other cores the diatoms have often been dissolved by soil formation. The KRWY deposits were formed in a fresh water environment, which probably was permanently submerged for long periods of time. The co-occurrence of the planktonic, tychoplanktonic, epipsammic and epiphytic habitats are indicative thereof. The site was outside the sphere of influence of the sea.

NIBA-EC group: 3.98–3.50 below HB (21.14–20.66 m –NAP)

Diatoms

In this layer mainly species of freshwater planktic and freshwater epiphyton habitats have been found. Brackish-freshwater tychoplankton occurs only in relatively small quantities. In the groups mentioned *Aulacoseira crenulata*, *Aulacoseira islandica*, *Aulacoseira subarctica* (all plankton) and *Epithemia adnata* (epiphyton) are most commonly found. Marine diatoms are not present.

Pollen

The pollen samples from the NIBA-EC group belong to pollen Zone B. In this zone, the percentage of pollen of *Pinus* clearly decreases and the percentages of thermophilic tree species such as *Corylus*, *Quercus* and *Ulmus* increase. *Hedera helix* is also found in this zone. In this zone a strong expansion of pollen types of marsh and open water vegetation can be observed. Species indicating marsh fern-reed-sedge vegetation are, apart from Cyperaceae and *Dryopteris* types, *Typha latifolia*, *Sparganium* and *Alisma plantago-aquatica*, but also tall forbs from wet habitats such as *Filipendula*, *Lythrum salicaria*, *Valeriana oficinalis*, *Iris pseudocorus*, *Euphorbia palustris*, *Calystegia sepium* and Tubuliflorae. Also pollen of *Brassicae* species are present, in this context, probably originating from the marsh plants *Nasturtium* and / or *Rorippa*. Other species from wetland- and riparian vegetation are of the type *Polygonum persicaria* type – here probably originating from *P. hydropiper*, *P. minus* or *P. mite*.

In this zone the flora of open water is present in a great diversity with relatively high percentages. Nymphaeoide vegetations are represented by pollen of *Nymphaea alba* and *Nuphar luteum*, often with large numbers of basal hair cells and trichosclereids of these species, indicating a very local origin. *Oenanthe aquatica* type, *Butomus umbellatus*, *Cicuta virosa*, *Berula erecta*, *Apium inundatum* type, *Myriophyllum verticilatum* and *M. spicatum*, *Potamogeton* and *Ceratophyllum demersum* play a role alongside algae such as *Pediastrum*, *Botryococcus*, Zygnemataceae and *Spirogyra*. Noteworthy is the regular occurrence of *Salvinia natans* (a free floating water fern) and a single find of *Trapa natans* (water chestnut, a potential food plant for Mesolithic man). Both species are known from the mid-Holocene of the Netherlands (Zandstra, 1966; Out, 2010; Van Haaster & Brinkkemper, 1995).

Palaeo-environment

The diatoms in the NIBA-EC group include species that thrive in a freshwater depositional environment. The species composition, with much plankton, but also epiphyton and epipelon/epipsammon, is indicative of a predominantly permanently submerged environment with littoral vegetation of aquatic plants. The pollen species assemblage confirms this. This indicates the presence of eutrophic, relatively deep, stagnant open ponds with littoral vegetation and wet brushwood at the edges. The clayeyness of this unit fits within this type of aquatic environment.

EC layer: 3.50–2.80 below HB (20.66–19.96 m –NAP)

Diatoms

In this layer, for the first time diatoms are found, originating from the marine environment. The environmental groups which occur in the layer are – in addition to the marine habitats of marine tychoplankton, marine epipsammon and plankton – the groups of brackish-fresh tychoplankton, freshwater epiphyton and freshwater epipelon /epipsammon. At the species level these are: *Staurosira venter*, *Pseudostaurosira brevistriata*, *Staurosira construens* (all brackish-fresh tychoplankton), *Fragilaria sopotensis* (marine epipsammon) and *Cymatosira belgica* (marine tychoplankton). In the upper sample of this layer, the number of marine species increase slightly, including *Thalassiosira decipiens* (marine plankton).

Pollen

The samples from the EC layer belong to the pollen Zone C. In this zone – as is the case with the diatoms – the first marine elements are found, such as pollen types of salt-marsh vegetations (Chenopodiacea, *Armeria*) and further foraminifera and dinoflagellates. Characteristic of the zone C is the marked increase in pollen of *Alnus* and the occurrence of *Tilia*, in relatively low percentages. Further *Fraxinus*, *Viburnum opulus*, *Humulus lupulus*, *Frangula alnus* and *Myrica occur*, and in addition *Hedera helix* and pollen grains of *Ilex*, also in very low percentages. Also in this zone marsh vegetations and those of open freshwater play a major role. But, the percentages decrease sharply whenever the first marine elements do occur in the deposits. The decrease in the spores of ferns is clearly connected with this. The fact is that marsh ferns (*Thelypteris palustris*) – probably the major part of the present spores of *Dryopteris* type – is a very halophobic species. Therefore the reed beds rich in marsh ferns decrease in size during the deposition of the EC layer. Also the continuing drowning of the landscape during this deposition period may have brought about the further decrease in this type of vegetation.

The picture of the pollen of this zone falls in the Atlantic which is consistent with the ^{14}C datings in the top of the NIBA-EC unit.

Palaeo-environment

The diatoms and also the pollen spectrum show that the EC layer was formed within the sphere of influence of the sea. Relatively many diatoms of the allochthonous coast group (marine plankton and tychoplankton), foraminifera and dinoflagellates were found in the samples of this layer. These elements were supplied from the sea by tidal movements. This caused the depositional environment to become slightly salty. The clays of the layer were deposited largely in a submerged environment (interdistributary bay environment). The water in these deltaic lakes was still predominantly fresh to brackish, given the large amount of fresh and brackish-fresh pollen types and diatom species. In light of the lacustrine nature of the deposits many pollen may have been supplied from elsewhere through water currents. This also applies to the marine diatoms (allochthonous coastal group). The increase in these coastal allochthonous diatoms in the upper sample from the layer EC indicates a continuous increase in the tidal influence and salinity within the study area.

NAWO layer: 2.80–1.47 below HB (19.96–18.63 m –NAP)

Diatoms

In this layer mainly diatoms of groups of marine plankton and tychoplankton occur. In addition, also brackish-fresh plankton is frequently found. Ecological groups that are observed less frequently are freshwater epiphyton and marine-brackish epipelon. At the species level the most commonly diatoms are: *Thalassiosira proschkinae* (marine plankton), *Cymatosira belgica* and *Delphineis minutissima* (both marine tychoplankton), *Thalassiosira pseudonana* (brackish-freshwater plankton) and *Nitzschia frustulum* var. *inconspicua* (freshwater epiphyton).

Pollen

The pollen samples from the NAWO layer fall, like those of the EC layer, in pollen Zone C. Many pollen will have been supplied from the fluvial hinterland which explains why the pollen zones of the EC and NAWO layers are very similar.

Palaeo-environment

The increasing dominance of marine plankton and tychoplankton in this layer indicates that the site was under the increasing influence of the sea. The eastern tidal channel deposits of the NAWO layer also point thereto. Freshwater diatoms are still present although only in minor amounts. The occurrence of brackish-fresh, salt tolerant plankton (mainly *Thalassiosira pseudonana*) is indicative of the brackish nature of the depositional environment of the NAWO layer. That still a relatively large freshwater supply from the hinterland took place, is evidenced by the freshwater pollen assemblage which is still strongly present in the pollen spectrum.

SBBL layer: 1.47–0 below HB (18.63–17.16 m –NAP)

This layer was not investigated on pollen and diatoms. Deposits were formed in an open marine environment and for the major part during the Subatlantic.

3N.6 Case Study References

Bailey, G. N. 2004. World prehistory from the margins: the role of coastlines in human evolution. *Journal of Interdisciplinary Studies in History and Archaeology,* 1, 39-50.

Beets, D. J. & Van Der SpeK, A. J. F. 2000. The Holocene evolution of the barrier and back barrier basins of Belgium and the Netherlands as a function of relative sea level rise, late Weichselian morphology and sediment supply. *Neth. Journal of Geosciences,* 79, 3-16.

Behre, K. E. 2005. *Das Moor von Sehestedt. Landschaftgeschichte am östlichen Jasenbusen.*

Berendsen, H. J. A. & Stouthamer, E. 2001. *Paleogeographic development of the Rijn-Maas Delta, The Netherlands.* Assen, Koninklijke Van Gorcum.

Brand, K. J. J. 1983. Over het ontstaan en de ontwikkeling van de Hont of Westerschelde. *Zeeuws Tijdschrift,* 3, 99-110.

Brouwer-Burg, M. 2013. Reconstructing "total" paleo-landscapes for archaeological investigation: an example from the central Netherlands. *Journal of Archaeological Science,* 40, 2308-2320.

Cohen, K. M. & Hijma, M. P. 2008. Het Rijnmondgebied in het vroeg-Holoceen: inzichten uit een diepe put bij Blijdorp (Rotterdam). *Grondboor & Hamer,* (3/4), 64-71.

Cohen, K. M., Stouthamer, E., Pierik, H. J. & Geurts, A. H. 2012. *Digitaal Basisbestand Palaeogeografie van de Rijn-Maas Delta / Rhine-Meuse Delta Studies' Digital Basemap for Delta Evolution and Palaeogeography. Dept. Fysische Geografie. Universiteit Utrecht. Digitale Dataset, persistent identifier: urn:nbn:nl:ui:13-nqjn-zl, https://easy.dans.knaw.nl/ui/datasets/id/easy-dataset:52125.*

Cremer, H. & Bunnink, F. P. M. 2010. *Diatomeeën- en pollenscans van de boringen Yangtzehaven (B37A0652, B37A0653 , B37A0656, B37A0661, B37A0663, B37A0665).* TNO rapport TNO-034-Ut-2010-01150-B.

Cremer, H., Koolmees, H. & Bunnik, F. P. M. 2013. *Diatomeeën- en pollenanalyses en scans van de geselecteerde boringen van de opgraving Yangtzehaven.* Utrecht, TNO rapport R10346.

De Ridder, T. 2000. *Van donk tot stad.* Vlaardingen, VLAK-overdruk nr.3. .

Dekker, C. 1971. *Zuid-Beveland. De historische geografie en de instellingen van een Zeeuws eiland in de middeleeuwen.* Assen.

Denucé, J. 1933. *Le cours de l'Escaut de la mer jusqu'à Rupelmonde au 15e siècle.* Anvers, Veritas.

Dolukhanov, P. M., Subetto, D. A., Arslanov K.A., Davydova, N. N., Zaitseva, G. I., Kuznetsov, D. D., Ludikova, A. V., T.V., S. & Savelieva, L. A. 2010. Holocene oscillations of the Baltic Sea and Lake Ladoga levels and early human movements. *Quaternary International,* 220, 102-111.

Edelman, T. 1958. Oude ontginningen van de veengebieden in de Nederlandse kuststrook. *Tijdschrift Economische en Sociale Geografie,* 49, 239-245.

Eijskoot, Y., Brinkkemper, O. & De Ridder, T. 2011. *De Vergulde Hand-West. Onderzoek van archeologische resten van de middenbronstijd tot en met de late middeleeuwen; inclusief Bijlagen en Kaartbijlagen. RCE Rapportage Archeologische Monumentenzorg 200.*

Gaffney, V., Thomson, K. & FitcH, S. (eds.) 2007. *Mapping Doggerland: The Mesolithic landscapes of the southern North Sea.* Oxford, Archaeopress.

Gottschalk, M. K. E. 1955-1958. *Historische geografie van westelijk Zeeuws-Vlaanderen.* Assen, Van Gorcum.

Gottschalk, M. K. E. 1971. *Stormvloeden en rivieroverstromingen in Nederland = Storm surges and river floods in the Netherlands.* Assen, Van Gorcum.

Hettema, H. 1951. *De Nederlandse wateren en plaatsen in de Romeinse Tijd.* Den Haag.

Hijma, M. P. & Cohen, K. M. 2010. Timing and magnitude of the sea-level jump preluding the 8200 yr event. *Geology,* 38, 275-278.

Hijma, M. P. & Cohen, K. M. 2011. Holocene transgression of the Rhine river mouth area, The Netherlands / Southern Nord Sea: palaeogeography and sequence stratigraphy. Sedimentology, 1453-1485.

Hijma, M. P., Cohen, K. M., Hoffmann, G., Van Der Spek, A. J. F. & Stouthamer, E. 2009. From river valley to estuary: the evolution of the Rhine mouth in the early to middle Holocene (western Netherlands, Rhine-Meuse delta). *Geologie & Mijnbouw,* 88, 13-53.

Hijma, M. P., Cohen, K. M., Roebroeks, W., Westerhoff, W. E. & Busschers, F. S. 2012. Pleistocene Rhine-Thames landscapes: geological background for hominin occupation of the southern North Sea region. *Journal of Quaternary Science,* 27(1), 17-39.

Hijma, M. P., Van Der Spek, A. J. F. & Van Heteren, S. 2010. Development of a mid-Holocene estuarine basin, Rhine–Meuse mouth area, offshore the Netherlands. *Marine Geology,* 271, 198-211.

Kiden, P., Denys, L. & Johnston, P. 2002. Late Quaternary sea-level change and isostatic and tectonic land movements along the Belgian-Dutch North Sea coast: geological data and model results. *Journal of Quaternary Science,* 17, 535-546.

Kubiak-Martens, L., Verbruggen, F. & Kooistra, L. I. 2013. *Hoofdstuk 9. Archeobotanie mesolithische Yangtzehaven – landschapsreconstructie en voedselvoorziening. Eindrapport inventariserend veldonderzoek (fase 3).* Zaandam, Rapportage BIAX.

Kuipers, S. F. 1984. Bergen en burgen op Schouwen-Duiveland. *Kroniek van het land van de zeemeermin (Schouwen-Duiveland),* 9, 5-38.

Leenders, K. A. H. W. 1986. *2000 jaarkustontwikkeling van Cap Gris Nez tot Hoek van Holland. - Rijkswaterstaat, taakgroep 1000 van het projekt Kustgenese.* Rijskwijk.

Long, A. J., Waller, M. P. & Stupples, P. 2006. Driving mechanisms of coastal change: peat compaction and the destruction of late Holocene coastal wetlands. *Marine Geology,* 225, 63-84.

Louwe Kooijmans, L. P. 1975. Benen jacht- en visgerei uit de Midden-Steentijd, gevonden op de Maasvlakte (circa 7000 v.Chr.). *In:* Louwe Kooijmans, L. P., Sarfatij, H. & Verhoeven, A. (eds.) *Archeologen werken in Zuid-Holland. Opgravingen en vondsten uit de laatste 15 jaar.* Rijksmuseum van Oudheden/Leiden tentoonstellingscatalogus

Louwe Kooijmans, L. P. 1980. Archaeology and coastal change in the Netherlands. *In:* Thompson, F. H. (ed.) *Archaeology and coastal change.* The Society of Antiquaries of London.

Louwe Kooijmans, L. P. 1985. *Sporen in het Land. De Nederlandse delta in de prehistorie.* Amsterdam, Meulenhoff Informatief.

Louwe Kooijmans, L. P. 2005. Jagerskamp in de moersassen. De donken bij Hardinxveld. *In:* Louwe Kooiijmans, L. P. (ed.) *Nederland in de prehistorie.* Amsterdam, Bert Bakker.

Makaske , B., Maas, C. J. & Van Smeerdijk, D. G. 2008. The age and orgin of the Gelderse IJssel. *Netherlands Journal of Geosciences,* 87(4), 323-337.

Rieu, R. S., Van Heteren, S. & Van Der Spek, A. J. F. 2005. Development and preservation of a miod-Holocene tidal-channel network offshore the western Netherlands. *Journal of Sedimentary Research,* 75(3), 409-419.

Schiltmans, D. E. A. 2012. Evaluatierapport project Rotterdam Yangtzehaven. *BOORrapporten, Rotterdam,* 523.

Staalduinen, C. J. 1979. *Toelichtingen bij de Geologische Kaart van Nederland 1:50.000. Blad Rotterdam West (37W).* Haarlem, Rijks Geologische Dienst.

Steur, G. G. L. & Ovaa, I. 1960. Afzettingen uit de Pre-Romeinse transgressie-periode en hun verband met de loop van de Schelde in Midden-Zeeland. *Geologie & Mijnbouw,* 22, 671-678.

Sturt, F., Garrow, D. & Vradley, S. 2013. New models of North West European Holocene palaeogeography and inundation. *Journal of Archaeological Science,* 40(11), 3963-3976.

Van Den Berg, J. & W., H. 1986. Een Romeinse schelpkalkbranderij uit de eerste eeuw te Koudekerke (zld): met notities over zoutwinning. *Westerheem,* 29, 220-232.

Van Dinter, M. 2013. The Roman Limes in the Netherlands: how a delta landscape determined the location of the military structures. *Netherlands Journal of Geosciences,* 92(1), 11-32.

Van Heeringen, R. M. 2010. *Aardewerkanalyse Vergulde Hand West.* Amersfoort (Vestigia rapport).

Van Heteren, S., Van Der Spek, A. J. F. & De Groot, T. A. M. 2002. *Architecture of preserved Holocene tidal complex offshore the Rhine-Meuse mouth, the Netherlands. NITG 01-27-A.* Netherlands Institute of Applied Geoscience TNO – National Geological Survey.

Van Trierum, M. C. 1992. Nederzettingen uit de IJzertijd en de Romeinse Tijd op Voorne-Putten, IJsselmonde en in een deel van de Hoekse Waard. *Boorbalans,* 2, 12-102.

Verhart, L. B. M. 1988. Mesolithic barbed points and other implements from Europoort, The Netherlands. *Omrol,* 68, 145-194.

Verhart, L. B. M. 2005. Een verdronken land. Mesolithische vondsten uit de Noordzee. *In:* Louwe Kooijmans, L. P. (ed.) *Nederland in de prehistorie.* Amsterdam, Bert Bakker.

Veski, S., Heinsalu, A., Klassen, V., Kriisks, A., Lõugas, L., Pska, A. & Saluäär, U. 2005. Early Holocene coastal settlements and palaeoenvironment on the shore of the Baltic at Pärnu, soutwestern Estonia. *Quaternary International,* 130, 75-85.

Vlam, A. W. 1946. Bijdrage tot de geschiedenis van de Schelde. *Archief, Vroegere en latere mededelingen uitgegeven door het Zeeuwsch Genootschap der Wetenschappen*, 32-50.

Vos, P. C. 2002. Delta-2003, 5000 jaar terugblik, kaartatlas met toelichting. Landschapsreconstructie van de kustdelta van Zuidwest Nederland in opdracht van het project GEOMOD van het Rijksinstituut voor Kust en Zee (RIKZ) van het Ministerie van Verkeer en Waterstaat. *TNO-rapport NITG 02-096-B*.

Vos, P. C., Bazelmans, J., Weerts, H. J. T. & Van Der Meulen, M. J. 2011. *Atlas van Nederland in het Holoceen.* Amsterdam, Bert Bakker.

Vos, P. C. & Bazelmans, J. G. A. 2002. De geogenetische aanpak: gericht prospectief archeologisch onderzoek op geologisch laagniveau. *Archeologische Monumentenzorg – Nieuwsbrief van de ROB,* 2, 28-29.

Vos, P. C., De Klein, M. P. C. & Rutten, G. L. 2012. Efficient stepped approach to site investigation for underwater archaeological studies. *The leading Edge, special selection: Archaeology*, 936-940.

Vos, P. C. & Eijskoot, Y. 2009. *Geo- en archeologisch onderzoek bij de opgravingen van de Vergulde Hand West (VHW) in Vlaardingen. Deltares-rapport, 0912-0245.*

Vos, P. C. & Van Heeringen, R. M. 1997. Holocene geology and occupation history of the province of Zeeland. *In:* FISCHER, M. M. (ed.) *Holocene evolution of Zeeland (SW Netherlands).* Haarlem, Netherlands Institute of Applied Geoscience TNO.

Vos, P. C. & Zeiler, F. D. 2008. Overstromingsgeschiedenis van Zuid-west Nederland, interactie tussen natuurlijke en antropogene processen. *Grondboor & Hamer,* 62((3/4) special: Kustontwikkeling), 86-95.

Westerhof, W. E., Wong, T. E. & De Mulder, E. F. J. 2003. De ondergrond van Nederland. Deel 3, hoofdstuk 4. Opbouw van het Neogeen en Kwartair. *In:* Mulder, E. J. F. E. A. (ed.) *De ondergrond van Nederland. Geologie van Nederland, deel 7.* Utrecht.

Wilderom, M. H. 1964. *Tussen Afsluitdammen en Deltadijken II, Noord-Zeeland (Schouwen-Duiveland, Tholen en St.-Philipsland).* Middelburg.

Wind, C. 1973. De IJzertijd. *In:* Vos-Dahmen Von Buchholz, T. (ed.) *Van steurvisser tot stedeling. Het avontuur van de archeologische speurtochten naar vijfendertig eeuwen Vlaardingen.* Vlaardingen.

Zeiler, J. T. 2012. *Hoofdstuk 7. De fauna van de Yangtzehaven. Archeozoölogisch onderzoek van botmateriaal van de Tweede Maasvlakte te Rotterdam (Vroeg – Midden Mesloithicum). Eindrapport inventariserend veldonderzoek (fase 3).* Haren, Rapportage ArchaeoBone, rapport nr. 103.

4. Analysis

The coastal zones of the Channel-Southern North Sea region are of enormous variety and geomorphological interest on account of the wide range of geological exposures along its coastline. The geological history, including the impacts of mountain-building phases, have caused the rocks to be compressed, folded and faulted and, subsequently, they have then been subjected to the processes of weathering and erosion over millions of years. Later, the impacts of glaciation and changes in sea level have led to the evolution and shaping of the coastline as we know it today. Over the last two centuries geologists, geographers and archaeologists have provided evidence of coastal change, this includes records of lost villages, coastal structures such as lighthouses, fortifications and churches, as well as other important archaeological sites that may have been constructed thousands of years before. Some important historical assets have been lost or obscured through sea level rise or coastal erosion whilst, elsewhere, sea ports have been stranded from the coast following the accretion of extensive mudflats and saltmarshes. The Arch-Manche project has sought to advance our understanding of the scale and rate of long-term coastal change by maximising the use of currently under-used historical resources, including archaeology, palaeoenvironmental data, works of art, maps, photographs, as well as historical literature accounts. Information about the various data sources and the methodology can be found in Section 2 of this report.

