Adverse Weather Conditions in Medieval Britain: An Archaeological Assessment of the Impact of Meteorological Hazards

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Abstract

The history of the medieval period in Britain is punctuated by catastrophic events, including wars, political unrest, disease, famine and 'natural' disasters. While archaeological evidence for warfare, epidemics and diet have seen extensive research within the sub-disciplines of battlefield/conflict archaeology and paleopathology, 'natural' disasters have not sparked comparable investigations. This research aims, to a limited extent, to redress this. As with other calamities, disasters caused by natural hazards have, over the longue-durée, influenced humanity's regional social, economic and cultural development. This research therefore focuses on the multitude of impacts resulting from those hazards dependent on weather systems throughout the later British Middle Ages, defined here as AD c. 1000-c. 1550, analysing the different ways in which medieval populations responded to meteorological hazards through both physical and spiritual means using both archaeological and historical sources. The extent to which British medieval society adapted to the risk of natural hazards is also assessed.

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List of Abbreviations

BBC – British Broadcasting Corporation
DMV – Deserted Medieval Village
LIA - Little Ice Age
NCDC – National Climatic Data Center
OS - Ordnance Survey
OSL - Optically Stimulated Luminescence
RCHME – Royal Commission on Historic Monuments England
RCAHMW - Royal Commission on the Ancient and Historic Monuments of Wales
WEF - World Economic Forum

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1.0 Introduction

Meteorological hazards come in many different forms, from widespread flooding associated with high rainfall or rapid snowmelt to hurricane force winds and thunderstorms. These events themselves, however, can only become 'disasters' when they affect human populations. A storm in the open ocean in which no ships are affected can only be considered a natural hazard but not a disaster. These various hazards occur widely and frequently around the world and with global population now at a historically unprecedented level, they now more than ever interact with people and property. For example, in the US alone, 2013 was witness to nine meteorological hazards which each caused losses exceeding $1 billion in damage (NCDC 2014). As a result of the widespread and costly damage they have the potential to unleash, meteorological hazards are now regarded among both the most frequently occurring and the most damaging risks to modern society (WEF 2014: 16).

When human populations are confronted by hazardous anomalies within the natural world such as floods or storms, it is their understanding of the factors influencing change and their belief in human ability to mitigate, protect and adapt to new conditions that shape the strategies they adopt in the face of disaster. For example, Spanish folklore, probably with medieval origins, relating to storms recorded in the early 20th century holds that stones collected from riverbeds or irrigation channels on Holy Saturday can be brought out in the future and thrown in the direction of an impending storm in order to disperse the storm and protect the village (Brenan 1963: 130). While this practice, from a scientific perspective, is absolutely useless in preventing the approach of a storm, without knowledge of the true factors influencing storm propagation and movement, it is easy to understand how a method such as this could seep into local tradition, perhaps after it had once been employed successfully against a looming storm. This cultural component with which individuals and groups approach environmental hazards, which varies drastically both chronologically and geographically, strongly influences a society's resilience - its ability to successfully survive and recover from the destruction wrought by natural hazards. In the previous scenario for example, by believing that stones held the power to avert a storm, resilience could have been negatively affected by offering false hope which may have discouraged the villagers from taking more reliable practical precautions.

By analysing medieval Britain through an archaeological lens it is possible to illuminate both the impacts of natural hazards on a pre-industrial society with deeply religious worldviews as well as the varied responses which were adopted to manage the stresses exerted by natural physical processes. In Britain, earthquakes are rare occurrences and there are no active volcanoes but meteorological hazards, especially storms, floods and lightning, are common with the North Sea area experiencing among the most frequent storm tracks in the northern hemisphere (Lamb 1991: 3). By nature of the available evidence, some hazards offer greater potential for archaeological investigation than others, high snowfall for example is a particularly ephemeral hazard, although flooding, which can be more readily identified is often a secondary result of such precipitation. This study therefore primarily considers wind-blown sand, floods, lightning and windstorms, all of which have left physical signatures which, together with historical evidence, allow a wider picture to be built of the encounters that took place between medieval populations and environmental phenomena.