This section presents the results of the analysis, demonstrating how information extracted from each of the datasets has been used to maximise the potential for understanding coastal change. Analysis has included work within each data source, such as direct comparison between paintings and modern coastal conditions, the use of sequences of maps and charts to determine change over time, the analysis of monitoring data gathered from archaeological sites, and the comparison of results from the programs of geophysical survey and coring to investigate submerged landscapes. These results were then used in combination to provide a multi-source detailed analysis of change in a range of locations across the Channel-Southern North Sea region.

4.1. Results

This section presents the initial ranking results for each of the data types across the whole project study area. This is followed by the analysis of the ranked data to demonstrate how it can provide information on coastal change. A ranking approach was used across the data sources in order to extract information on sites of highest potential to inform on coastal change, this helped target sites for more detailed investigation. It also demonstrated where sites or areas of the coast were represented within several of the available data sources. Detailed results of each case study area can be found in Section 3.

4.1.1. Archaeology, Heritage and Palaeoenvironmental Data

A total of 3150 archaeological and palaeoenvironmental sites were assessed across the partner case study areas. It should be noted that the distribution and number of sites depicted on the map does not mean there are more sites in any one partner country but reflects the size and number of case study areas and the amount of data available for the study. The table below lists the highest ranking sites, the locations are shown in Figure 4.1.

UID	SITE NAME	COUNTRY	CASE STUDY AREA	PERIOD	SITE TYPE	TOTAL SCORE	BROAD E'MENT
27	CROOKLETS BEACH - Prehistoric Remains	UK	North Cornwall/Devon	Prehistoric	Submerged landsurface	100	Marine
361	SAINT-MICHEL-EN-GREVE - Croix de Mi-Lieu	France	Leguer Estuary	Medieval	Monument	100	Intertidal
700	SAINT-MICHEL-EN-	France	Leguer Estuary	Roman	Other	100	Intertidal

	GREVE - Roman road						
1297	HOEDIC - Douet alignement	France	Quiberon Peninsula	Neolithic	Monument	100	Coastal
1298	HOEDIC - Groah Denn alignement	France	Quiberon Peninsula	Neolithic	Monument	100	Coastal
600	PITTS DEEP - Submerged Peat Deposits	UK	Solent/Isle of Wight	Prehistoric	Submerged landsurface	100	Marine
708	BULVERHYTHE - Submerged Forest	UK	Hastings	Prehistoric	Submerged landsurface	100	Marine
707	BOULDNOR - Submerged Mesolithic landscape	UK	Solent/Isle of Wight	Mesolithic	Submerged landsurface	100	Marine
713	LITTLE GALLEY HILL - Submerged Forest	UK	Hastings	Bronze Age	Submerged landsurface	100	Marine
457	LANNION - Petit Taureau	France	Leguer Estuary	Early Medieval	Marine installation	100	Intertidal
1074	SAINT-PIERRE-QUIBERON - Ile Guernic	France	Quiberon Peninsula	Neolithic	Other	100	Coastal
1163	SAINT-PIERRE-QUIBERON - Kerbourgnec	France	Quiberon Peninsula	Neolithic	Monument	100	Intertidal
1166	SAINT-PIERRE-QUIBERON - Petit Rohu	France	Quiberon Peninsula	Neolithic	Other	100	Intertidal
324	RUSSELLS LAKE - Prehistoric Forest	UK	Langstone Harbour	Prehistoric	Submerged landsurface	100	Marine
1213	QUIBERON - Beg er Vil	France	Quiberon Peninsula	Mesolithic	Other	100	Coastal
313	DOELPOLDER NOORD – buried landsurface	Belgium	Scheldepolders	Prehistoric	Buried lansurface	100	Coastal
2446	WAASLAND POLDERS – buried landsurface	Belgium	Scheldepolders	Prehistoric	Buried lansurface	100	Coastal
339	BAKERS RITHE - Prehistoric Forest	UK	Langstone Harbour	Prehistoric	Submerged landsurface	100	Marine
604	HURST SPIT - Hurst Castle	UK	Solent/Isle of Wight	Medieval	Coasal defense	100	Coastal
1491	HOEDIC - Sterflant	France	Quiberon Peninsula	Iron Age	Other	88	Coastal
1494	RAVERSIJDE - peat excavation	Belgium	Raversijde	Roman	Submerged landsurface	88	Intertidal
1285	ILE D'HOUAT - Ile aux chevaux	France	Quiberon Peninsula	Mesolithic	Other	88	Coastal
711	HASTINGS - Submerged Forest	UK	Hastings	Unknown	Submerged landsurface	88	Marine
686	TREBEURDEN - Enclosure	France	Leguer Estuary	Medieval	Other	88	Coastal
687	PLESTIN LES GREVES - Railway	France	Leguer Estuary	Inter-war	Monument	88	Coastal
716	PENNINGTON MARSHES - Peat	UK	Solent/Isle of Wight	Unknown	Submerged landsurface	88	Marine
717	PYLEWELL LAKE - Peat	UK	Solent/Isle of Wight	Unknown	Submerged landsurface	88	Coastal
718	RIVER YAR - Peat	UK	Solent/Isle of Wight	Unknown	Submerged landsurface	88	Marine
712	HAWKERS LAKE - Submerged Peat	UK	Solent/Isle of Wight	Unknown	Submerged landsurface	88	Marine
714	OXEY MARSH - Submerged Forest	UK	Solent/Isle of Wight	Unknown	Submerged landsurface	88	Marine
715	PEGWELL BAY - Submerged Forest	UK	Solent/Isle of Wight	Unknown	Submerged landsurface	88	Marine
719	TANNERS HARD - Submerged Forest	UK	Solent/Isle of Wight	Unknown	Submerged landsurface	88	Marine
1083	SAINT-PIERRE-QUIBERON - Groh-CollÃ©	France	Quiberon Peninsula	Neolithic	Other	88	Coastal

1161	QUIBERON - Port Haliguen fishtraps	France	Quiberon Peninsula	Bronze Age	Marine installation	88	Intertidal
1162	QUIBERON - Saint Julien fishtraps	France	Quiberon Peninsula	Bronze Age	Marine installation	88	Intertidal
1581	PAKEFIELD - Submerged Forest	UK	East Anglia	Palaeolithic	Submerged landsurface	88	Intertidal
2460	HASTINGS – significant prehistoric finds	UK	Hastings	Prehistoric (multi)	Other	88	Coastal
705	HURST CASTLE SPIT - Core Samples	UK	Solent/Isle of Wight	Prehistoric	Other	88	Marine

Table 4.1. Highest scoring archaeological and palaeoenvironmental sites from all partner case study areas.

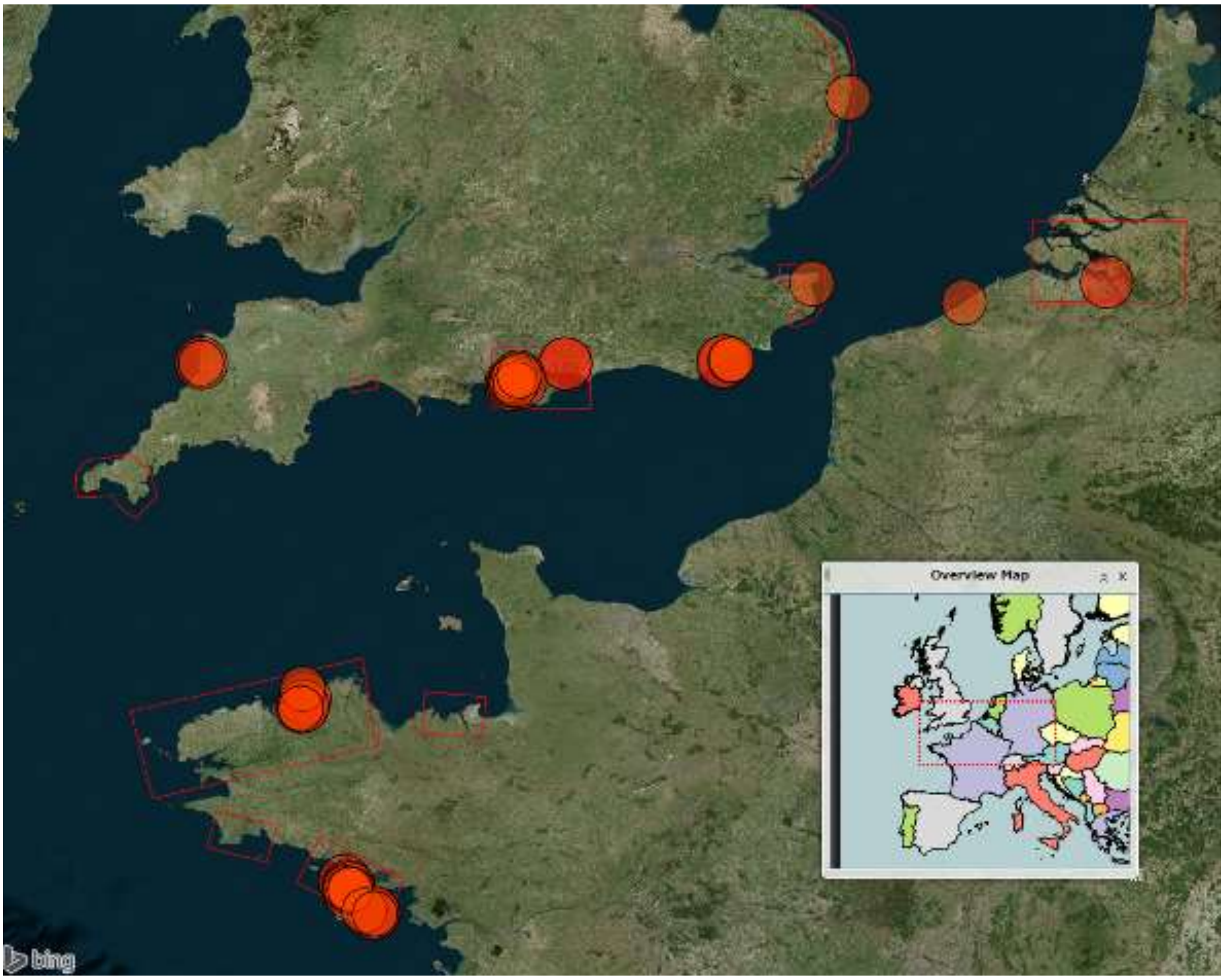


Figure 4.1. Map showing the location of the highest ranking archaeological/palaeoenvironmental sites assessed during the project.

The highest ranking sites range from the Mesolithic to modern times and are found both in the marine and intertidal zones as well as on the near shore coast. However, the majority of sites which ranked high are submerged landsurfaces. These are found in all partner countries and many contain long stratigraphical dated sequences that have been subject to detailed investigation. The ranking demonstrated that certain types of site and deposit can gain consistent positive scores for their potential to inform on coastal change. Five of the sites which ranked high: Bouldnor Cliff, Langstone Harbour, the Leguer Estuary, Raversijde and Scheldt polders, were all investigated further through detailed fieldwork, fieldwork techniques applied are outlined in Section 2 of this report.

4.1.2. Art Representations

The ranking system for the artworks has provided a shortlist of those artists who depicted the coastline in the most accurate way, and armed with this information we can examine these artist's works and make qualitative judgments about long-term coastal change. In some cases, where artists were known for their particular attention to detail, for example the works by the Pre-Raphaelite artists and their followers in England, it may be possible also to assess quantitative changes (e.g. the extent of cliff retreat or beach change), particularly where structures such as lighthouses, fortifications, coastal protections or other historical ruins are located close to the coastline. In addition, beach conditions can be assessed when the level of the beach is shown in historical images, for example, adjacent to structures such as piers, breakwaters and sea walls.

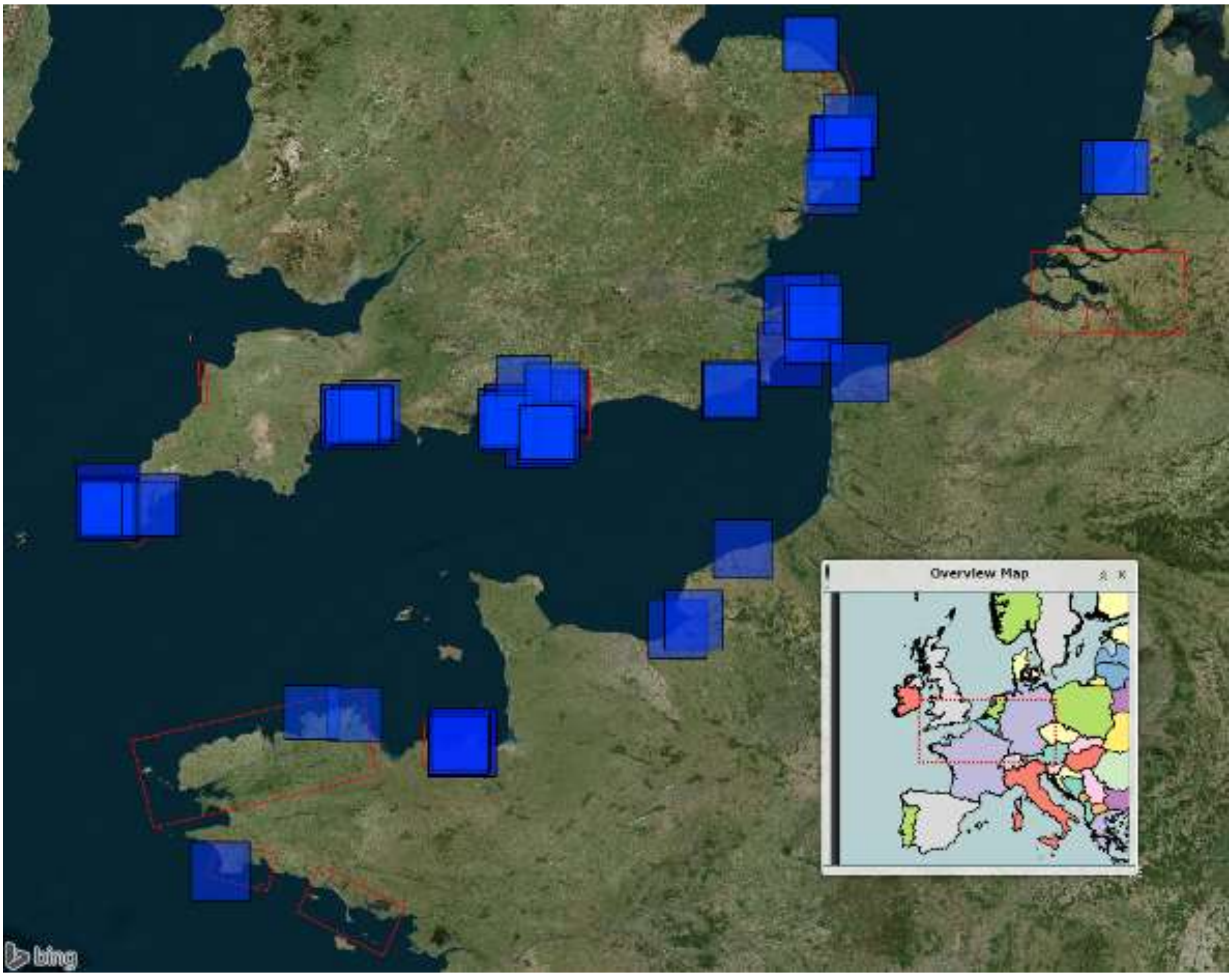


Figure 4.2. Map showing the location of the highest ranking artworks assessed during the project.

The table below provides a list of the highest ranking artists for each of the study areas, listing also the medium which the artist used most commonly and the typical scores that their works achieved. It should be noted that there were other artists who also painted these parts of the European coastline whose works lie outside the study areas.

East Anglia UK		
Artist	**Medium Used**	**Ranking Score**
Alfred Robert Quinton	Watercolour	70
Walter Frederick Osborne	Oil Painting	70
John Moore of Ipswich	Oil Painting	66
Myles Birket Foster	Watercolour	62
Alfred Heaton Cooper	Watercolour	62
Edwin Hayes	Oil Painting	59
Thomas Smythe	Oil Painting	55
John Varley	Watercolour	55
William Daniell	Engraving	55

East Kent UK		
Artist	**Medium Used**	**Ranking Score**
William Dyce	Oil Painting	62
Henry Pether	Oil Painting	55
William Daniell	Engraving	55

Hastings UK		
Artist	**Medium Used**	**Ranking Score**
Alfred Robert Quinton	Watercolour	70
William H. Borrow	Oil Painting	59
Charles A. Graves	Oil Painting	59
Edwin Hayes	Oil Painting	51

Solent/Isle of Wight UK		
Artist	**Medium Used**	**Ranking Score**
Charles Robertson	Watercolour	77
William Gray	Watercolour	44
William E. Atkins	Watercolour	70
Alfred Robert Quinton	Watercolour	70
William Westall	Engraving	62
Robert Brandard	Engraving	55
Clarkson Stanfield	Engraving	55
Henry Pether	Oil Painting	55
William Turner of Oxford	Watercolour	51

West Devon/East Dorset UK		
Artist	**Medium Used**	**Ranking Score**
Arthur Perry	Watercolour	70
J. Baker	Engraving	66
W. Dawson	Engraving	66
Daniel Dunster	Engraving	66
Alfred Robert Quinton	Watercolour	62

West Cornwall UK		
Artist	**Medium Used**	**Ranking Score**
Alfred Robert Quinton	Watercolour	70
John Brett	Oil Painting	62
John Mosford	Oil Painting	59
William Daniell	Engraving	55

Brittany France		
Artist	**Medium Used**	**Ranking Score**
Eugène Isabey	O/WC/E	74
Paul Sébillot	WC/P/E	62
Theóphile Busnel	WC/P/E	62
Maxime Maufra	O	59
Duroy Bateau	WC/P/E	59
Alexandre Nozal	WC/P/E	59
Theodore Godin	O	55
Henry Riviere	WC/P/E	55
Emmanuel Lansyer	O	51
Gaston de Latiney	WC/P/E	51

Key	
Watercolour	WC
Engraving/Etching	E
Oil Painting	O
Pencil	P

Table 4.2. Highest ranking artists from the case study areas.

4.1.3. Map Representations

A total of 101 maps from the partner counties were evaluated based on topographic, geometric and chronometric accuracy (Figure 4.3). These maps ranged from small to large scale and date from as early as the 16th Century. The ideal way to analyse coastal evolution through historical maps is by integration into a GIS (for instance ArcGIS or QuantumGIS) making it possible to georeference the maps and to make diachronical series' of coastal evolution based on the historical maps by digitizing the parts of interest in the form of points, lines or polygons. Hereafter, quantitative analysis on the observed changes is possible. Additional data, for instance physical data, artworks or historical photographs, can be integrated easily.

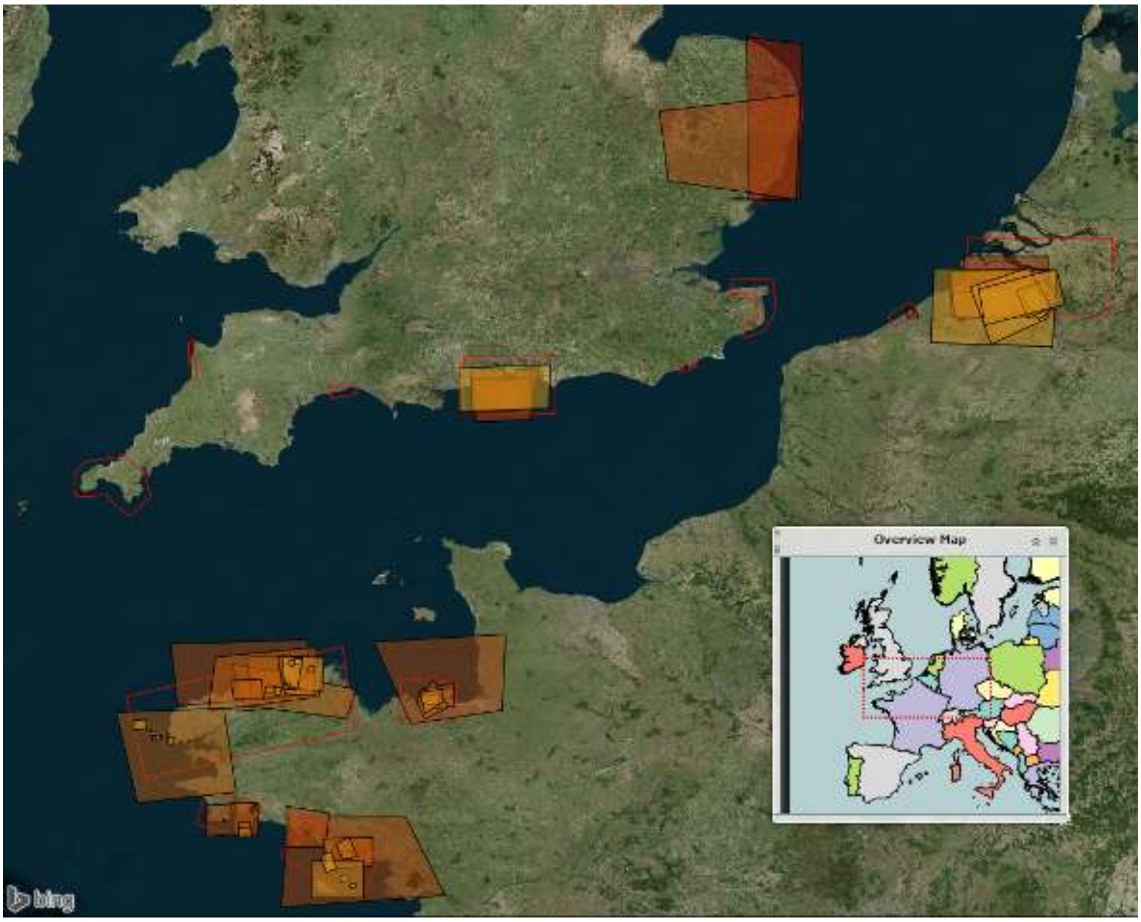


Figure 4.3. Location of historic maps assessed. The outline represents the area covered by the map, the colour reflects the ranking results – red is higher and yellow is lower.