Therefore, the main aims of this study are threefold:

- To assess the physical impacts of meteorological hazards in the British Middle Ages (AD 1000-1550).
- To characterize the medieval experience of meteorological hazards.
- To understand how medieval communities and individuals responded to meteorological hazards, through both spiritual and material means.

1.1 Literature Review

Natural hazards have long been included in archaeological narratives. Rarely, but best publicised, archaeologists have encountered major sites which have fallen victim to natural hazards. Pompeii and Akrotiri for example were sealed and preserved by volcanic eruptions (Cioni *et al.* 2000), while Troy and Jericho were both damaged by earthquakes (Andrews 1965; Nigro 2014). Outside of these cases, hazards have usually been discussed for one of two reasons. Firstly, natural hazards have frequently been used to explain the collapse of ancient civilizations, for example, Minoan Crete and the volcanic eruption on Thera (Marinatos 1939), drought in the decline of the Indus Valley civilization (Staubwasser *et al.* 2003) and droughts and flash flooding in the case of the Moche in Peru (Shimada *et al.* 1991: 261-264). In these cases, whether or not the hazard triggered collapse has always been a controversial topic and connecting societal change to environmental triggers remains divisive (Torrence and Grattan 2002). Secondly, geo-physical hazards have provided a focus for archaeologists, collaborating with earth scientists, to investigate past geo-tectonic activity which can offer invaluable data, providing greater time-depth than instrumental records, to assist the prediction of future events (Sintubin 2011). Occasionally, this type of investigation has been combined with explicitly archaeological research agendas, for example studying the impact of tsunamis on ancient Mediterranean ports (Morhange *et al.* 2014) and the impact of the Storegga Slide tsunami on Mesolithic populations living in Doggeland (Weninger *et al.* 2008). Despite this type of research, only rarely have natural hazards from historic or prehistoric periods been investigated across a wide area with a view to understanding perceptions, socio-economic impacts and responses, both material and spiritual.

While geophysical hazards have seen a relatively high degree of research, the impact of weather on past societies as an avenue for research has generally been neglected. Archaeologists have instead, due to the wealth of proxies within the archaeological record for palaeoclimatic reconstruction, focussed on climate (Pillatt 2012: 30). Weather can be defined as the day to day patterns of atmospheric phenomena experienced in a certain location while climate describes the average weather experienced over the longer term (Kington 2010: 4). Archaeological evidence for weather events rather than wider climatic trends can often be difficult to detect and date accurately and it is often problematic to integrate wider climatic information with archaeological data due to the disparity in temporal and spatial scales (Cooper and Peros 2010: 1226). The relatively recent development of the theoretical models of contingency and punctuated equilibrium (Bell 2012: 44; Gould 1999) however, promote the inclusion of weather in archaeological narratives and recent storm events have illustrated the effect of high magnitude events on the landscape (Brown 1997: 140-141). The historical record, where available, often highlights the important role played by weather in the past and can usually provide dating information as well as a wider context. An example of the detailed level of information offered by the historical record can be seen in Widell's (2007) study of natural catastrophes in Northern Syria and this is even more effective when integrated with palaeoenvironmental data as in Kerr *et al.*'s (2009) study of early medieval Ireland. Evidence for medieval weather-related hazards is frequently encountered on archaeological sites with layers of sediment deposited by flood events often found in medieval contexts, standing building evidence for damage from storms or lightning preserved in the fabric of medieval churches and cathedrals and a considerable numbers of sites affected by wind-blown sand. Only rarely however, have these been investigated as primary aims of research, although in some cases this has been identified as a research aim for the future (Hall and Price 2012: 55). Sear *et al.*'s (2011) study of coastal erosion at Dunwich, Suffolk, and Gardiner and Hartwell's (2006) retrogressive landscape analysis in relation to flood breaches in East Sussex for example are rare in placing hazards central to the research agenda but by design are restricted to limited locales. Historical studies have more frequently concentrated on the impact of weather events, in particular the work of Lamb (1982, 1991) has been key in the development of the study of climate, weather and society. Hanska's (2002) work provides an important pan-European documentary-based study of spiritual responses to natural disasters but lacks any integration with material evidence. Similarly, works such as Zadok's (2013) study of medieval crop-protection methods touch on the effects of natural hazards on day to day life but rely solely on documentary evidence. From the perspective of historical climatology there has been extensive study of some weather related hazards, for example De Kraker's (1999) study of dyke failures in Flanders, but these are often more interested in reconstructing a series that can be used to compare to other climatic proxies rather than analysing wider social repercussions. Risk as a more general topic has often been touched on by historians and economists of the medieval period, with McCloskey's (1976; 1991) work on scattered agricultural holdings by the English peasantry perhaps one of the best known. A study focussing on the impact of meteorological hazards on medieval society as well as the responses they adopted to cope with these events, is therefore long overdue.