In terms of topographical accuracy the maps varied widely, but many of them proved to be rich in detail. Key factors influencing the level of accuracy were the scale and purpose of the map. Key factors influencing the geometric accuracy were: the date of production with accuracy increasing through time, although some exeptions to this were found, the scale of the map with large scale maps being most useful for coastal research, and the reason the map/chart was produced impacting detail in particular areas. The chronometric accuracy varied largely due to the amount of detail available on the origin and date of the map or chart. While some included date of production, whether a copy or orignial or the measurements it was based on, others had little information on their origin or context.

MAP_uid	Title	Year	Case Study Area	Total Map Score
148	Hurst Spit to the Isle of Wight	1934	Solent/IOW	88.6
125	Kaart en meting van de schorren gelegen voor de polders van Nieuw-Arenberg en Kieldrecht	1816	Scheldt polders	87.5
89	Plan du terrain au dessus du moulin du Boschet	1756	Cote d'emeraude	87.5
144	A Plan of Hastings and St Leonards	1890	Hastings	85.83
146	England South Coast	1848	Langstone	83.3
141	OS map 1st edition	1880	East Anglia	81.6
123	Kaert Figuratif vande geprojecteerde Dyckague vanden Nieuwen Arenberg Polder	1783	Scheldt polders	80.8
107	Plan de Concarneau	1764	Cote d'emeraude	76.6
137	Hydrographical map of the river Scheldt	1892	Scheldt polders	75
98	Carte hydrographique, topographique et archaeologique du golfe du Morbihan et de son littoral	1869	Quiberon	75
124	Plan van de blicken ende schorren onder de jurisdictie van Kieldrecht	1783	Scheldt polders	75

Table 4.3. Highest ranking maps from across the partner countries.

Maps ranked highly across the case study areas, this highlights the potential of this resource, and the analysis of this for understanding coastal change is detailed below. The main focus has been on the Scheldt polders area, but the results of the ranking demonstrates the potential for further work on the other case study areas. The highest ranking maps are listed in Table 4.3 above. Although direct comparisons between the maps and the current situation can be made and are useful, the highest resolution data is available when a series of maps depicting the same area over several hundred years can be analysed, this has been achieved in the Scheldt polders study area, see Section 4.2.3 below.

4.1.4. Historic Photographs

A total of 1115 historic photographs and postcards were assessed as part of the project, the photos were ranked based on the potential they have to provide information on the changing coast. Photos were generally selected from areas along the coast where historic paintings and archaeological sites were also known. It should be noted that this study is not intended to be exhaustive, it simply aims to highlight the potential for historic photos to provide information on coastal change. Historic photos were mainly assessed in the UK and French case sudy areas, with some examples from the Dutch and Belgian coasts. Figure 4.4 shows the location of the highest ranking photographs.

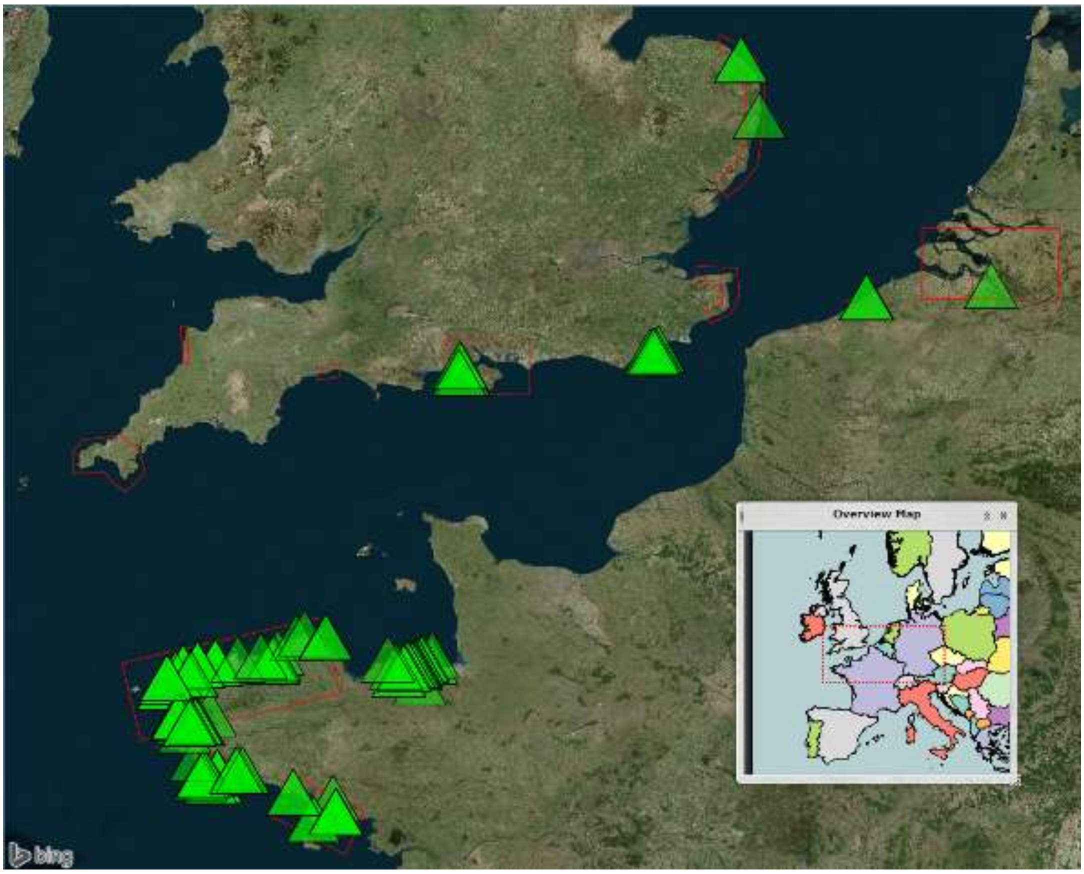


Figure 4.4. Location of the highest ranking historic photographs assessed.

Unlike the artworks, maps and charts, the historic photographs did not need to be assessed for their reliability. Photographic images capture detailed and objective views of the coast's composition, providing quantifiable representations that could be used for comparative analysis. The photographs were ranked based on their usefulness in supporting understanding of long term coastal change, this was primarily based on the subject matter.

Img_uid	Title	Year	Score Heritage View	Case Study Area	Physical Image State	Total Score
1200	Lymington River and the Solent	1952	High	Solent/IOW	Good	100
1201	Hurst Castle & Lighthouse	1953	High	Solent/IOW	Good	100
69	Yarmouth Harbour	1910	High	Solent/IOW	Good	100
998	Er Lannic	1920	High	Quiberon	Good	100
147	Men Ozac'h	1900	High	Northern Finistere/Tregor	Good	100
159	Allée couverte Kernic	1920	High	Northern Finistere/Tregor	Good	100
1198	Oostende - Kursaal	1899	High	Oostende/Raversijde	Good	100
1196	De molen van Doel	1900	High	Scheldt polder	Good	100

Table 4.4. Table of a selection of high ranking photographs from across the partner countries.

Many of the high ranking photographs in the French case study areas depict prehistoric monuments including passage graves and megaliths which are now partially or fully submerged. In the UK high ranking photographs include those that depict heritage features including castles and lighthouses. All of these can be compared to the present day situation, using the heritage feature to measure change against, they can also be compared to archaeological data where the environment in which the feature was constructed is known.

4.2. Measuring the Scale and Rate of Coastal Change

All those involved in coastal management have a requirement for high quality data and a thorough understanding of the physical processes at work around the Channel-Southern North Sea coastlines. An appreciation of the impacts of coastal evolution and processes is fundamental if we are to understand and manage our frontages in the most effective way. Long term coastal monitoring is increasingly recognised as an invaluable data source to support coastal risk management, as well as providing information to assist, for example, the design and construction of coastal defence measures, which can, as a result be commissioned with greater confidence in the efficiency of design.

Future requirements for coastal management can be established more accurately using monitoring data, which may change the risk management philosophy from a reactive to a more proactive one. However, for many parts of the coastline of the Channel-Southern North Sea, coastal monitoring is a relatively recent innovation with few stretches of the coastline having been monitored for longer than twenty years. The aim of Arch-Manche is, therefore, to raise awareness of the potential of these currently under-used tools (archaeology, palaeoenvironment, artworks, photography and cartography) to support our understanding, and to extend the time line of information back by hundreds and even thousands of years.

This section looks at how the data sources described above have been used to measure the scale and rate of coastal change and their relevance to coastal management. Detailed results and analysis can be found in the individual case study reports (Section 3).

4.2.1. Analysis of Archaeological and Palaeoenvironmental Data

As mentioned above over 3000 sites were assessed as part of the project and six sites were selected for detailed fieldwork and investigation. Information from these sites tells us about the scale and rate of coastal change in these areas across the Channel and Southern North Sea regions. Sites in the region from the Mesolithic period contain evidence of rapid sea level rise as thousands of kilometres of inhabited land were lost to the sea, current climate change models predict future increases in sea level, making inundated Mesolithic sites in particular, important case studies for coastal management. Archaeological research in such sites can also contribute new sea level index points, providing valuable information to improve existing climate change models.

Palaeoenvironmental data provides evidence of past landscapes from early prehistoric times through to the present. Analysis reveals evidence of the environment including plants, animals and insects, the types of soils, and whether it was dry, damp or wet, saline or brackish. Recording changes to these environments demonstrates the impact of rising or falling sea levels and relationships with coastal adaptations. Humans have used the coastal zone for thousands of years, the position of settlements shows the proximity to coastal areas, meanwhile specific features like trackways to cross marshy areas show adaptations to marine environments. Studying the archaeological record can demonstrate how humans adapted to change, and in more recent times, how they effected change. The sites targeted for detailed fieldwork are shown in Figure 4.5.

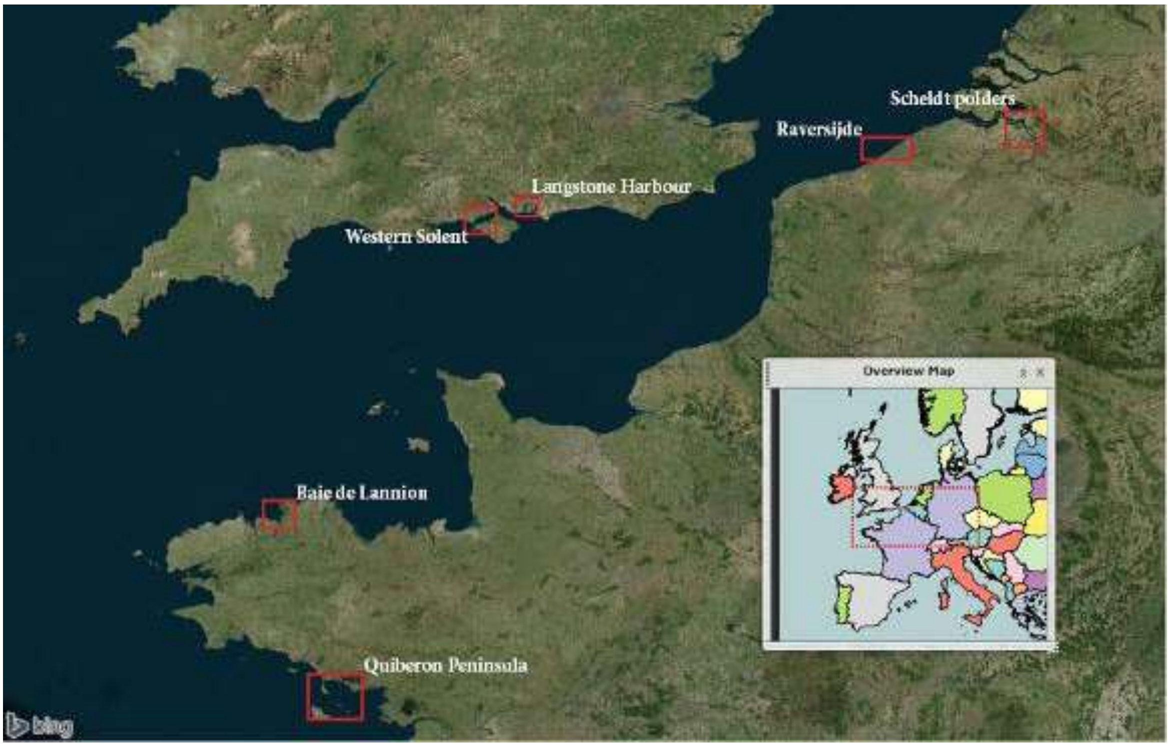


Figure 4.5. Location of fieldwork sites selected for detailed investigation.

The results of the analysis on a selection of these sites and what they can tell us about coastal change are detailed below. Full details can be found in the relevant case study reports.

Langstone Harbour

Langstone Harbour is a large, shallow marine inlet on the south coast of England that has a long archaeological record of occupation and use, stretching from the early Palaeolithic right through to the present day. The harbour is an eroded inland basin within which the islands at the northern end contain the remaining in-situ archaeological deposits, now threatened by coastal erosion. See case study report 3D for more detailed information. At the case study site of Langstone Harbour data from archaeological surveys has been used to model the evolution of the harbour from the Mesolithic to modern times.

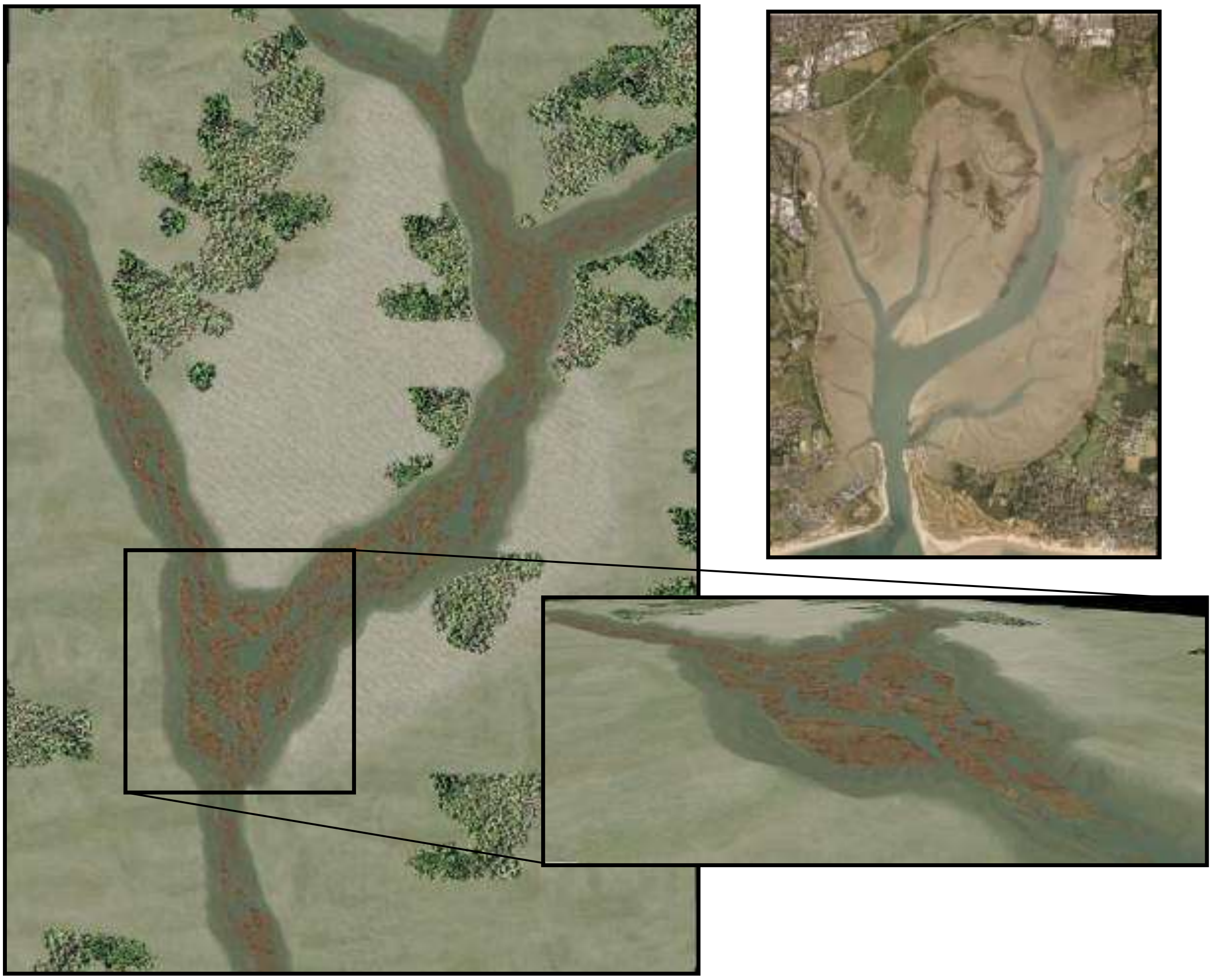


Figure 4.6. Reconstruction of Langstone Harbour during the Mesolithic period, above right: Langstone Harbour in 2013, aerial photography courtesy of the CCO. .

In the Mesolithic period Langstone Harbour was an inland site, the landscape was dominated by a valley with steep sides leading down to fresh water streams. The two deep ravines were up to 150m wide in places and the area now forming the harbour was some 14m above the ravine floors (Allen & Gardiner, 2000:203). Environmental data demonstrates that the land above the ravines was a rich and diverse landscape consisting of a mixed forest attractive to human populations, this is further reinforced through the array of flint tools found across the harbour. By the Neolithic the valley became in-filled with organic material giving it a more shallow gentle profile and by the Bronze Age the area developed towards a stronger marine environment made up of salt marsh and tidal rivers. A small rise in sea level during the Iron Age made the area much wetter and the now, almost non-existent valley was flooded.

The project has built on the work carried out in the 1990's as part of the Langstone Harbour Project (Allen & Gardiner, 2000). Fieldwork in 2012 and 2013 focussed on augering off the islands in the north of the harbour and a marine geophysical survey to track the buried palaeochannels. A seismic profile in the main Langstone Channel shows a large buried palaeochannel which may be evidence of the deep ravine from the Mesolithic period.

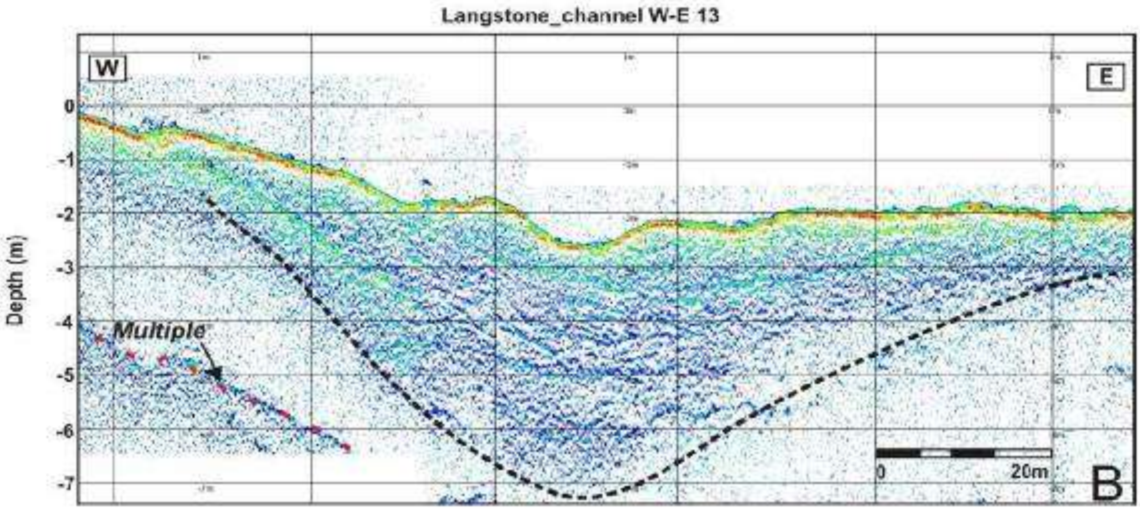


Figure 4.7. Seismic profile in Langstone Channel showing a large buried palaeochannel.

Shallow palaeochannels in the area of the Bakers Rithe and Russels Lake submerged forests were also tracked. Bakers Rithe submerged forest was dated to 2310-1950 Cal BC and Russels Lake dates from 3350-2910 Cal BC (Allen & Gardiner, 2000:89-90). By this time the earlier ravines had become infilled and were much shallower, this is demonstrated by the large palaeochannels found during the seismic survey, these had a shallower and more gentle profile.

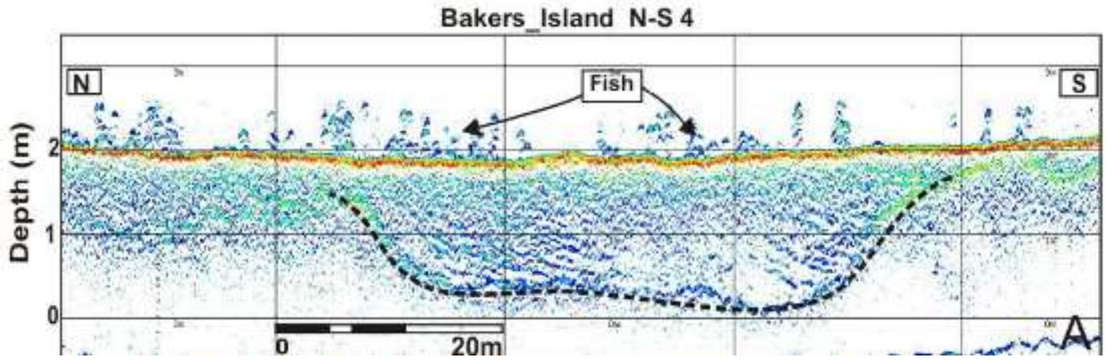


Figure 4.8. Seismic profile showing a large buried palaeochannel (black dashed line) in the area of the submerged forests.