1.2 Weather in medieval Britain

In order to understand weather patterns and meteorological hazards in the medieval period, a brief outline of present British weather patterns (after Kington 2010: 5-11) is first required. The main characteristics of the British weather regime are driven by the meeting of warm subtropical and cold polar air masses. This results in very unpredictable weather, with radically changing conditions, often observable over short timescales, such as a few hours. The different regions of Britain experience slightly different weather patterns. Simplistically put, the maritime influences on the west cause increased rainfall and milder temperatures relative to the east which is affected more by continental systems with reduced rainfall and colder conditions. Precipitation is usually not extreme but frequent. Rapid downpours, however, are well known, usually occurring in thunderstorms throughout the summer months. The prevailing wind is most frequently from south to west, although local conditions can be the determining factor, less often switching between north to east, calm conditions, south to east and north to west.

For millennia until relatively recently, with the mechanization of agriculture and the weatherproofing of modern homes, the weather has been a central concern to people's daily lives. The particularly changeable nature of British weather patterns, at least compared to the Mediterranean (Jones 2013: 37), combined with the vulnerability of an agrarian society, forced medieval people to carefully observe and attempt to predict the weather. Anthropological studies of traditional societies reveal the extent to which folk-knowledge can be used to understand and interpret meteorology with a good degree of accuracy (Green *et al.* 2010). Medieval farmers, whose livelihoods depended on the weather, had their own array of popular phrases which allowed them to tap into a body of folk knowledge to forecast future weather (Simek 1996: 103-104). The behaviour of animals was also a recognised method of foretelling what the weather would bring (Jones 2013: 39). According to the Aberdeen Bestiary[1], for example, the caw of crows gave warning of rain (Aberdeen Univ. Lib. 1995: 58r). Perhaps the most accepted methods however, known as prognostication, were based on either: the day of the week on which Christmas Day or New Year's Day fell, the days out of the 12 days of Christmas on which the sun shone or in which month the year's first thunder was heard (Jones 2013: 40). Each of these different occurrences had different implications for what the year was likely to bring. The fact that these prognostications are found in pamphlets which belonged to people involved in agriculture (*ibid*) demonstrates that these were not just theoretical methods but were applied by people on the ground to predict day to day weather patterns. The need to have some idea of what atmospheric conditions were likely to appear in the coming days is demonstrated by historical accounts of the dire consequences caused by weather patterns. The *Anglo Saxon Chronicle*, for example, records many instances of bad weather, such as in 1117 which was described as "a very bad year for corn through the rains which scarcely ceased at all" (Giles 1914: 184). Similarly, in 1348/1349 floods and rain at Longdon, Worcestershire, caused the corn to rot, exacerbating the dire consequences of the Black Death (Dyer 1994: 71). Morhange *et al.* (2014) have cautioned against exaggerating the extent to which disasters affected past societies, arguing that current events and the modern research environment have increasingly caused this to occur. The archaeological and historical evidence however, proves that these hazards did affect a significant number of people in the medieval period and it is important to investigate the extent to which they were exposed as well as the means with which they responded to disaster.