Combining this data has facilitated the creation of a 3D reconstruction of the harbour from the Mesolithic to the current day. The timescale can be changed by the user so it is possible to see how the harbour evolved, adding a fourth dimension. The model can be viewed through the Arch-Manche portal www.archmanche-geoportal.eu

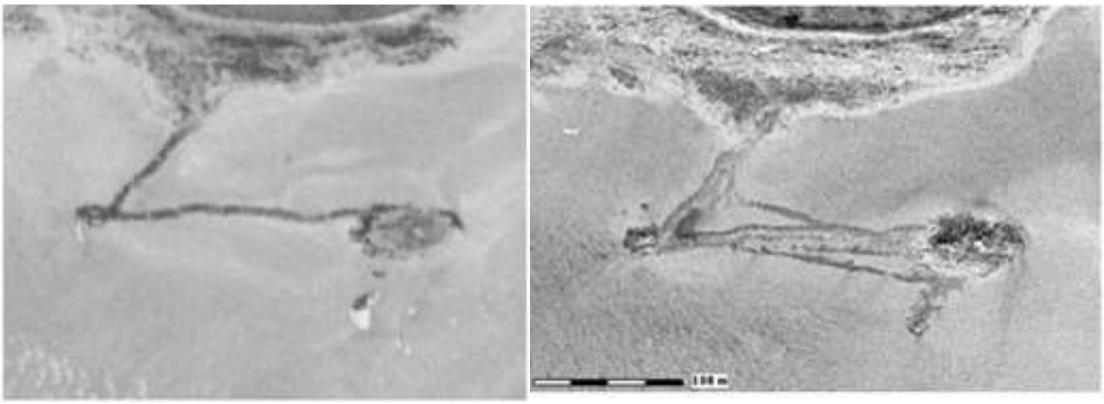
Lannion

Archaeological fieldwork was carried out on fish traps along the Léguer estuary in the Bay of Lannion (see case study report 3I for full details). The focus of the fieldwork was on the Petit Taureau fish trap which represents several phases of development. This area of the coast is subject to intensive erosion, accelerated by sudden climatic events such as storms. As well as this the area is at risk from human activities including marine aggregate and sand extraction.

The fish traps can provide important information on past coastal and sea level change, the level at which they are built provides precise indications of the local sea level as they are built at a very specific height in order to work, the fish trap dam stops being efficient when it is no longer accessible at low tide. Many older fish traps are now completely submerged in the mouth of the estuary, with time they were progressively built upstream. As well as rising sea levels affecting the efficiency of the traps, they are also impacted by changing sediment levels as they trap the sediment, raising the level of the seabed and again causing the trap to become less efficient.

Fieldwork on the Petit Taureau fish trap revealed four phases of construction, the earliest phase dates to the 7th Century AD and the latest stage dates to the 15th Century AD. The evidence demonstrates that the fish trap needed to be re-built several times, and it is thought this is due to the impact of the trap on sediment flow, as people had to continually modify the shape of the trap with the changing environment.

Fish traps can therefore not only be used as sea level indicators but can also provide information on how such structures impact the sediment regime, both of which are useful for coastal managers. Later work on this site has also been used to look at more recent changes in sediment levels, aerial photographs of the site from 1952 only show one of the construction phases, by 2000 all are visible (Figure 4.9).



1952 2000

Figure 4.9. Comparison of 1952 and 2000 aerial photography demonstrating the changing sediment levels on the Petit Taureau fish trap (after IGN – Geoportail).

Studying and dating a large number of fish traps will provide further sea level index points and can be used to reconstruct the changing sea level and sediment dynamics along the coast. Many sites like this have been used to provide accurate data in the creation of local sea level curves and more recently they can provide information on the impact of sand extraction on the local environment, as shown in Figure 4.9.

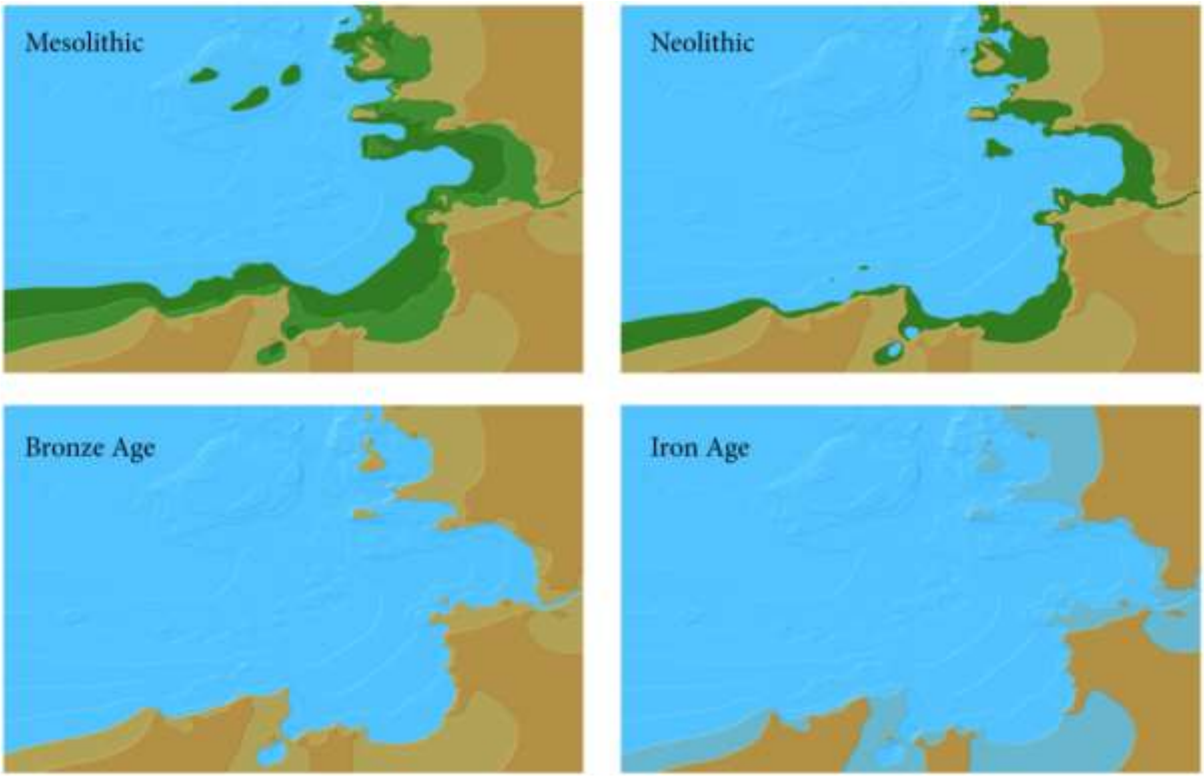


Figure 4.10. The changing coast of the Bay of Lannion from the Mesolithic to the Iron Age.

Data from this area has also been used to create a 3D model of the changing landscape from the Mesolithic to the Iron Age (Figure 4.10), the model is available through the Arch-Manche portal www.archmanche-geoportal.eu.

Scheldt Polders

The Scheldt polders case study was chosen due to its potential to provide data for palaeogeographical landscape reconstruction. It is an area where interactions between nature and humans are intensely intertwined and is a valuable example of how environmental change affects human life, but also the capability of humans to sculpt a landscape. Much of the area is under imminent threat from harbour extensions and de-embankment. See case study 3M for full details.

In the Scheldt polder samples extracted through coring have been used to gather data on past landscapes. Both existing and new samples were analysed to record changes in sediment types with depth. Sediments contain archaeological and climatic details of the surrounding environment at the time they were laid down. As the layers built up this created a sequential record of events. This data allowed the progressive development of archaeological landscapes to be reconstructed. The presence and absence of silt and peat layers showed the relationship between natural inundations and those instigated by humans.

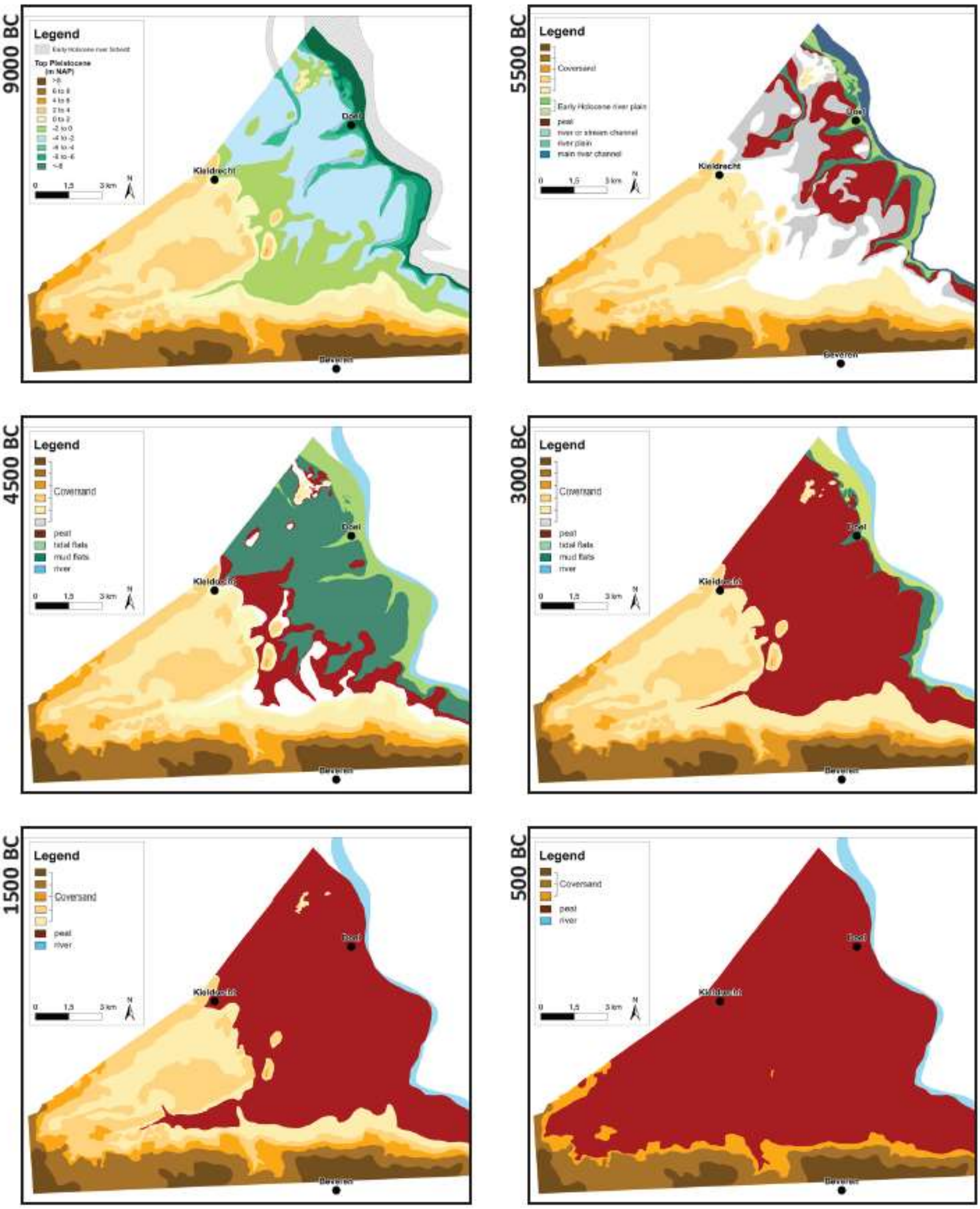


Figure 4.11. Series of palaeogeographical maps of the Waasland Scheldt poders from 9000BC to 500BC (courtesy K.Heirman, UGent).

This data allowed a series of palaeogeographical maps from 9000 BC to 500 BC to be created (Figure 4.11), these 2D reconstructions demonstrate how the landscape evolved over time, this is then complemented by later work reconstructing the landscape in the Post Medieval period based on historic maps, see below (section 4.2.3).

Southwestern Netherlands

Two sites were studied in detail in the Southwestern Netherlands. At the Verguldе Hand West site data from large-scale archaeological excavations from the Middle Bronze Age to the Middle Ages is brought together with geological research in order to reconstruct past palaeoenvironments. The history of this landscape is intrinsically linked to human occupation and activity. Due to the extensive geological, palaeoenvironmental and archaeological research the landscape and occupation history can be reconstructed in detail. The landscape history has been visualised in a series of local palaeogeography maps from 1600 BC to 1050 AD and in profile reconstructions from 550 BC to 2000 AD. Full details are available in case study report 3N.

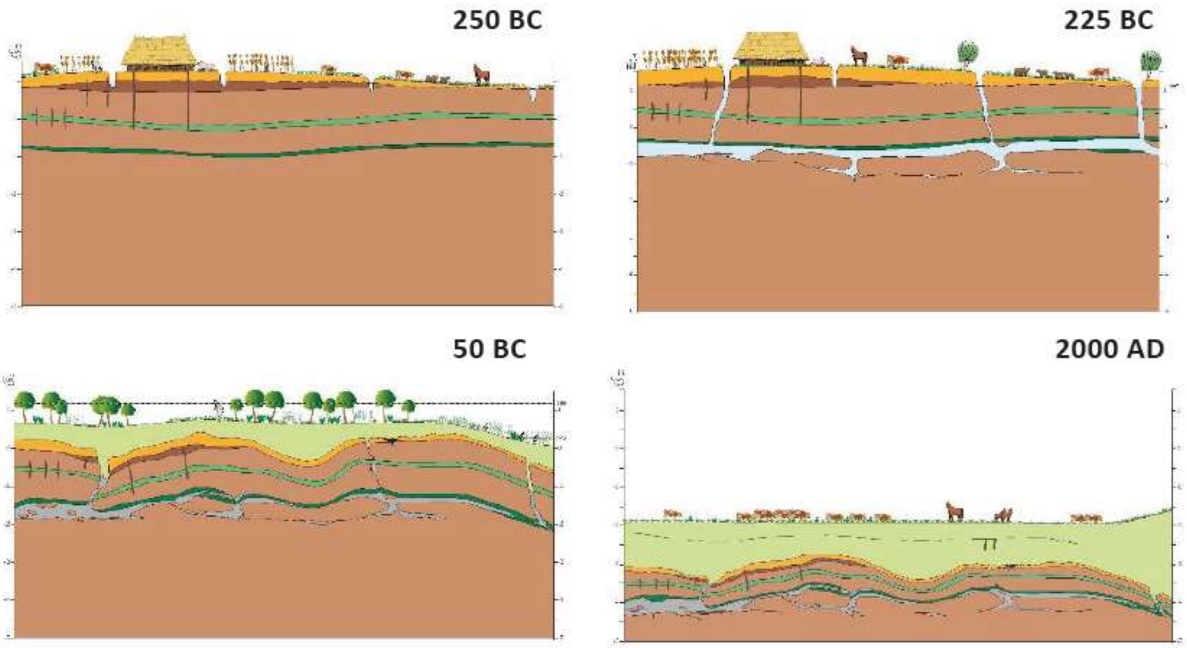


Figure 4.12. 2D profile reconstructions from the site of vergulde Hand West (courtesy Vos, P.C. & Y. Eijskoot, 2009. Geo- en archeologisch onderzoek bij de opgravingen van de Vergulde Hand West (VHW) in Vlaardingen. Deltares-rapport, 0912-0245, 160 pp.).

Data from the Yangtze Harbour site in the Netherlands has been used to develop models of the Mesolithic landscape which had been drowned and buried below current seabed levels. In addition to modelling the landscape form, data from palaeoenvironmental work and archaeological analysis was used to generate illustrative presentations of the past landscape. The area was mostly a dry river plain around 9000 BC, by 7250 BC large parts of the area became wetland and over time the habitable areas became much smaller, the landscape was then rapidly drowned around 6500 BC.

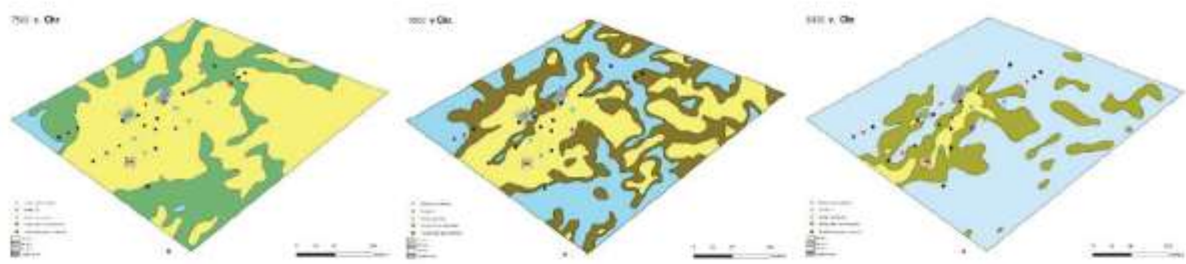


Figure 4.13.2D plan view reconstructions of Yangtze Harbour (courtesy P.Vos, 2013, Deltares).

The Southwestern Netherlands is also a valuable case study site in assessing the impact of human influence on coastal change, particularly during the Roman period. Tidal channels through coastal barriers were used to drain the high peat areas in the hinterland. The drained peat areas became habitable and the peat was also extracted on a large scale. However, because of the lowering of the surface major parts of the peat areas were flooded and the tidal channels increased in size eroding the peat near the tidal outlets. By about 270 AD a self-reinforcing process of peat erosion, lowering of the surface, increase in tidal storage capacity and expansion of tidal channels came into being causing the Roman peat excavation areas to be completely submerged by 350 AD such that habitation and peat excavation in those areas had become impossible. The process of drowning of peat areas continued there until about 800 AD when almost the whole of Zeeland was flooded.

4.2.2. Analysis of Artworks

The popularity of the seaside particularly during the nineteenth and early-twentieth centuries, has meant that there is excellent coverage of many parts of the Channel - Southern North Sea coastline. This includes both original paintings and watercolour drawings but also kinds of engravings, many of which were included in illustrated topographical and travel books and guides. The same artists would often return to the spot many times to re-paint or update a particular view as the coast changed and expanded over that time period. Where one is confident of the accuracy of the artist, it is, therefore, useful to examine a sequence of their work or to group artists' works together to help increase understanding of a particular location.

Desk studies and fieldwork at the case study sites have sought to use data from the historical images to illustrate those aspects of coastal change that are of particular importance to the wide range of scientists, managers and stakeholders with an interest in coastal risk management. The following section provides some examples of how such historical images can be examined and interpreted, explaining the information that they provide. These include examples of hard cliffs, coastal cliff instability, soft cliffs, beaches, low-lying coastlines and locations where art can illustrate understanding of environmental change. Furthermore, some artworks suggest no significant change since they were painted, when compared with the present day situation. This does not of course mean that there have not been fluctuations in, for example, beach levels over the intervening period, but the overall situation would suggest a status quo over the time period concerned.

The analysis of a selection of artworks is presented below, for more details see the case study reports in Section 3.

Hard Cliffs – Saint-Matthieu, France, *cap abbaye et phare*

The engraving by Félix Benoist (Figure 4.14) shows the ancient (Pre-Cambrian) hard rock coastline at the western tip of the Brittany peninsula near the port of Brest. The cliffs have been subjected to aggressive marine erosion and weathering over the last 150 years and some changes to the cliff can be observed today (see areas hatched in red). Such images may also depict development and environmental changes that have taken place over the intervening period. As might be expected such durable coastlines remain similar in appearance to that portrayed by the artist in the nineteenth century.

Figure 4.14. Engraving by Félix Benoist of the Brittany Peninsula, compared with a photograph from 2013 (after Motte, 2013).

Coastal Cliff Instability – Ventnor, Isle of Wight, UK

Artworks can also be used in areas of coastal cliff instability, this has been particularly useful at Ventnor on the Isle of Wight. Ventnor undercliff is a 12km long coastal cliff and landslide complex between Luccombe and Blackgang on the south coast of the Isle of Wight. The Undercliff is regarded as one of the most unstable developed geological settings in the UK; the complex cliffs are formed from weak rocks that are sensitive to the effects of toe erosion and groundwater. There is concern that increases in relative sea level and winter rainfall will result in accelerated ground movement rates and more frequent landslide events over the next 100 years.

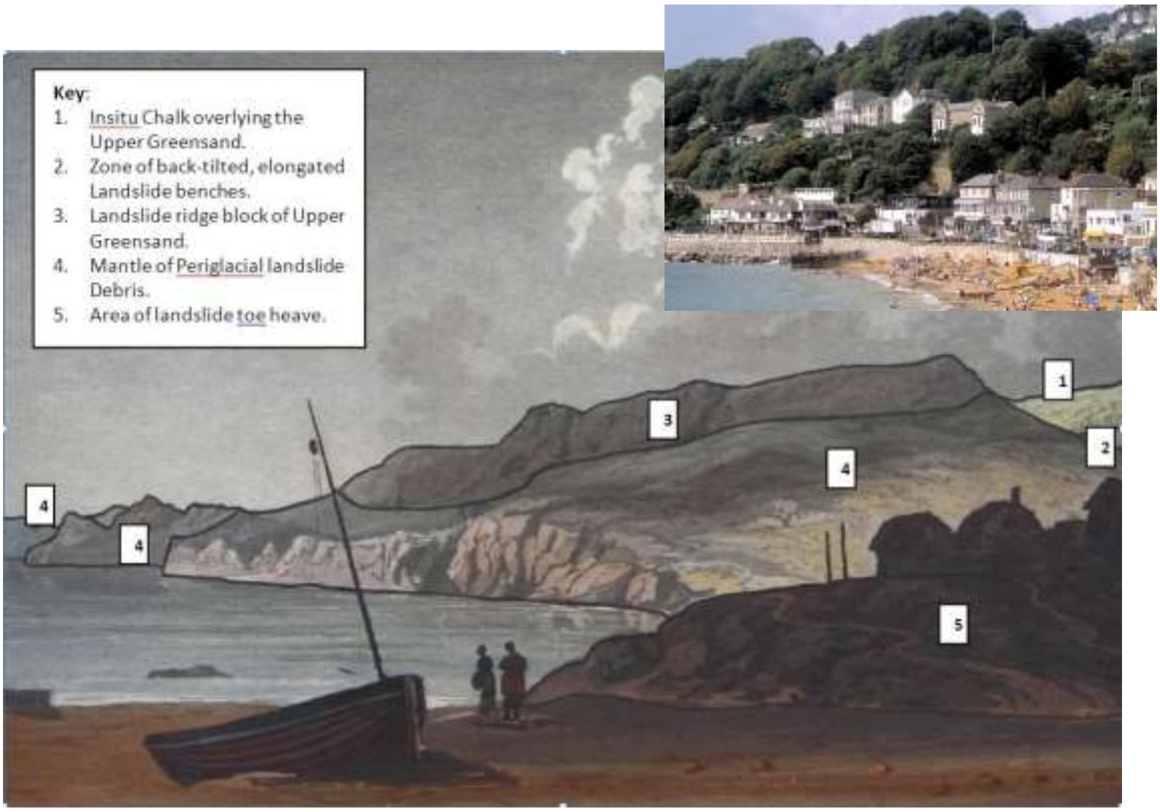


Figure 4.15. Ventnor Cove' by Charles Raye. 1825. The geomorphology of the seaward face of the Undercliff landslide complex is clearly visible compared with the present day view. Image courtesy R.McInnes.

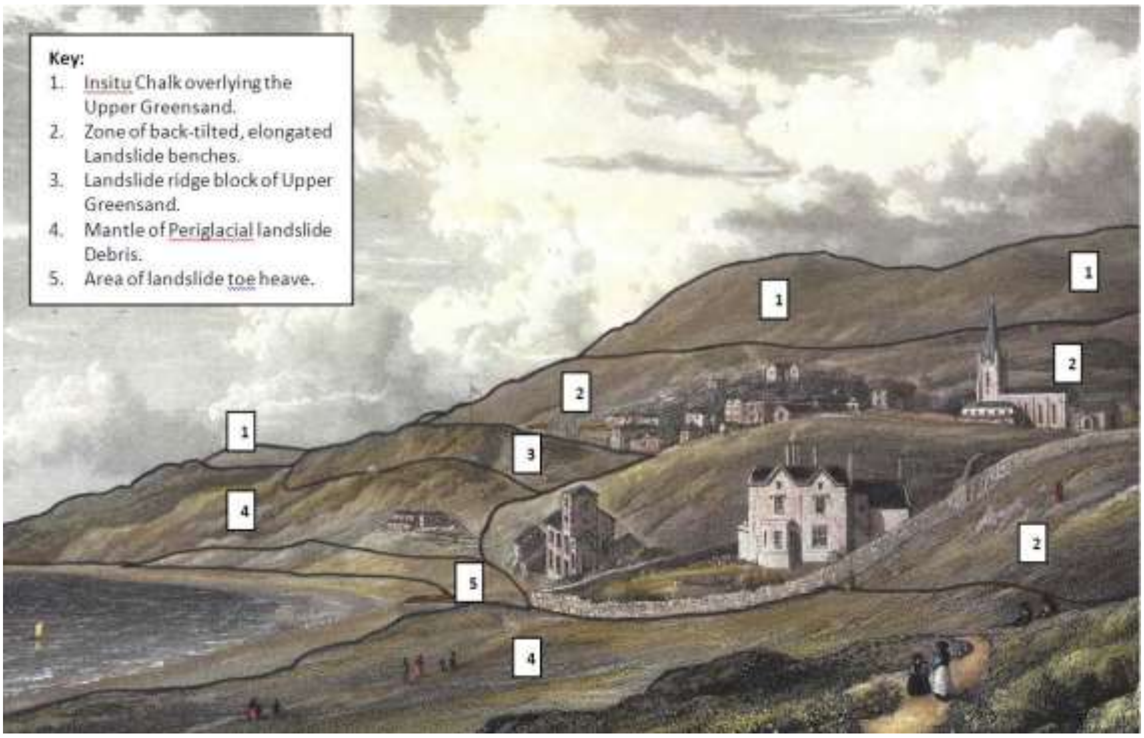


Figure 4.16. A view of the same location by William Westall is rather more extensive and even more detailed. Victorian and Edwardian development over the coastal slopes and planting and spread of the Holm Oak in the early 20th century now masks the geomorphology. Image courtesy R.McInnes.

Figure 4.17. 'Ventnor Beach' by Rock & Co. 1863. The view shows a rock formation seaward of the existing sea cliff. The rocks illustrated in this engraving, which have long since been lost to erosion, identified a former cliff line further seaward. Image courtesy R.McInnes.

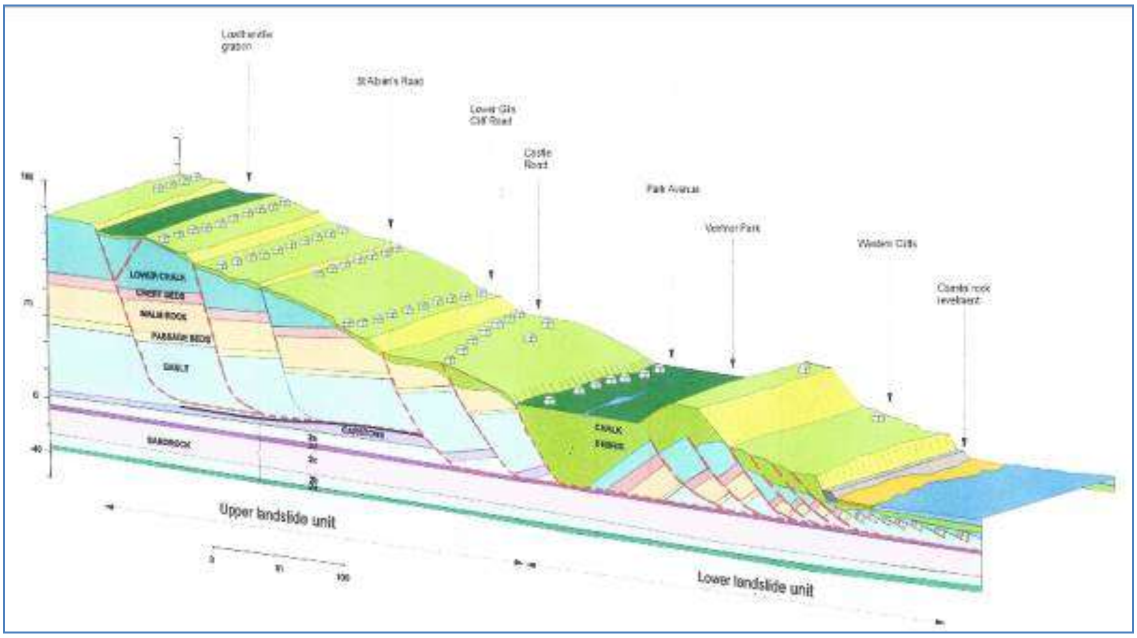


Figure 4.18. The rocks depicted in the engraving by Rock & Co have long since been lost through erosion, they identified a former cliffline further seaward and helped to develop this landslide model for the Undercliff (courtesy of Halcrow, 2006).

In recent years research has sought to understand more about the formation and development of the Undercliff landslide complex in order to support effective planning and risk management. A fundamental need was to understand how the landslide complex was formed and its extent seawards.

The paintings studied show the town of Ventnor before the coastal frontage was extensively developed from the 1830s onwards, allowing some of the main components of the landslide complex to be identified, as well as providing information on the former cliff line further seawards.

Beach Change – Saint-Malo, France, *Le grand Bé à mare basse*
Artworks have also been used to assess changes in beach levels, the example below is from Saint-Malo in France.

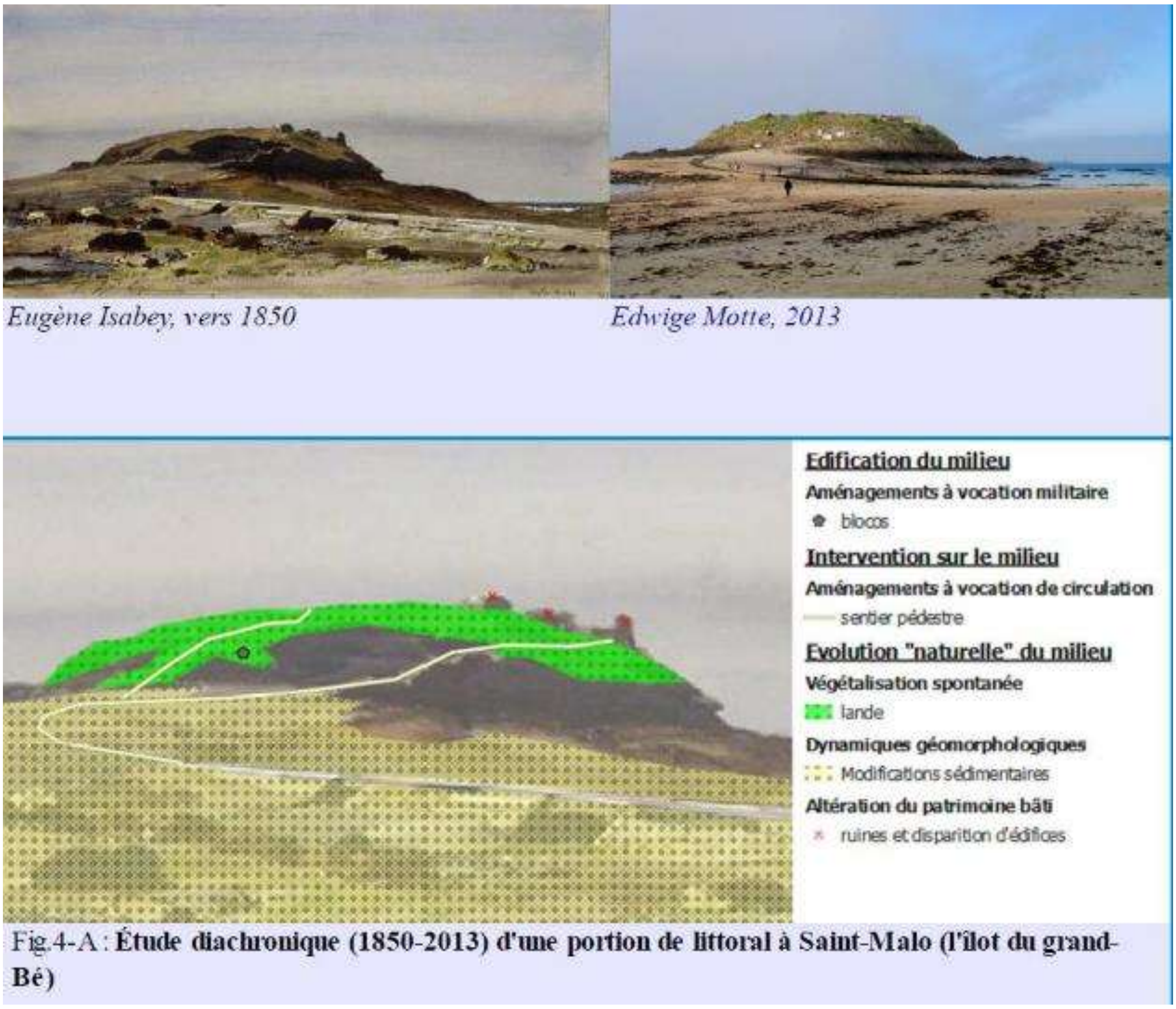


Figure 4.19. Painting of the Isalnd of Grand Bé at St Malo c1850, compared with a photograph from 2013 (after Motte, 2013).

Eugéne Isabey (1803-1886) produced numerous accurate paintings in oils along the Channel coasts of Brittany and Normandy. Her view, painted in about 1850, shows the Island of Grand Bé at St Malo at Low Tide. The present day view suggests that this beach has accreted significantly over time. Natural vegetation growth has also taken place on the island itself. The Bay of St Malo is exposed to significant storm surges with waves often overtopping the defences, so beach fluctuations can be expected. However, the painting of Isabey and the present day view confirm the healthy condition of the beach.

Low-Lying Coastlines – Brading, Isle of Wight, UK
William Daniell RA produced numerous aquatint engravings of the British coast between 1814 and 1825; he is regarded as one of the finest early topographical artists. His engraving of '*Brading, Isle of Wight'* (1823) is a good example of how artworks can be used for low-lying coastlines. The engraving was made before the harbour was reclaimed for agricultural use. A road and railway link was provided across the harbour together with a tidal embankment in the 1930s. The present day view is taken closer to the sea. The East Yar

river has been channelised and development has taken place at Bembridge (on the right). Artworks of this kind can record not just physical changes but also human intervention, which may result also in environmental change (Image courtesy: Wight Light Gallery).

Figure 4.20. 'Brading, Isle of Wight' (1823) by William Daniell RA. Image courtesy Robin McInnes

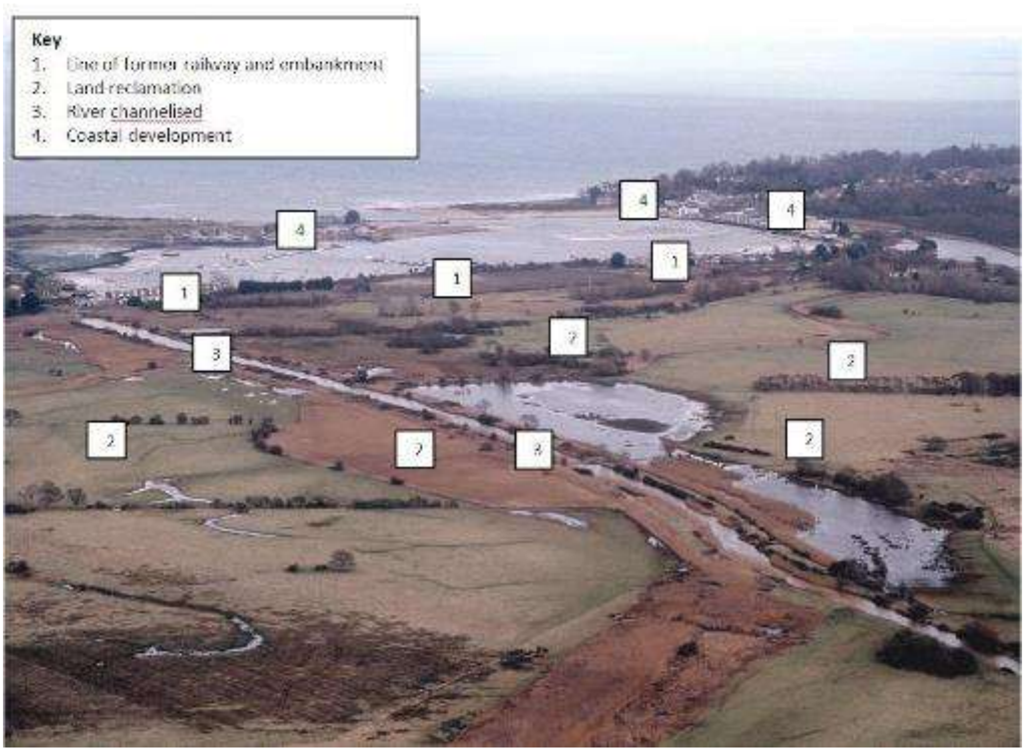


Figure 4.21. Present day view showing how the River Yar has been channelised and development has taken place at Bembridge (on the right). Image courtesy Wight Light Gallery.

4.2.2.1 Qualitative and Quantitative Assessments of Coastal Change

It has been demonstrated clearly through the case study examples how art can be used as a qualitative tool to support understanding of long-term coastal change. Also, however, where images are painted by high ranking artists, which include structures such as buildings or coast protection works (seawalls or groynes) it may be possible to measure or compare coastal change over time.

Figure 4.22. (above): Sidestrand Church Tower, Norfolk by Charles Frederick Rump shows the close proximity of the structure to the cliff edge (Image Courtesy: Sheringham Museum).

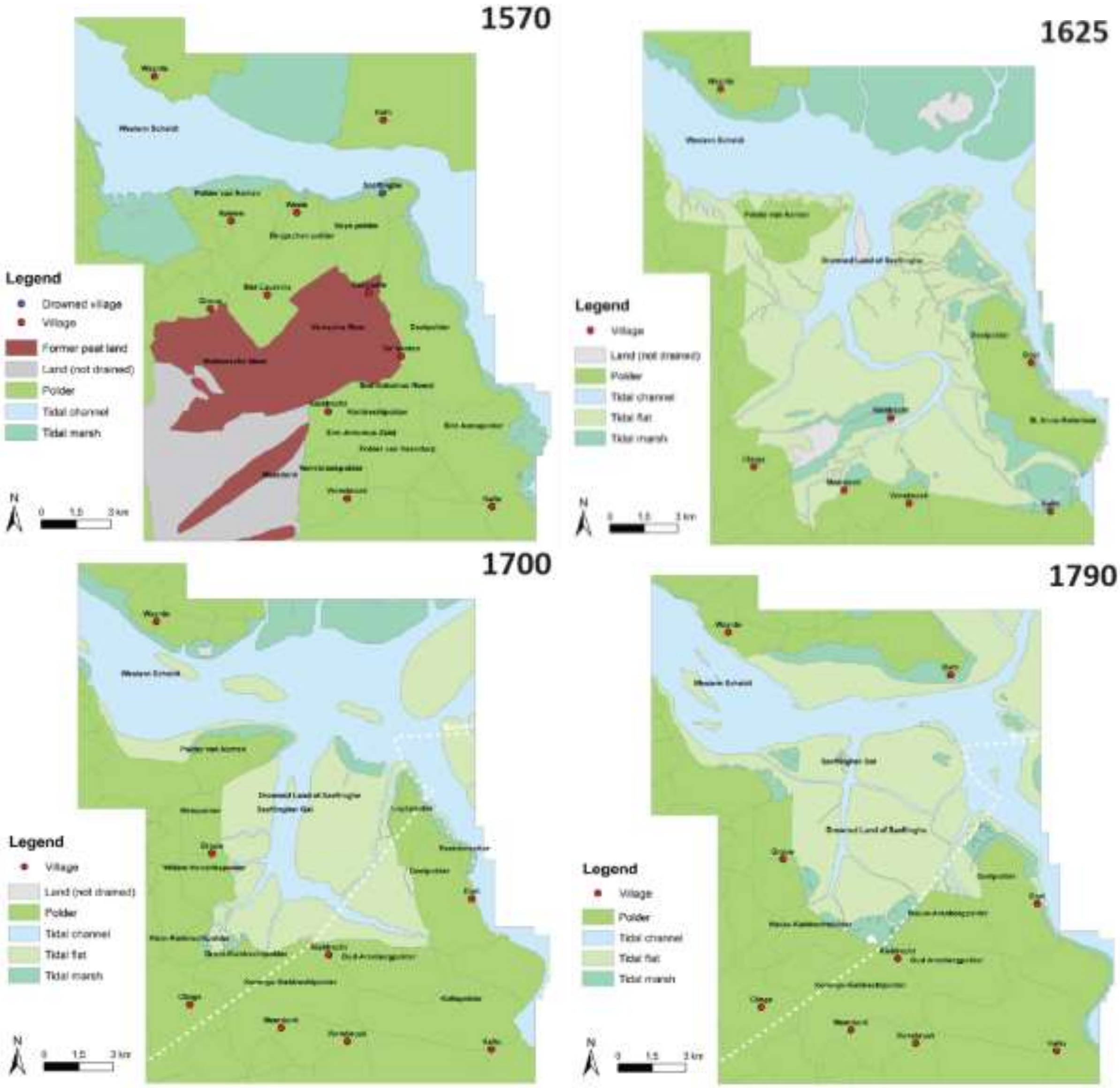
Figure 4.23. (above right): A photograph of the tower even closer to the cliff edge. If the height of the structure is known an assessment can be made from paintings and photographs of the distance to the cliff edge (photograph courtesy of N. Storey).

Figure 4.24. This view of 'West Bay, Dorset' (East Devon-West Dorset Case Study) shows the extent of the beach on either side of the harbour arms in 1824/25. By comparing the length of the arms with historic maps the position of the beach can be plotted. William Daniell produced 308 accurate aquatint views covering the whole of the British coast between 1814-25. Image courtesy R.McInnes.

4.2.3. Analysis of Maps and Charts

Maps and charts provide an important source of information from the Middle Ages onwards. Through time there is a rapid rise in the quantity of available maps and charts. However, the quality and detail varies widely between different maps, therefore it is important to analyse maps prior to interpretation. The most significnt study of maps and charts has been within Belgium and the Netherlands, the results are presented below along with some examples from the UK and France.

The Waasland polders Post Medieval landscape was reconstructed using historical maps. The highest ranking maps were selected for GIS-rectification and digitization. As a result, in five reconstruction maps the landscape evolution from 1570 (just prior to the inundations) to 1850 is shown.



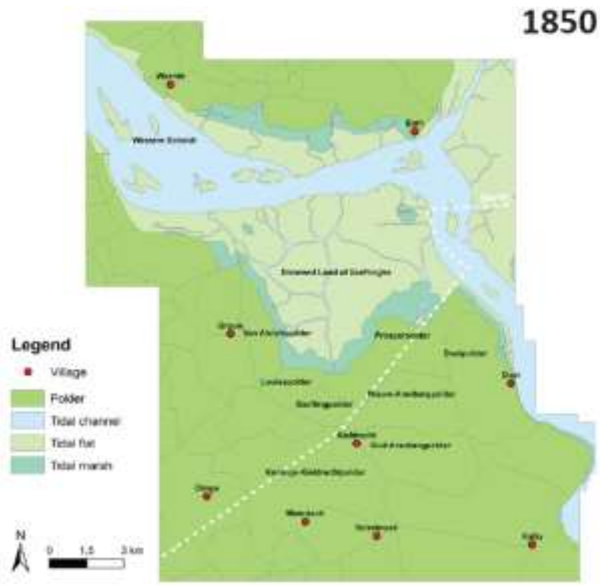


Figure 4.25. Reconstruction of the Waasland polders post-medieval landscape using historical maps from 1570 to 1850 (courtesy I.Jongepier, UGent).