Medieval British society cannot be considered monolithic. The largest disparities existed in terms of wealth and power, with the feudal system imposing a strict dichotomy between lords and peasants but regional differences also existed, for example between urban and rural, coastal and inland, lowland and

[1] Written c.1200.

upland settlements. Discrete differences in beliefs must have also existed throughout Britain. While the Church imposed considerable uniformity, local differences were still important. For example many Gaelic saints were venerated along the coast of the Irish Sea due to Irish and Scandinavian contact (Edmonds 2014) whereas Anglo-Saxon saints were common throughout England, even after the Norman conquest (Hayward 1999). While these different saintly cults had local peculiarities, cults of different origins both treated natural hazards in a similar way. This can be seen, for example, in the life of Saint Sunniva[2], an Irish princess, who was forced to leave Ireland and settled on the island of Selja off the coast of Norway along with her followers. Following a disagreement with the pagan locals, who accused the Christians of stealing their sheep, the heathen ruler, Jarl Hákon, brought an army to eliminate Sunniva and her followers. Just prior to the arrival of Hákon's troops however, the Christians prayed to God who sent a landslide which entombed the colony, thus making Sunniva a martyr (DuBois 2008: 68). A connection with hazards and saints was far from a regional abnormality however as illustrated by the story of the Anglo-Saxon Saint Swithun. When Swithun was canonized the monks decided, contrary to his wishes, to move his body from the churchyard into the choir of the church, however on the day this was to take place, 15th July, violent rains arrived which did not abate for forty days and the plan to relocate his body was abandoned (Cassan 1827: 114). From these accounts it is clear that medieval Christians strongly believed the natural world was well within the power of God and the saints to control. Changes in the natural world were interpreted spiritually with factors such as the weather frequently interpreted as signs from the divine (Dutton 2008). According to Watkins (2007: 23) "The world was conceived as a web of signs and symbols which illustrated or illuminated scripture rather than a mass of causes and effects to be elucidated through the exercise of reasoning". Christian teaching through sermons, masses, festivals, art and theatre were fundamental in shaping British medieval beliefs and identity and as a result would have strongly influenced their perception of natural hazards. Although it is difficult to gauge to what extent the continuity of pagan beliefs from earlier times persisted into the later medieval period, there are numerous accounts from medieval chronicles of rituals described as pagan (Watkins 2007: 88-94) and in connection to natural hazards, Hanska (2002: 170) believes pagan protective rites were integrated into Christian doctrine by the early Catholic Church.

While a considerable amount is known about medieval knowledge and beliefs relating to weather and meteorological hazards from the period's extensive documentary record, research has not previously applied archaeological methods to consider how weather-related hazards influenced society at the macro-scale. This study, therefore approaches the encounter of medieval communities with meteorological hazards from an archaeological perspective, in addition to the main aims outlined above attempting to illustrate the exposure, vulnerability and responses adopted by these populations throughout the later Middle Ages.

[2] Two chapels dedicated to St Sunniva existed in Britain on Shetland, at Balta and Yell (MacKinlay 1914: 305).

1.3 Methodology

As discussed above, archaeologists have rarely considered meteorological hazards beyond the level of individual events or sites. As a result, this study was forced to approach the subject using a variety of sources of evidence. The starting point for this was a broad literature search through both archaeological and historical sources. This study therefore combines disparate types of data, from OSL dating of aeolian sand deposits to medieval chronicles. The use of historical sources provides an invaluable strand of information, frequently providing dating and information that archaeology alone is unable to provide. The nature of the subject matter, therefore, makes it questionable whether a similar study that focussed on a prehistoric period could be feasible (Wilkinson 2012: 58).

While an attempt was made to be as comprehensive as possible, especially with lightning and windstorms, it is inevitable that some sources will have been missed and therefore the evidence presented cannot be considered exhaustive. It is important to point out however, that this would always be the case because an unknowable number of events went completely undocumented and documentation has subsequently been lost or destroyed. While attempts have been made in the past to compile complete lists of historic weather events (e.g. Britton 1937) these sort of compilations are plagued by problems such as scribal errors, exaggeration and misreporting of events, requiring careful source criticism (Brázdil *et al.* 2005: 373-374). In order to build an illustrative list of events, online databases of British historical sources were queried with relevant search terms such as 'flood', 'storm' and 'lightning'. Inevitably, as these sources were followed up, other events were encountered and these too were added to the list. For hazards such as lightning and windstorms, the evidence for which can be positively identified only in conjunction with documentary evidence, this then allowed a literature search for archaeological studies which had been conducted on affected sites to see what, if any, evidence for the effect of natural hazards had been encountered. This provided a surprising number of case studies although the number of events with good archaeological evidence remains low.

The hazards with the most archaeological evidence, flooding and wind-blown sand, proved equally problematic to research. In common with the historical record, the archaeological record is incomplete, as sites have been lost as a result of various destructive processes, including the action of natural hazards themselves, and many sites remain unknown or under researched. There must be many sites which were engulfed by wind-blown sand or buried by flood deposits, for example, which remain unknown, buried beneath sand dunes or alluvium. In addition, wind-blown deposits are frequently encountered on coastal sites around the British Isles so to assess absolutely all medieval period sites where these sediments were encountered would have been unmanageable. As a result, this study focuses on medieval settlements although other sites which are important to the discussion, such as rabbit warrens and hoard depositions, are also included. In addition, the unique and extensively studied environment of the Machair of western Scotland and the Hebrides, which presents its own methodological challenges (Barber 2011), is excluded to allow the discussion of wind-blown sand to be more focussed.

As the hazard for which the most evidence exists, floods are the event for which the compilation of a comprehensive list of events would be most problematic. The difficulties here include defining the area of effect of a flood as while inundations usually affect many areas along the course of a river, historical sources usually only define one location, usually a town. In addition, the magnitude of flooding is usually difficult to ascertain from historical or archaeological sources. Minor floods probably occurred on most rivers almost every year and these were far from always negative occurrences while only more major floods threatened lives and livelihoods. With the vast number of rivers in Britain and a 550 year window of time, it is clearly a vast task to compile what would remain, due to the patchy and unreliable nature of the historical record, an incomplete record of medieval inundations. As a result of these considerations this study selects illustrative case studies to explore the impacts and responses which the different natural hazards engendered as fully as possible.

2.0 Wind-Blown Sand

While sand does not call to mind the scenes of destruction often associated with geophysical hazards such as earthquakes and volcanoes, when areas of human settlement or agriculture are affected, the results can be devastating. Sand inundation may incorrectly be assumed to be a hazard limited to arid regions but Britain possesses numerous coastal sand dune environments (Doody 1991: 35-38; fig. 1) and sand inundation has been a problem since prehistory (Sommerville 2003: 24) with well known examples including the Neolithic village of Skara Brae[3] on Orkney (Griffiths 2011: 19) and the Bronze Age and site at Gwithian[4] in Cornwall (Nowakowski 2007). Medieval legend alludes to the hazard in the story of Lomea, an Island off the Kent coast which, according to documentary evidence, was consumed by aeolian sand in an Atlantis-like catastrophe in a storm of 1099. No material evidence however, has since been found supporting the existence of Lomea (Crawford 1931: 101-103). Concrete archaeological evidence does exist from a selection of events that illustrate the damaging impact of wind-blown sand across medieval Britain. Some of the most comprehensive evidence comes from Viking-Age Orkney as well as later medieval examples from mainland Britain. By its nature, wind-blown sand is geographically limited to areas where a supply of sand exists which can be influenced by winds. Sites next to sandy coastlines are most vulnerable where winds can 'roll' sand inland although the wind can also transport sand onto higher ground such as cliffs surrounding and surrounding high ground (Toft 1988: 24). Risk in Britain is therefore focused around coastal and neighbouring regions, where the impact of storm activity is frequently strongest. Extreme conditions though, are not necessary for wind-blown sand to become a problem and dependant on conditions, aeolian sand can be considered either a creeping or a sudden-onset hazard. While moisture content, grain size and uniformity dictate the effect of the wind (Ritchie 1972: 20), wind-speeds of just 10 m/s are enough to cause free sand to move in almost any location (Sherman and Nordstrom 1994: 263). Strong winds and storm events however, precipitate the deposition of the greatest volumes of sand and it is these events that normally result in the most devastating losses.