The analysis of the maps has shown that almost the entire study area was embanked by 1570, by 1625 we see extensive tidal marsh formed after the inundations (from the Eight years' War) with a large tidal channel crossing the entire area. In 1700 the eastern course of the channel changed, this was probably of anthropic origin in order to facilitate future tactical inundations. By 1790 the area witnesses' new embankments converting the former higher tidal marsh to embankments, sedimentation has also allowed the tidal marsh to be heightened. The tidal marsh decreased further by 1850 as a result of further embankments. Full details are available in case study report 3M.

Similarly, in the UK, historic maps were used to assess the rate of saltmarsh and mudflat erosion in the north west Solent. The highest ranking maps from the area were georeferenced and the limit of the saltmarsh digitised. This allowed us to see the rate of change from 1781 to the present day.

This analysis has helped us to understand the rate of change in this area. Over a period of 153 years from the date of the first map (1781) to the second map (1934), the area witnesses around 500m regression of the saltmarsh. Over the next 57 years this is between 200-400m, then dramatically in just 22 years the saltmarsh erodes by up to 500m in places. The rate of erosion has dramatically increased in the last 100 years. The specific cause of saltmarsh regression is currently little understood and these maps cannot provide an answer, but they can provide high resolutuin detail on the rate and scale of change from the 18th century.

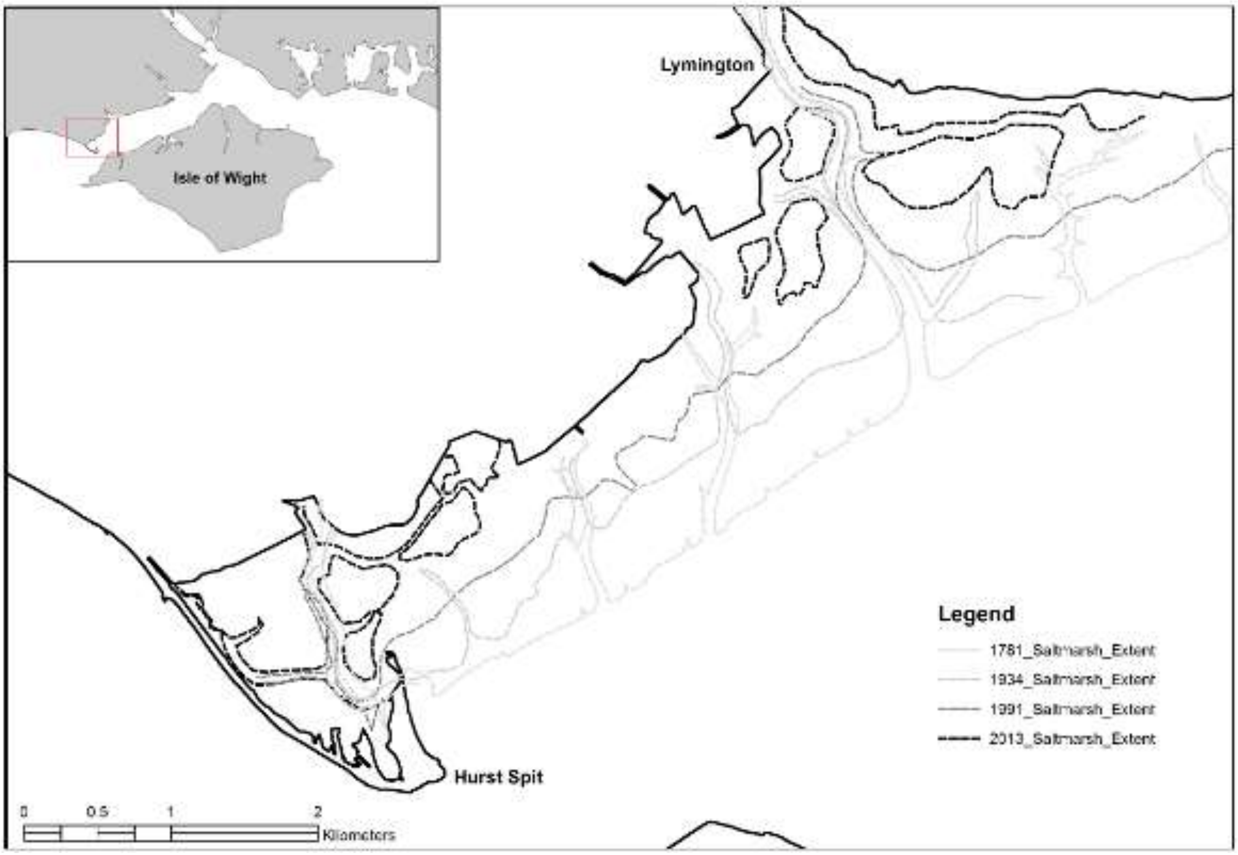


Figure 4.26. Saltmarsh and mudflat regression in the north west Solent from 1781, 1934, 1991 and 2013 based on the analysis of historic maps.

The examples above highlight the potential of historic maps for landscape reconstruction. Several maps were scored in the other case study areas and further work is required in order to georeference these and create corresponding evolution maps of all partner case study areas. This has been done at a smaller scale in some areas, see individual reports for details. Maps have also been combined with the other data sources in the Langstone Harbour case study area, this has resulted in the creation of a 3D evolution model of the harbour from the Mesolithic to present day. See section 4.2.5 below.

4.2.4. Analysis of Historic Photos

The introduction of photography as a means of depicting the coastline first commenced in the 1840s but only became more widely used in the late 1850s. Later, photographic postcards also became popular following the introduction of the first postcard in Austria in 1869. The use of photographs and photographic postcards, and their potential to assist the understanding of coastal change, has been explained through the French and UK case study examples. Below is a selection of sites where historic photographs have proved to be valuable tools in understanding past changes to the coast.

The Men Ozac'h monument is located in a large flat sandy bay, in the estuary of the "Aber Wrac'h" river, which is a geomorphologial feature typical of this area, called the "Aber Coast". This coasts belongs to the "Low Shelf of Léon" formation (northern Finistère), comprising deep indentations and bordered by numerous island and islets; the rocky parts alternate with large sandy beaches. The tide range in this part of Brittany (c. 8 metres) exposes large areas of seabed to enlarge the territory during low tide. As shown within the photographs, the small islands can be reached on foot during low tide.

This area is subject to intensive coastal erosion, due to several factors:

- its geographical location, facing the west and exposed to the main storms;

- the effects of the tide and waves on the soft rock formations;
- the buildings (ports, quays) which can modify local sedimentation processes and retain sand.

Figure 4.27. Views of the tidal Men Ozac'h standing stone (menhir), Plouguerneau (Finistère) (photos by A; Devoir, early 20th century) © Labo Archéosciences UMR 6566 CReAAH.

Among the available pictures of the site, number one was selected for ranking as it appeared to be the most informative due to the view showing the landscape around the standing stone and because the person standing next to the 'menhir' provides a "scale" for the monument. The ranking score achieved was high at 77. Despite the very high quality of palaeoenvironmental indications, the ranking score is not maximum due to the fact that menhir (standing stones) monuments are difficult to date with precision, as they are known to have been constructed from the Neolithic to Bronze Age period.

Photograph number two shows the monument at high tide and number three details the presence of attached seaweed. Both images provide historic evidence for the position of the 'menhir' which is regularly (twice a day) submerged by sea water. The original view (glass photographic supports and positive papers) are part of the collection of the Laboratoire Archéosciences (Rennes University).

In the UK many historical photographs are now available through online collections. Images from the 'Britain from Above' have been used to look at changes in sediment levels and salt marsh erosion. The images below are from Hurst Spit and Lymington Harbour in the western Solent.

Figure 4.28. Hurst Spit in 1953 (left) and 2013 (right).

Hurst Spit is a cuspate shingle foreland dominating and protecting the entrance to the western Solent. This feature is best known to most for the presence of Hurst Castle. The castle is a national historic monument and tourism asset situated at the tip of the spit. Its survival depends on the future stability of the spit yet, by its very nature, the spit is an evolving coastal beach-form capable of dispersal or migration.

For observers of shoreline behaviour, the spit is of particular importance because of the natural protection it has long provided for the sheltered coasts and habitats of the western Solent seaway. The spit is an ephemeral coastal feature that is capable of changing its form and shifting its position. It is now known that its entire development must lie within the past 8,000 years. Some perceptible shifts in the configuration of the spit are evident in recent history and can be seen through historic photographs. Below is an aerial photograph from 1953 obtained through the Britain from Above Project. This is presented next to a current view of the area.

Comparison of these images shows the extent of the sediment erosion on the spit, the sea now reaches the walls of Hurst Castle. However, further north at the old jetty by the lighthouse the accretion of shingle around the jetty made this no longer usable by boats.

Loss of intertidal mudflats and saltmarsh at the entrance of Lymington Harbour can also be seen through historic photos. Below is an aerial view from 1952 compared to a view from 2013.

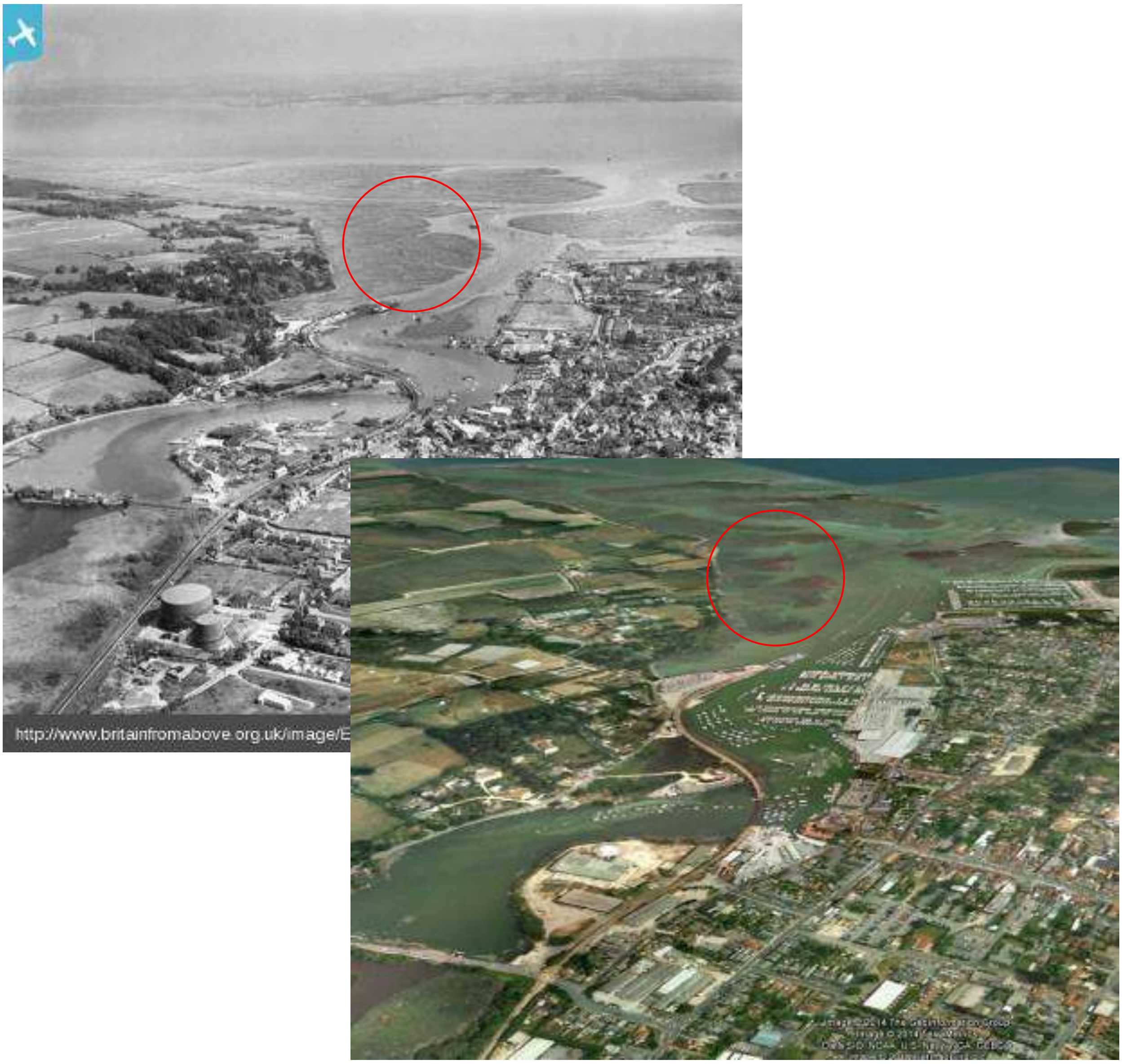


Figure 4.29. Lymington Harbour in 1952 (left) and 2013 (right). The red circle marks the most notable changes in the saltmarsh.

The specific cause of saltmarsh loss is little understood. A combination of factors including wave action, lack of sediment supply, dieback of vegetation, tidal currents and sea level rise are all thought to influence the erosion of the saltmarsh (NFDC, 2014). The use of historic resources such as these images may not provide the answer as to the specific causes of erosion, but can provide high resolution data on the rate and scale of erosion since at least the 1950's. Combining this with historical maps, charts and archaeological and palaeoenvironmental data will provide a long term perspective on the rate and scale of change to help with management in the future.

4.2.5. Combined Resources

The Arch-Manche project combined the various data sources outlined above to extract maximum amounts of information that provide details on long-term coastal change. This section presents a selection of sites that have been studied using a combination of the data sources and demonstrates how this can advance our understanding of the scale and rate of long term coastal change, realising the potential of these previously under-used data sources.

The 3D model of Langstone Harbour was primarily created using archaeological and palaeoenvironmental data as detailed above, this covered the Mesolithic to the Saxon period. However, in order to reconstruct the post-medieval landscape several high ranking historic maps and charts were used (Figure 4.30). This has allowed us to create a model covering a period of over 8,000 years, demonstrating how the harbour has changed. Similarly in Belgium, the Scheldt polders have been mapped using a combination of archaeological and palaeoenvironmental data for prehistoric periods and historic maps and charts for the post-medieval period.

Figure 4.30. Left: reconstruction of the post-medieval landscape prior to the reclamation of Farlington marshes in 1771. This has been based on high ranking historic maps such as the one presented above right by Milne and can be compared with the present day (bottom right), aerial image courtesy of the CCO.

Combined resources have also proved valuable for the Saint-Servan Promontory, France. The use of historic maps, heritage feature data and historic aerial photographs have enabled the analysis of change around the Saint-Servan (Alet) Promontory.

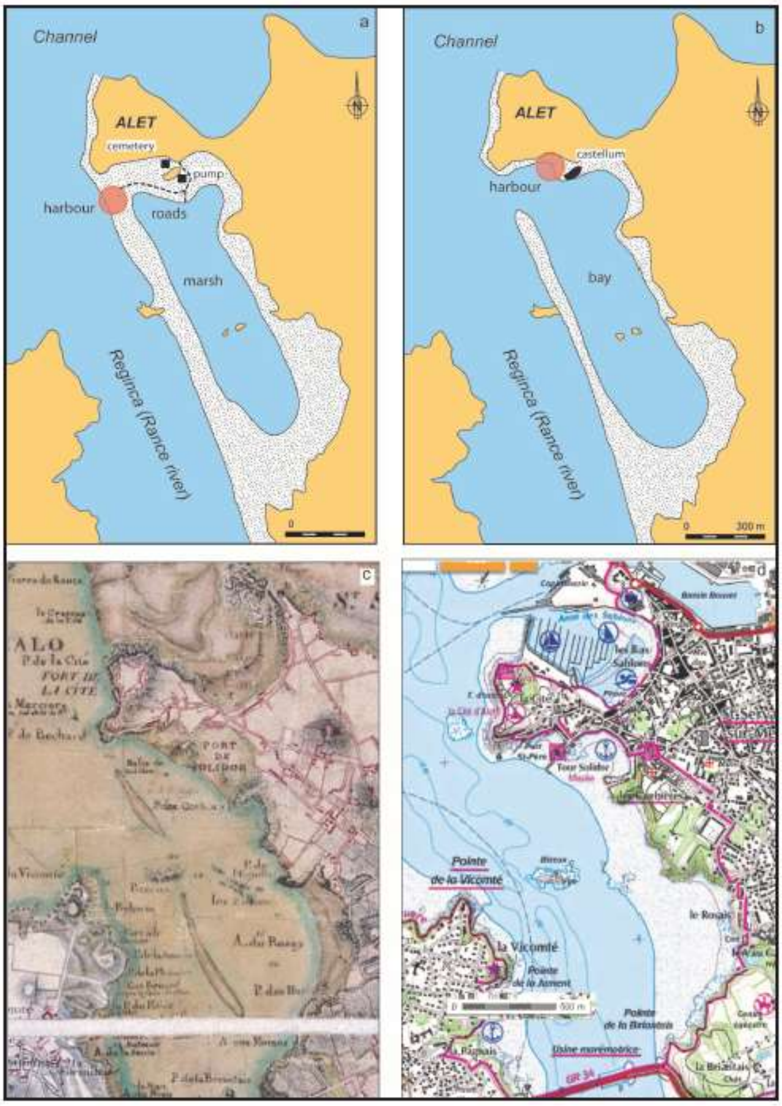


Figure 4.31. Above: Saint-Servan (Alet) promontory and coastal evolution of the harbour: evolution of the topography before (a) and after (b) the 4th century AD. The beak of the alluvial bar led to modification in the use and frequentation of the area. On the ancient map (18th century, Ministère de la Défense, Vincennes) (c) some remains of the alluvial bar still appear. (d) 20th century view (IGN map).

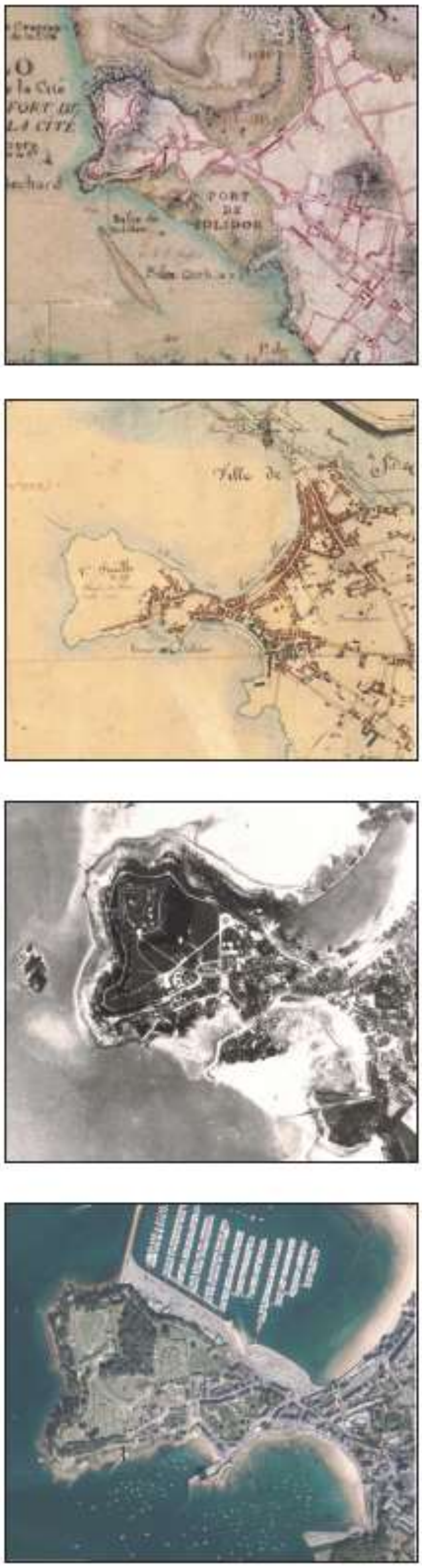


Figure 4.32. Right: Saint-Servan (Alet) promontory and coastal evolution of the harbour. From top to bottom: Carte des Ingénieurs Goégraphes du Roi (c. 1785) (Ministère de la Marine). Napoleonian cadastre (1835) (Archives du département d'Ille-et-Vilaine). Aerial views (1945 and c. 2012) (Geoportail, IGN source).

During the first millennium BC the bay was protected from the sea by an alluvial bar (Figure 4.31 – top left), evidence of this has been found through archaeological and palaeoenvironmental studies. It is unclear whether the breakthrough of the bar is due to natural causes or human action, but it is thought that this occurred around the 4th Century

AD. This led to the abandonment of a Roman pumping station (the fresh water pumping station was found at a location 4 meters below the current high water level) and necropolis, as well as this harbour activities appear to have been moved to the Saint-Père Bay (Langouët, 1996).

During the following centuries, the major modifications of this area are linked to religious and historic events with the building of churches, fortifications and ramparts (Middle Ages to 17th-18th centuries). During the modern period, the density of habitation and the development of modern sailing harbour installations are visible while comparing the maps and aerial photographs; more recently, the building of the Rance Tidal Power Station has had a great impact on the whole estuary and, more precisely, on the Saint-Servan/Alet area.

4.3. Implications for Coastal Management

Over the last thirty years, significant progress has been made towards achieving more sustainable management of coastal zones in the Southern North Sea - English Channel regional sea area. Initiatives promoted by the European Commission, governments and networks such as coastal fora and coastal defence groups have also encouraged a better understanding of physical processes in order to inform coastal policy making. The Channel - Southern North Sea coastline, which is composed largely of softer rocks with considerable lengths of unstable clifflines, as well as low-lying coastlines, are particularly prone to a range of natural hazards including coastal erosion, landslides and sea flooding. These hazards and the resulting risks to coastal property and assets, as well as infrastructure and the natural environment, have led to the development of risk management strategies such as shoreline management plans in some areas, which provide a framework for addressing risks looking ahead over the next century.