2.01 Mitigation

Options once sand has become a problem at a site are limited. In extreme events it can be extremely labour intensive or patently unfeasible to remove the sand and deposit it in a more suitable location. This is made easier today by modern technology not available in the past such as mechanical earth-movers but it remains far from an easy option, as demonstrated at East Lindsey, Lincs., in March 2013 (BBC 2013). Even if the sand can be successfully removed, structural remains and agricultural produce will be severely damaged as a result of the process of sand inundation and excavation, and repair and replacement could prove prohibitively expensive. In cases of total inundation, marginally less costly might be establishing a new settlement close by, hopefully in a location of reduced risk but again this would be a difficult task. Frequently, it might prove easier for survivors to relocate to existing nearby settlements rather than attempting to re-establish their previous living conditions at or close to the site of the hazard.

[3] besanded c. 2470-2190 cal. BC (Sommerville *et al.* 2003: 634).
[4] inundated throughout the Bronze Age (Nowakowski 2007: 22).

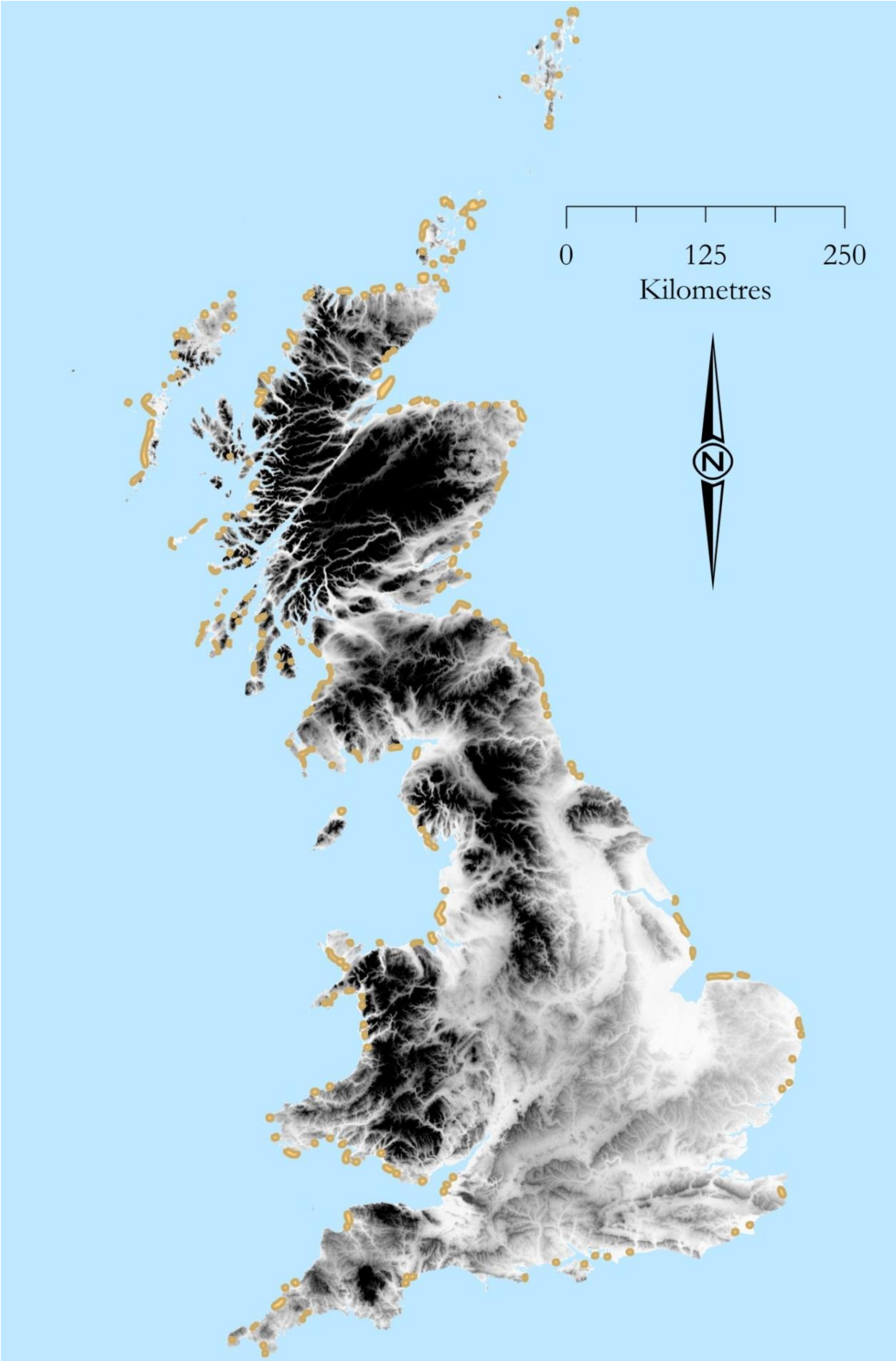


Figure 1 - Sand dune environments around Britain's coasts (Created by the author after Doody 1991: 37).

2.02 Protection

Sand is a difficult hazard to protect against due to its sheer volume and the continual force of the wind. Fencing is a simple yet effective measure used to protect against the movement of sand. The barrier formed halts the progress of blown sand forming a sand bank which can have other protective benefits (eg. from coastal floods; Pye, Saye and Blott 2007: 3-7). Once the sand reaches the height of the fence however, new fencing further inland or a taller barrier at the original site is required to offer further protection. Fencing cannot remove the hazard, only buying time by focussing the effect at a preferable location (Sherman and Nordstrom 1994: 270).