Whilst, in some locations, monitoring of coastal change has been undertaken in recent decades, for most of the coastline there is no long-term record of coastal evolution and, indeed, aerial photography only became available more widely after the Second World War. The importance of a strategic monitoring framework, particularly in the face of climate change, has become increasingly recognised and will provide a benchmark against which future changes can be measured. However, it has been recognised that a thorough understanding of coastal evolution and change can only be considered effectively if a long-term perspective of change can be obtained. In view of the absence of data from past decades, the Arch-Manche project has highlighted the benefit of making use of archaeological and palaeoenvironmental data, historical images, including landscape paintings, watercolour drawings, various kinds of prints (for example, engravings, aquatints and lithographs) together with photographs, photographic postcards and old maps and charts, to inform us on long-term coastal change. This research has highlighted that, in many locations, these resources have been under-used as a resource to support understanding of long-term coastal change.

The significant challenges to be faced around the Channel - Southern North Sea, as a result of coastal change exacerbated by climate change over the next century, can be addressed most effectively by taking advantage of the wisdom of hindsight, drawing in historical information from artworks, photography and cartography as well as archaeological and palaeoenvironmental data, to support the new technologies available to coastal scientists, engineers and coastal managers, who are facing such problems on a day-to-day basis. The recognition that sustainable coastal management should be based upon a thorough understanding of long-term coastal evolution, and the need to develop adaptation strategies through collaboration between coastal engineers and planning officers, highlights, all the more, the importance of taking advantage of those records that are available.

By looking back over time, and viewing the coastline before much of the human intervention, and having the ability to note progressive changes and alterations to the coast, allows us to assess impacts and support wise management. The use of such tools as archaeology, art, cartography and photography, which are familiar to many coastal residents who often have a long-standing knowledge and interest in the history of their coastline, therefore, provide a good way of engaging with these stakeholders when discussing issues relating to coastal change and its implications in practice.

The wealth of coastal landscape art and photographic images, as well as cartography, archaeology and palaeoenvironmental data, can be used most effectively when these resources are brought together and considered alongside one another. With these additional resources those responsible for coastal management will be much better prepared to address the challenges to be faced in the future.

5. Conclusions and Recommendations

The coastline is constantly evolving. Analysis of the past enables us to assess progressive changes and alterations to the coast. Data from archaeology, heritage features, art, photographs, maps and charts provides both qualitative and quantitative information on coastal evolution. Research during the Arch-Manche project has highlighted that these data have been under-used as a resource to support understanding of long-term risks associated with a range of coastlines.

Coastal risk management and sustainable development in support of the planning process requires a thorough understanding of the rate, scale and pace of coastal change. Historically decision-making on the coast, in many areas, has not been able to take advantage of a sufficiently long-term perspective. This is because data and information on coastal erosion rates, for example, has not been available. There are very few locations around the European coastline where monitoring and recording of coastal change, in a systematic way, has been undertaken for more than 10 – 15 years. Monitoring provides an invaluable data source for those involved in coastal management. It also provides the basis for design and development of coastal defenses and will encourage a change in risk management philosophy from a reactive to a proactive approach.

The impacts of climate change and sea level rise, including an apparent trend for more unpredictable weather patterns, can only be measured and set in context if the long-term evolution for each coastal frontage is understood. Fortunately the need for a strategic approach to monitoring our coastlines is now being recognised and adopted more widely. However, trends can be understood better and predicted more effectively if the science is also supported by historical data and information.

By examining maritime heritage, seabed archaeology and depictions of the shoreline, beaches, the backshore and coastal hinterland, it is possible to offer a 'seamless' vision of the coastal zone extending back over time and to allow 'the wisdom of hindsight' to support integrated coastal zone management. By making such information available to all those involved in coastal management, particularly coastal engineers and their planning officer colleagues, wise decisions can be made in terms of planning for our coastal zones looking ahead for the next century. Armed with a more comprehensive understanding of long-term coastal change, planning decisions should result in the removal of risks by avoiding inappropriate development or by relocating development away from vulnerable frontages through effective land use planning.

In this region the diverse geological exposures and resulting coastal landforms including both hard and soft cliffs, coastal landslide systems, shingle and sandy beaches, saltmarsh and mudflats have allowed the approach developed through the project to be tested at suitable case study locations, and the applications of the heritage, art, photographic and cartographic resources to be tested and demonstrated very effectively.

5.1. Conclusions for the use of Archaeological and Palaeoenvironmental Data

- The historical evolution of the coast provides valuable information on past trends which can help develop future coastal climate change scenarios. Present coastal landforms have developed since the last Ice Age, studies of their evolution based on archaeology, palaeoenvironmental and coastal heritage features provides a seamless timescale from the Ice Age to the mid-20th century;
- Early archaeological evidence demonstrates how people were impacted by coastal change in the past and how populations reacted to some large-scale landscape and climate changes;

- More recent human activity along the coast can show us how humans have had a direct impact on coastal stability. Some has been positive but much has been counterproductive;
- In order to facilitate an understanding of the challenges we are likely to face with rising sea levels and a changing coast, it is possible to look back at the archaeological record for evidence of changes similar to those predicted for the future. This is particularly true of the Mesolithic period which experienced a rapid rise in sea level similar to those predicted in the future;
- The archaeological record from the Mesolithic period is now predominantly submerged in the Channel and Southern North Sea, such conditions allow for high levels of preservation including organic material which can be used to reconstruct the past environment. This data can help provide an insight into the effects of change on the coastlines of Europe and can provide lessons for the future;
- Archaeology and heritage assets can often be dated accurately to provide a calibrated time-frame, which can be used alongside geomorphological and coastal process studies to support coastal risk management; and
- The project has demonstrated an approach, which allows archaeological, palaeo-environmental and heritage assets to be prioritised in terms of their value in support of the understanding of coastal change, these results and the application of this data in the creation of 2,3 and 4D models demonstrating coastal change, is available through the portal www.archmanche-geoportal.eu.

5.2. Conclusions for the Use of Artistic Resources

- The coastlines of the Channel – Southern North Sea have been illustrated by artists, cartographers and photographers extending back to the seventeenth century and earlier. There is a rich resource of historical images available of the coastlines held in public collections that can be utilised to support understanding of long-term coastal change;
- In order to ensure that images being assessed to support understanding of coastal change can be confirmed as being true representations of the coastline concerned, ranking systems have been developed or refined for historical artworks, maps and photographs; this approach ensures accuracy and consistency of approach;
- Such historical images represent a currently under-used and under-valued resource. However, the increase in availability of museum and gallery on-line databases together with national databases such as *Jocande* in France and *BBC Your Paintings* in the United Kingdom offer greatly improved access for research and more general use by all those involved with coastal management;
- The cross-border dimension of the project has been addressed comprehensively by ensuring that the methodology has been tested and confirmed at case study sites which include the full range of coastal geomorphological landform types to be encountered across the Southern North Sea – Channel region;
- Sample testing of the ranking approach in other locations in the region (outside the case study sites) has demonstrated the wide transferability of the methodology across the European Union and Internationally;
- A portal www.archmanche-geoportal.eu has been established containing details of the artworks that were assessed as part of this project. For each case study location a short-list has been compiled of those artists who can be relied upon in terms of producing accurate depictions of the coastline at the time they were painted.
- The project clearly demonstrates the value of art, photography and cartography as additional resources to support understanding of coastal change. When these tools are used in combination, and through linking the disciplines of art and science, a much greater appreciation of long-term coastal evolution as well as the impacts of human intervention can be achieved and understood;

- A detailed description has been provided of the art history story of the Channel-Southern North Sea region, which aims to highlight the longstanding artistic links and influences that have developed around the coast of this part of north western Europe;
- The potential applications of historical resources such as topographical paintings, photographs and old maps and their ability to foster increased interest in local museums, art galleries and archives should be highlighted to curators.

5.3. Key Arch-Manche Conclusions

- Looking back to go forward – understanding past coastal change enables more accurate predictions of future changes and potential impacts in areas under stress;
- The long-term perspective provides a sound evidence base for future coastal planning and sustainable development;
- Areas of the Channel-Southern North Sea coastline are particularly prone to a range of natural hazards including coastal erosion, landslides and sea flooding. Project data has helped identify areas at particular risk;
- Some coastal areas have greater physical stability over the long-term as witnessed through Arch-Manche analysis, helping identify areas of lower risk;
- While detailed coastal monitoring data is often available for the last few decades, the approach taken by Arch-Manche can fill the large 'data gap' for earlier periods from the Palaeolithic to the 20th century;
- Archaeology, coastal heritage, art, charts, maps and photographs are sources of value to coastal scientists, engineers and coastal managers, making decisions on coastal management on a day-to-day basis.

5.4. Recommendations

- The transferability of the Arch-Manche approach has been demonstrated through the case study work. Those involved in coastal risk management should be encouraged to test the methodology on their particular coastal frontage;
- The creation of 2, 3 and 4 Dimensional models has proven to be a valuable tool in understanding change over time, these should be created for other case study areas and incorporated into the portal;
- The case study work has illustrated how the data can inform us of changing environmental conditions (vegetation patterns – tree, shrub and plant species) over time. This approach should be tested to demonstrate how the data may support the wider study of environmental and ecological change;
- The contribution that the Arch-Manche approach has been demonstrated to provide means other areas of the Channel – Southern North Sea coast, and more widely in any areas of the European coast impacted by change, should be encouraged to apply the methodology. This will aid future long term sustainable coastal management;
- The increasing availability of digital heritage resources, online art gallery and museum databases has proved particularly helpful in developing the project. This should be highlighted to curators and archivists of public collections bordering the Channel-Southern North Sea;

The wealth of coastal landscape art and photographic images, as well as cartography, archaeology and palaeoenvironmental data, can be used most effectively when considered alongside one another. With these additional resources those responsible for coastal management will be much better prepared to address the challenges to be faced in the future.

The data assessed, results of the project, technical report and 2, 3 and 4-D models are all accessible through the Arch-Manche portal, www.archmanche-geoportal.eu and website www.archmanche.hwtma.org.uk/downloads

Arch-Manche Technical Report References (excluding case study references these can be found in the individual case study reports, see section three)

Adams, J & Flatman, J 2013, High to Post-Medieval, 1000 to 1650. In Ransley, J. Sturt, F. Dix, J. Adams, J and Blue, L (eds). *People and the Sea: A Maritime Archaeological Research Agenda for England. Research Report* (171). Council for British Archaeology, York.

Addison, J., 1965. *'The Spectator'*. Editor D. E. Bond. Oxford.

Archibald, E. H. H., 1980. *'Dictionary of Sea Painters'*. Antique Collectors Club. Woodbridge, Suffolk.

Archibald, E. H. H., 1982. '*Dictionary of Sea Painters'*. Antique Collectors' Club. Woodbridge. ISBN:0-902028-84-7.

Allen, MJ & Gardiner, J. 2000. *Our Changing Coast: a survey of the intertidal archaeology of Langstone harbour, Hampshire*. CBA Research Report 124.

Auricchio, L., 2004. *'The Transformation of Landscape Painting in France'*. In Hellbrun *'Timeline of Art History'*. New York. Metropolitan Museum of Art.

Bailey, G N, 2004 The wider significance of submerged archaeological sites and their relevance to world prehistory, in NC Flemming (ed), *Submarine Prehistoric Archaeology of the North Sea*. York : Council for British Archaeology Research Report 14, 3-10

Beatniffe, R., 1808. *'The Norfolk Tour, or Travellers Pocket Companion'*. Private Press.

Bell, M & Warren, G, 2013 The Mesolithic. In Ransley, J. Sturt, F. Dix, J. Adams, J and Blue, L (eds). People and the Sea: A Maritime Archaeological Research Agenda for England. Research Report (171). Council for British Archaeology, York.

Bénézit, E., 2006. *'Dictionnaire des Peintres, Sculptures, Dessinateurs et Graveurs'*. Publisher: Gründ Editions. Paris. Oxford University Press.

Benoist, F., 1852. *'La Normandie Illustraée'.* Nantes Charpentier

Bergeret-Gourbin, A-M., 2010. *'Honfleur Entre Tradition et Modernité 1820-1900'*. Edition Societé des Amis du Muse Eugene Boudin. ISBN: 978-2-902985-15-9.

Biet M.C., Bouze O., 2007, Bretagne d'antan, la Bretagne à travers la carte postale ancienne, HC ed., Rennes.

Blakemore, M. J. & Harley, J. B. 1982. Concepts in the history of cartography. *Cartographica,* 17**,** 1-120.

Borlase, W., 1769. *'Antiquities, Historical and Monumental, of the County of Cornwall'*. London.

Bossu, J. 1982. *Vlaanderen in oude kaarten: drie eeuwen cartografie,* Tielt, Lannoo.

Bradbury, A. P., 2007. *'Benefits of a large scale, long-term regional coastal monitoring programme for southern England'*. In McInnes (Ed.) Proc. Int. Coastal Mgt. Conf. Cardiff. Thomas Telford.

Brannon, G. & A., 1821-1876. *'Vectis Scenery'*. Private Press. Wootton, IW.

Brettell, R., undated. *'A day in the country: Impressionism and the French landscape'*.

Britton, J. & Brayley, E. W., 1832. *'Devon and Cornwall Illustrated'*. London.

Burke, E., 1757. *'Philosophical Enquiry into the Origins of our Ideas of the Sublime and Beautiful'*.

Cariou A., 2011. *De Turner à Monet, La découverte de la Bretagne par les Paysagistes au XIXe siècle.* Musée des Beaux-arts de Quimper – Palantines, 191 p.

Carter, D., Bray, M. J. & Hooke, J., 2004. *SCOPAC Sediment Transport Study*. Report to SCOPAC.

Channel Coast Observatory, 2004-2014. *Annual Strategic Coastal Monitoring Programmes.* www.channelcoast.org.

Clark, J., 1829. *'The Influence of Climate in the Prevention and Cure of Chronic Diseases'*. London.

Clark, Sir K., 1949. *'Landscape into Art'*. Penguin.

Clarke, W. G., 1921. *'Norfolk and Suffolk Illustrated'*. A. & C. Black. London.

Cliquet, D., Coutard, S., Clet, M., Allix, J., Tessier, B., Lelong, F., Baltzer A,. Mear, Y., Poizot, E., Auguste, P., Alix, P,. Olive, J. and Guesnon, J. 2011 The Middle Palaeolithic Underwater Site of La Mondrée, Normandy, France, in J. Benjamin et al. (eds.) *Submerged Prehistory*. Oxford: Oxbow Books. 111-28.

Collective 1992. *La Mer et les Jours, XVe siècle – 1940. 5 Siècles d'Arts et Cultures Maritimes en Côte d'Armor.* Catalogue de l'exposition du Château de la Roche-Jagu, 20 juin – 1er novembre 1992. Conseil Général des Côtes d'Armor, 239p.

Collective 2008. Catalogue, *Henri Rivière: Graveur et Photographe*, Musée d'Orsay exhibition.

Co-ordination Centre, west Flanders, 2010. *Belgian report on the Implementation of the ICZM Recommendation 2002/413/EG for the Period 2005-2010.*

Daniell, W. & Ayton, R., 1814. *A Voyage Round Great Britain.* Longman & Co. London.

Darwin, C., 1859. *The Origin of Species by Means of Natural Selection*' Publ. John Murray. London.

De Maeyer, P., De Vliegher, B.-M. & Brondeel, M. 2004. *De spiegel van de wereld: fundamenten van de cartografie,* Gent, Academia Press.

De Ronde, J. G., Mulder, J. P. M. & Spanhoff, R., 2003. *'Morphological Developments and Coastal Zone Management in the Netherlands'.* Proc. Int. Conf. on Estuaries and Coasts. Hangzhou, China. November 2003.

De Ruig, J. H. M., 1998. *Coastline Management in the Netherlands: Human Use versus Natural dynamics.* Journal of Coastal Conservation. 4. 127-134.

Deboudt, P., 2010. *Towards coastal risk management in France*. Oceans – Coastal Management. Xxx (2010). 1-13. Elsevier.

Defra, 2009. *Strategy for Promoting an Integrated Approach to the Management of Coastal Areas in England'* Crown copyright.

Delarre, B., Chaine, C. & Ickowicz, P., 2009. *'Les Peintres à Dieppe'*. Terre en rue. 272 pps.

Delefortrie, S., Saey, T., Van De Vijver, E., De Smedt, P., Missiaen, T., Demerre, I. & Van Meirvenne, M. 2014. Frequency domain electromagnetic induction survey in the intertidal zone: Limitations of low-induction-number and depth of exploration. *Journal of Applied Geophysics,* 100**,** 14-22.

Dellino-Musgrave, V & Ransley, J 2013 Early Modern and Industrial, c 1650 to 1850. In Ransley, J. Sturt, F. Dix, J. Adams, J and Blue, L (eds). *People and the Sea: A Maritime Archaeological Research Agenda for England. Research Report* (171). Council for British Archaeology, York.

Delouche D., 1996. L'invention de la Bretagne dans La Peinture du 19 e siècle, in « Cent ans de Tourisme en Bretagne », Ed by Apogée, pp.19-30.

Delouche D., 2003. La Peinture en Bretagne. Collection Patrimoine de la Région Bretagne, 84 p.

Dickson, R., 1811. *'Sketches Illustrative of Picturesque Scenery in Norfolk'*. Norwich.

Drummond, M. & McInnes, R., 2001. *'The Book of the Solent'*. Cross Publishing.

Dudley Barrett, D., 2010. *'Artists on the Edge – the Rise of Coastal Artists' Colonies 1880-1920'*. Amsterdam University Press. ISBN: 978-80-8964-251-6.

Duffy, M., 2011. *'The Influence of Charles-Francois Daubigny on French Plein-Air Landscape Painting'*.

Ellis, A. (Ed.), 2004. *'Art in Public Collections in Kent'*. Public Catalogues Foundation.

Ellis, A. (Ed.), 2005. *'Art in Public Collections in East Sussex'*. Public Catalogues Foundation.

Ellis, A. (Ed.), 2009. *'Dorset – Oil Paintings in Public Collections'*. Public Catalogues Foundation.

Ellis, A. (Ed.), from 2004. *'Catalogues of the Oil Paintings in Public Collections'*. Public Catalogue Foundation. London.

Englefield, Sir H., 1816. *'The Picturesque Beauties, Antiquities and Geological Phenomena of the Isle of Wight and the Adjacent Coast of Dorsetshire'*. Payne & Foss. London.

Engstrom, W. N., 2006. *Nineteenth Century Geomorphology of Southern California.* Journal of Coastal research. 20. 820-

Ergin, A., Williams, A. T. & Micallaf, A., 2006. *Coastal Scenery – Appreciation and Evaluation.* Journal of Coastal Research. 22. 958-964.

European Commission DG Environment, 2012. *LIFE and Coastal Management.* The LIFE Financial Instrument 2007-2013. Luxembourg. ISBN 978 9279 25091 0.

European Commission, 1999. *'Lessons learnt from the European Commission's Demonstration Programme on the integrated management of coastal zones'*. Brussels. European Commission.

European Commission, 2002. *'Recommendation of the European Parliament and Council concerning the implementation of integrated coastal zone management in Europe'*. Official Journal of the European Community No. L148, 06/06/2002, pps 0024-0027. Brussels.

European Commission, 2004. *EUrosion – Living with Coastal Erosion in Europe.*Luxembourg. ISBN: 92 894 7496 3.

European Commission, 2007. *'Communication on the integrated management of coastal zones'*. Brussels.

European Commission, 2011. *OURCOAST – Integrated Coastal Zone Management: Participation and Practices in Europe.* Report for DG Environment by ARCADIS and the EUCC. Netherlands.

Finden, E. & Finden, W., 1838. 'Views *of the ports, harbours and watering places of Great Britain'*. Virtue & Co. London.

Fitch, S. 2011. *The Mesolithic landscape of the southern North Sea.* A thesis submitted to the University of Birmingham

Foresight, 2004. *Future flooding*. Executive summary. Office of Science and Technology. UK.

Gaffney, F, Fitch, S, & Smith, D, 2009 *Europe's Lost World: The Rediscovery of Doggerland.* York: Council for British Archaeology Research Report **160.**

Gates, A., 2012. In 'British Impressions'. Messum's. London.

Gibbard, P. 2007. *Europe cut adrift*. Nature, vol. 448, p 259-260.

Gilpin, W., 1786. *'Observations Relating Chiefly to Picturesque Beauty, Made in the Year 1772...'*. Publ: R. Blamire. London.

Gilpin, W., 1804. *'Observations on the Coasts of Hampshire, Sussex and Kent relating chiefly to Picturesque Beauty, made in the Summer of 1774'*. Octavo. London.

Gilpin, W., 1804. *'Observations on the Coasts of Hampshire'*. London.

Goeldner-Gianella L., Feiss-Jehel C., Decroix G., 2011. *Les Oubliées du "désir du rivage" ?* L'image des zones humides littorales dans la peinture et la société françaises depuis le XVIIIe siècle, *Cybergeo : European Journal of Geography* [Online], Environnement, Nature, Paysage, document 530, mis en ligne le 20 mai 2011, consulté le 09 février 2014. URL : http://cybergeo.revues.org/23637 ; DOI : 10.4000/cybergeo.23637

Gottschalk, M. K. E. 1955-1958. *Historische geografie van westelijk Zeeuws-Vlaanderen,* Assen, Van Gorcum.

Graves, A., 1901. '*A Dictionary of Artists who have Exhibited Works in the Principal London Exhibitions from 1760-1893'*. Kingsmead Press. Bath.

Graves, A., 1984 (reprinted). *'A Dictionary of Artists 1760-1893'*. Kingsmead Press.

Gray, F., 2006. *'Designing the Seaside, Architecture, Society and Nature'*. Reaktion Books. ISBN 1-86189-274-8.

Haak, B., 1984. *'The Dutch Golden Age'*. 536 pps. Stewart, Tabor's and Chang.

Halcrow, 2002. *Futurecoast* study for Defra. Crown Copyright.

Halcrow, 2006. *Risk assessment of coastal erosion*. Joint Defra/EA flood and coastal erosion risk management R&D programme. Technical report: FD2324.

Halcrow, 2010. *National coastal erosion risk mapping programme*. Validation of first-round outputs to include the impacts of UKCP09 Climate change projections. Technical report for the EA.

Halsby, J., 1986. *'Scottish Watercolours 1740-1940'* Batsford. ISBN: 07134-186-680

Hardie, M., 1966. *'Watercolour Painting in Great Britain'*. 3 vols. B. T. Batsford Ltd. London.

Hardie, M., 2009. *'Artists in Newlyn and West Cornwall 1880-1940'.* Art Dictionaries Limited. Bristol. ISBN: 978-0-953260966.

Heirman, K, Missiaen, T, Vos, P 2013. *Holocene palaeogeographical evolution of the Waaslad Scheldepolders*. Unpublished Research Report.

Hemingway, A., 1979. *'The Norwich School of Painters 1803-1833'*. Phaldon Press Ltd. Oxford. ISBN: 0-7148-2001-6.

Hemingway, A., 1987. *'The Norwich School of Painters 1803-1833'.* Phaidon Press. Oxford

Hill, J S & Willis, S 2013 Middle Bronze Age to the end of the pre-Roman Iron Age, c 1500 BC to AD 50. In Ransley, J. Sturt, F. Dix, J. Adams, J and Blue, L (eds). *People and the Sea: A Maritime*

Archaeological Research Agenda for England. Research Report (171). Council for British Archaeology, York.

Hook, P. & Poltimore, M., 1986. '*Popular 19th century Painting - A Dictionary of European Painters'. The Antique Collectors' Club. Woodbridge. ISBN: 1 85149 011 6.*

Hosking, A. & Moore, R., 2001. *'Preparing for the Impacts of Climate Change on the Coast'*. Report for the Standing Conference on Problems Associated with the Coastline (SCOPAC), Swindon.

Houthuys, R, De Moor, G. & Somme, J, 1993. *The Shaping of the French-Belgian North Sea Coast Throughout Recent Geology and History.* Proc. 8th Symp. On Coastal & Ocean Mgt. New Orleans. Reprint from *Coastlines of the Southern North Sea*. 27-40.

Hublin, J-J, Weston, D, Gunz, P, Richards, M, Roebroeks, W, Glimmerveen, J & Anthonis, L, 2009 Out of the North Sea: the Zeeland Ridges Neandertal, *J Human Evolution* **57***,* 777-85

Hudson, R., 1993. *'The Grand Tour – 1592-1796'*. The Folio Society. London.

Hutchins, J., 1774. *'The History and Antiquities of the County of Dorset'*. Folio. London.

Janssens, L. 2006. *Kaarten op bestelling. De beroepsgroep van land- en edificiemeters in het hertogdom Brabant en de landen van Overmaas (1685-1795).* Unpublished PhD thesis, KU Leuven.

Jenny, B. & Hurni, L. 2011. Studying cartographic heritage: analysis and visualization of geometric distortions. *Computers & Graphics,* 35**,** 402-411.

Jenny, B. 2006. MapAnalyst - A digital tool for the analysis of the planimetric accuracy of historical maps. *e-Perimetron,* 1**,** 239-245.

Jenny, B., Weber, A. & Hurni, L. 2007. Visualising the planimetric accuracy of historical maps with MapAnalyst. *Cartographica,* 42**,** 89-94.

Johnson, C, 2011. *'Drawing Inspiration – The Cultural Legacy of Artists Working in Dorset and its Evidence of Landscape Change 1800-1960'*.

Kerlo, L. & Duroc, K., 2006. *'Peintres des Côtes de Bretagne'*. Chassé-Marée.

King, R., 1845. *'A Handbook of Lymington and the New Forest'*.

Kirby-Welch, D. & Morton Lee, J., 2009. *'Thomas Bush Hardy'*. Antique Collectors' Club.

Koeman, C. 1983. *Geschiedenis van de kartografie van Nederland: zes eeuwen land- en zeekaarten en stadsplattegronden,* Alphen aan den Rijn, Canaletto.

Kopp, E., 2009. *'Capturing Nature's Beauty – Three Centuries of French Landscapes'*.

Lambeck, K, 1995 Late Devensian and Holocene shorelines of the British Isles and North Sea from models of glacio-hydro-isostatic rebound, *J Geological Soc* 152, 437-48

Lambourne, L.. & Hamilton, J., 1980. '*British Watercolours in the Victoria and Albert Museum'*. Crown Copyright. London.

Langouët, L. 1996. *La cité d'Alet, de l'agglomération gauloise à l'île de Saint-Malo*. Les Dossiers du Centre Régional d'Archéologie d'Alet, supp. S, 128p.

Lebbe, L., Van Meir, N. & Viaene, P., 2008. *Potential Implications of Sea Level Rise for Belgium.* Journal of Coastal research. Vol.24. issue 2. 358-366.

Lee, E. M. & Clark, A. R., 2002. *Investigation and Management of Soft Rock Cliffs'*. Report for Defra. Thomas Telford, London.

Leribault C., 2012. *Eugène Isabey*. Cabinet de dessin, Louvre éd., 81 p.

López-Romero E., Daire M.Y., 2013 - The ICARE project: an insight into the formation and consolidation of archaeology in western France (ca. 1850-1990). *Bulletin of the History of Archaeology* 23(1):3, 1-11. DOI: http://dx.doi.org/10.5334/bha.2313

MacKenzie, I., 1987. '*British Prints'*. Antique Collectors Club. Woodbridge, Suffolk.

Mallalieu, H. L., 1984. '*The Dictionary of British Watercolour Artists up to 1920'*. Antique Collectors Club. Woodbridge, Suffolk.

Mallalieu, H., 1976. *'A Dictionary of British Watercolour Artists up to 1920'*. Antique Collectors' Club. Woodbridge. ISBN: 0902028 48 0.

Marchand G., Dupont C. 2013. *Beg-er-Vil à Quiberon, Un habitat du Mésolithique sur le littoral du Morbihan.* Première année de fouille triennale. Unpublished report, 250 p.

Marchand, M. (Ed.), 2012. *Concepts and Science for Coastal Erosion Management.* Concise Report for Policy-makers. EU DG Research FP6 Programme. CONSCIENCE Project. Deltares. Netherlands.

Marlais, M.; Varriano, J. & Watson, W., 2004. *'Valanciennes, Daubigny and the Origins of French Landscape Paintings'.*

Marsh, J., 2005. *'The Pre-Raphaelite Circle'*. National Portrait Gallery Publications. London. ISBN: 9781 88514 4460.

McGrail, S 1990 Boats and boatmanship in the late prehistoric southern North Sea and Channel Region. In Mcgrail, S (ed), *Maritime Celts: Frisians and Saxons*. York: Council for British Archaeology Research Report 71, 32-48.

McInnes R. G., Bradbury A. P., Cope S. & Moore, R., 2011. *Access – Adapting to Coastal Change along England's Southern Shorelines.* Report for SCOPAC.

McInnes, R. & Stubbings, H., 2010. *'Art as a Tool in Support of the Understanding of Coastal Change in East Anglia'*. The Crown Estate. London. ISBN: 978-1-906410-10-0.

McInnes, R. & Stubbings, H., 2011. *'A Coastal Historical Resources Guide for England'*. The Crown Estate. ISBN: 978-1-906410-19-3.

McInnes, R. & Stubbings, H., 2011a. '*Art as a Tool to Support Understanding of Coastal Change in East Anglia'.* The Crown Estate. London. ISBN: 978-1-906410-10-0.

McInnes, R. G. & Moore, R., 2011. *'Cliff Instability and Erosion Management in Great Britain – A Good Practice Guide'*. Halcrow Group Ltd, Birmingham.

McInnes, R. G., 2008. *Coastal Risk Management – A Non-Technical Guide.* Report for The Standing Conference On Problems Associated with the Coastline (SCOPAC). 80pps. Coastal & Geotechnical Services. St Lawrence, IW.

McInnes, R. G., Tomalin, D. & Jakeways, J., 2000. *Coastal Change, Climate and Instability.* Final Report of the LIFE Environment Project. Isle of Wight Centre for the Coastal Environment. Ventnor, IW.

McInnes, R. G.; Jakeways, J. & Fairbank, H., 2006. *RESPONSE – Responding to the Risks from Climate Change on the Coast.* Final Report of the EU LIFE Environment Project. Isle of Wight Centre for the Coastal environment.

McInnes, R., 2008. *'Art as a Tool in Support of Understanding Coastal Change in Hampshire and the Isle of Wight'*. The Crown Estate – Caird Fellowship. London. ISBN: 978-1-906410-08-7.

McInnes, R., 2008. *'Art as a Tool to Assist Understanding of Coastal Change'*. The Crown Estate – Caird Fellowship 2008. The Crown Estate. ISBN: 978-1-906410-087.

Messum's, 2012. '*British Impressions*'. Messum's. London.

Momber, G, 2013. The changing environment of the Mesolithic and occupation at Bouldnor Cliff. In *Ancient Maritime Communities and the Relationship between People and Environment along the European Atlantic Coasts*. Edited by Marie-Yvane Daire, Catherine Dupont, Anna Baudry, Cyrille Billard, Jean-Marc Large, Laurent Lespez, Eric Normand and Chris Scarre BAR International Series 2570.

Momber, G, 2014. Submerged archaeology and cultural responses to climatic amelioration. In A. Evans, J. Flatman, N.C. Flemming (eds.) *Prehistoric Archaeology of the Continental Shelf: a Global Review*. Springer. pp. 194-212.

Momber, G, Tomalin, D, Scaife, R, Satchell, J & Gillespie, J, 2011 *Mesolithic Occupation at Bouldnor Cliff and the Submerged Prehistoric Landscapes of the Solent.* London: Council for British Archaeology Research Report **164.**

Moore, R., Rogers, J., Woodget, A. & Baptiste, A., 2010. *Climate Change Impact on Cliff Instability and Erosion'.* Environment Agency/Defra Conference, Telford, UK.

Mortimore, R. & Duperret, A., 2004. *Chalk Cliff Instability.* Geol. Soc. Special Publication No.20. The Geological Society. London.

Moses, H., 1817. *'Picturesque Views of Ramsgate'*. London.

Motte, E., 2013. *'Represéntations et évolutions du Littoral en Bretagne'.* Mémoire de Master 2, Université Rennes 2, départment de Géographie, 23 p.

Mudie, R., 1840. *'Observations on the Coasts of Hampshire'*. London.

Munday, J., 1996. *'Edward William Cooke RA - A Man of his Time'*. Antique Collectors' Club. Woodbridge. ISBN: 1-85149-222-4.

Munn, G., 2006. *'Southwold – An Early Paradise'*. Antique Collectors' Club. Woodbridge. ISBN: 1-85149-518-5

Newton, L. (Ed.), 2005. *'Painting on the Edge – British Coastal Art Colonies – 1880-1930'*. Samson & Co. Ltd. ISBN: 1-904537-29-4.

NFDC, 2014. Saltmarsh Erosion. New Forest District Council http://www.newforest.gov.uk/index.cfm?articleid=7182

North Sea & Oceans Steering Committee and The Co-ordination Centre, West Flanders, 2002. *National Belgian report on the Implementation of Recommendation 2002/413/EC.*

Palmer, S. 1977 *Mesolithic Cultures of Britain.* Poole: DolphinBooks.

Parfitt, S. A., Barendregt, R. W., Breda, M., Candy, I., Collins, M. J., Coope, G, R., Durbidge, P, Field, M. H., Lee, R, J., Lister, A. M., Mutch, R. Penkman, K,. E. H., Preece, R. C., Rose, J., Stringer, C. B., Symmons, R., Whittaker, J. E., Wymer, J. J. and Stuart A, J. 2010 Happisburgh: The Earliest Record of Human Activity in Northern Europe, *British Archaeology* 114.

Parham, D & Maddocks, J 2013 Modern, 1850 to c 2000. In Ransley, J. Sturt, F. Dix, J. Adams, J and Blue, L (eds). *People and the Sea: A Maritime Archaeological Research Agenda for England. Research Report* (171). Council for British Archaeology, York.

Parkin, Rev. C., 1788. *'A New and Complete History of Norfolk'.* Norwich.

Parry, M. L. (ed.), 2000. *Assessment of potential effects and adaptations for climate change in Europe: the Acacia project*. Jackson Institute, University of East Anglia. Norwich.

Payne, C. & Brett, C., 2010. '*John Brett - Pre-Raphaelite Landscape Painter'*. Paul Mellon Centre. Yale University Press. New Haven and London. ISBN: 978-0300-16575 -3.

Peeters, J. H. M & Momber, G. 2014. The southern North Sea and the human occupation of northwest Europe after the Last Glacial Maximum. Netherlands Journal of Geosciences. Pp 1-16.

Pennant, T., 1801. *'Journey from London to the Isle of Wight'*. London.

Pevsner, N., 1956. *'The Englishness of English Art'*. London.

Pye, K., Saye, A. & Blott, S., 2007. *Sand dune processes and management for flood and coastal defence, part 1: Project overview and recommendations.* R&D technical report, report to Defra.

Reynolds, J, 1984. *'Birket Foster'*. Batsford. ISBN: 07134-3754-5.

Roberts, B. Uckelmann, M. Brandherm, D. 2013. Old Father Time: The Bronze Age chronology of western Europe. In Fokkens, H and Harding, A. (eds). 2013. *The Oxford Handbook of European Bronze Age.* Oxford: Oxford University Press.

Rodrigue, M., Cariou, A., 2005. *'Jules Noël'*. Catalogue de l'exposition, Editions Palantines, 192 p.

Roger, A., 2009. *'La Thoérie du Paysage en France (1974-1994)'*. 463 pps. Editions Champ Vallon. ISBN: 2876735083.

Royal Museums, Greenwich. 2012. www.rmg.co.uk

Ruskin, J, 1843. 'Modern Painters'. Private Press. London.

Russell, R., 1979. '*Guide to British Topographical Prints*'. David and Charles. Newton Abbot.

Shennan, I & Andrews, J 2000 *Holocene Land-Ocean Interaction and Environmental Change around the North Sea*. London: Geographical Society of London.

Sheridan, A. 2010. The Neolithization of Britain and Ireland: the 'Big Picture'. In B.Finlayson, G. Warren (eds), *Landscapes in transition.* Oxford, Oxbow, 89–105

Slive, S., 1998. *'Dutch Painting 1600-1800'*. Yale University Press.

Smith, A..J.; Curry, D. & Boillet, G., 1975. *The Structure and Geological Evolution of the English Channel.* Phil. Trans. Royal Soc. Of London. Vol.279. No.1288. 2-20.

Smith, J., 2000. *'A Catalogue Raisoneé of the Works of the Most Eminent Dutch, Flemish and French Painters'*. BiblioBazaar.lcc.

Staley, A., 2001. '*The Pre-Raphaelite Landscape'*. Paul Mellon Centre. Yale University Press. New Haven and London. ISBN: 0-300-08408-0.

Stanfield, C., 1847. '*Stanfield's Coast Scenery. A Series of Picturesque Views of the British Channel and of the Coast of France'*. Smith, Elder and Co., London.

Stark, J., 1828/34. *'Scenery of the rivers of Norfolk'*. Norwich.

Stechow, W., 1966. *'Dutch Landscape Painting of the Seventeenth Century'*. Phaidon Press. London.

Sturt, F & Van de Noort, R, 2013 The Neolithic and Early Bronze Age. In Ransley, J. Sturt, F. Dix, J. Adams, J and Blue, L (eds). *People and the Sea: A Maritime Archaeological Research Agenda for England. Research Report* (171). Council for British Archaeology, York.

Sutton, P., 1987. *'Masters of 17th Century Dutch Landscape'*. 563 pps.

Tapié, A., 2010. *'Peindre en Normandie a L'Epoque Impressioniste'*. Somogny, Paris. 215 pps. ISBN: 978-2-7572-0263-0.

Tizzard, L, Baggaley, T L & Firth, A J. 2011. Seabed prehistory: investigating palaeolandscapes with Palaeolithic remains from the southern North Sea, in J. Benjamin, C. Bonsall, C. Pickard & A. Fischer (ed.) *Submerged prehistory*. Oxford: Oxbow.

Tomalin, DJ, Loader, R 7 Scaife, RG, 2012 *Coastal Archaeology in a Dynamic Setting: A Solent Case Study*. British Archaeological Report British Series 568

Tomkins, C., 1796. *'Tour of the Isle of Wight'*. London.

Turley, R., 1975. *'Hampshire and Isle of Wight Bibliographies'*. Barry Shurlock & Co. (Publishers Limited). Winchester.

Turley, R., 1977. *'Hampshire and Isle of Wight Art'*. University of Southampton Lilbrary. Southampton.

Turner, J. (Ed.), 2000. *'From Rembrandt to Vermeer: 17th Century Dutch Artists'*. Grove Art.

Unknown, 1813. *'The History of the Town and Port of Dover and Dover Castle with a short account of the Cinque Ports'*. Quarto. 2 vols. London.

Verelst, D. 2002. Het Land van Beveren en de Scheldepolders. *In:* Derez, M., Nelissen, M. & Tytgat, J.-P. (eds.) *Arenberg in de Lage Landen: een hoogadelijk huis in Vlaanderen en Nederland.* Leuven: Universitaire Pers.

Verwaest, T., Van der Beist, K., Vanpoucke, P., Reyns, J., Vanderkimpen, P., De Vos, L., De Rouck, J. & Mertens, T., 2008. *Coastal Flooding Risk Calculations for the Belgian Coast.* Coastal engineering. Vols. 1-5. 5. 4193-4201.

Vos, P. C. & Van Heeringen, R. M. 1997. Holocene geology and occupation history of the province of Zeeland. *In:* Fischer, M. M. (ed.) *Holocene evolution of Zeeland (SW Netherlands).* Haarlem: Netherlands Institute of Applied Geoscience TNO.

Vos, P. C. 2002. Delta-2003, 5000 jaar terugblik, kaartatlas met toelichting. Landschapsreconstructie van de kustdelta van Zuidwest Nederland in opdracht van het project GEOMOD van het Rijksinstituut voor Kust en Zee (RIKZ) van het Ministerie van Verkeer en Waterstaat. *TNO-rapport NITG 02-096-B*.

Wallace, C., 2007. '*Under an Open Sky - Paintings of the Newlyn and Lamorna Artists 1880-1940'*. Truan. Cornwall. ISBN: 978 185022 168 5.

Walpole, J., 1997. *'Art and Artists of the Norwich School'*. Antique Collectors' Club. Woodbridge.

Walpole, J., 2009. *'Suffolk Artists of the 18th and 19th Centuries'*. Antique Collectors' Club. Woodbridge.

Walsh, M. 2013 Roman, c AD 43 to 400. In Ransley, J. Sturt, F. Dix, J. Adams, J and Blue, L (eds). *People and the Sea: A Maritime Archaeological Research Agenda for England. Research Report* (171). Council for British Archaeology, York.

Waterhout, B., 2008. *The Institutionalisation of European Spatial Planning.* Delft Univ. of technology. ISBN: 1574-6410.18.

Westley, K & Bailey, G. 2013. The Palaeolithic. In Ransley, J. Sturt, F. Dix, J. Adams, J and Blue, L (eds). People and the Sea: A Maritime Archaeological Research Agenda for England. Research Report (171). Council for British Archaeology, York.

Wood, C., 1978. *'The Dictionary of Victorian Painters (2nd Edition)'*. Antique Collectors Club, Woodbridge, Suffolk.

Wood, C., 1988. *'Paradise Lost – Paintings of English Country Life and Landscape, 1850-1914'.* Past Times. Oxford. ISBN: 0 7148 2001 6.

Wood, C., 1995. *'A Dictionary of Victorian Painters'*. Antique Collectors' Club. Woodbridge. ISBN: 1 85149171 6.

Wood, C., 1997., *'Paradise Lost - Paintings of English Country Life and Landscape 1850-1914'*. Past Times. Oxford. ISBN: 0 09 182028 0.

Woodward, B. B., Wilks, T. C. & Lockhart, C., c.1848. *'The History of Hampshire'*.

www.euroartcities.eu 2012

www.getty.edu 2012

www.kettererkunst.com 2012

www.macconnal-mason.com 2012

Tate Britain, 2004. www.tate.org.uk

Archaeology, Art and Coastal Heritage - Tools to support coastal management and climate change planning across the Channel Regional Sea: Technical Report

The coast of the Channel and Southern North Sea is a dynamic environment. Coastal erosion, increased storm frequency, flooding and instability are all providing challenges for managing risks associated with these threats. Understanding the long-term evolution of the coast is vital in order to understand how the present situation has arisen. From this informed position it is then possible to plan for future scenarios.

Detailed coastal monitoring data is usually only available for the past few decades, which means looking to alternative data sources to provide evidence from earlier periods. Archaeology, palaeoenvironmental data, coastal heritage, art, maps, charts and photographs can all be used to extract information on past coastal changes spanning from recent history back through hundreds of thousands of years to the earliest human use of the coast.

This is the final Technical Report for the project 'Archaeology, art and coastal heritage: tools to support coastal management and climate change planning across the Channel Regional Sea' (Arch-Manche). It details how data sources have been identified, ranked and analysed together to provide evidence of coastal change. Experiences of deploying a range of field investigation techniques to gather scientific data supporting understanding of past coastal change are detailed. The importance of this work in relation to coastal management is presented through a range of results from case studies within areas exhibiting different physical and geomorphological characteristics. The results demonstrate the as-yet unrealised potential within archaeological, paleoenvironmental, historical and artistic resources to inform on the scale and pace of coastal change.

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Arch-Manche
ARCHAEOLOGY, ART AND COASTAL HERITAGE

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