2.03 Adaptation

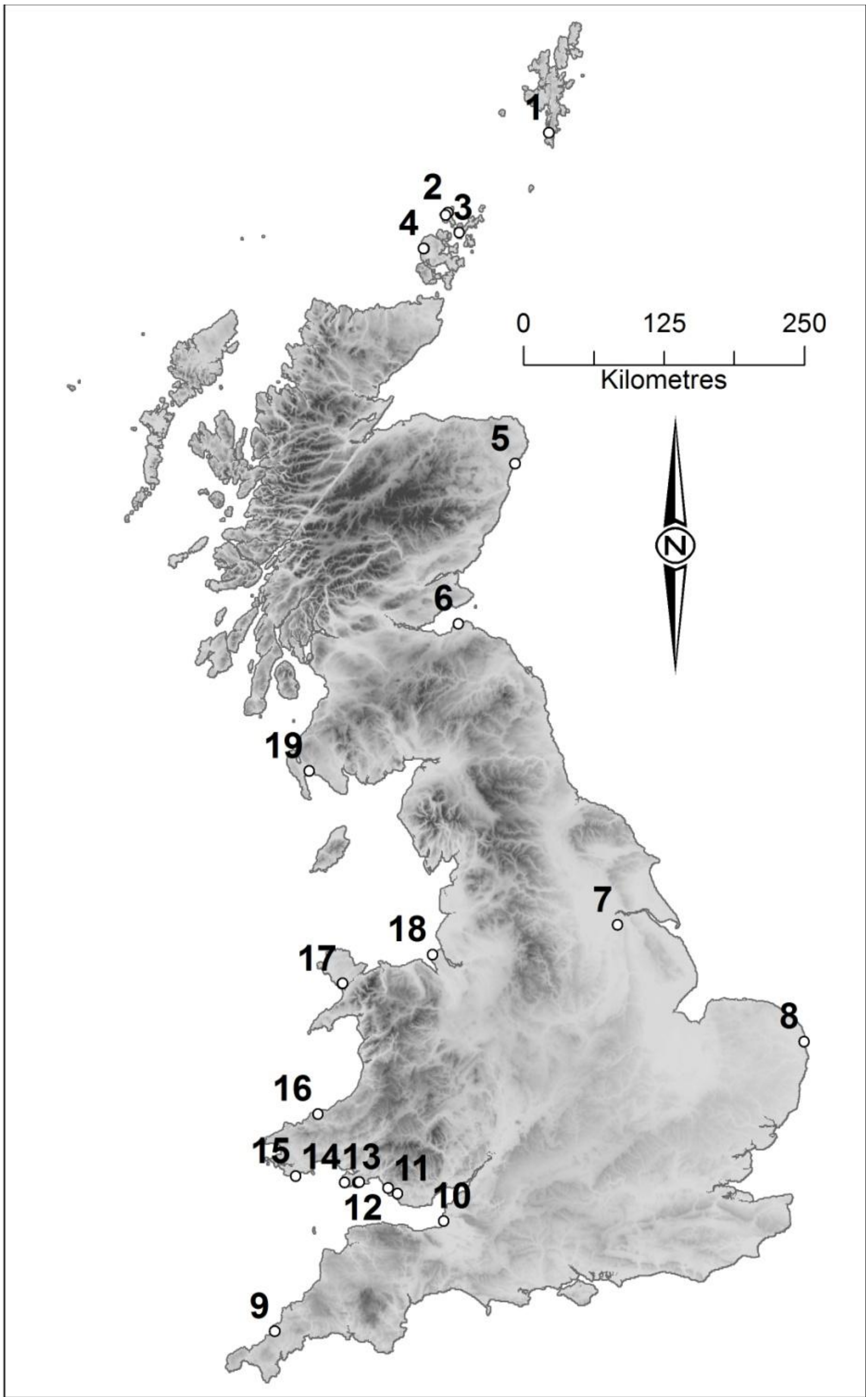
Much of the risk caused by wind-blown sand across northern Europe has directly resulted from human malpractice throughout the historic period (Van Doesburg 2009: 186). The most damaging activities to dune systems are overgrazing and the stripping of plants that hold the sand together and reduce the impact of aeolian forces (Doody 2013: 39-40). A case study for this change comes from the Culbin Sands, Moray, where sand dunes, some around 30m in height, over a wide coastal area became increasingly hazardous from at least the 17th to the early 20th century (Ross 1992: 65). A storm in 1694 caused the dunes to submerge a considerable area of the agricultural lands of the Laird of Culbin, although the scale of the loss was heavily exaggerated in later periods (Ross 1992: 2-4). Since the 19th century attempts to prevent the movement of sand at Culbin have focussed on afforestation, but only since the involvement of the Forestry Commission from 1922-1963 with the establishment of 2560 ha. of forest, mostly species of pine[5] (Ross 1992: 73-81), has the hazard been brought under control. Similarly, around the majority of the UK the hazard posed by wind-blown sand and sand dune migration has largely been eliminated or kept at bay through careful environmental management, prioritizing the re-establishment and protection from removal of plant communities (Sherman and Nordstrom 1994: 272), including pine and the hardy and self-propagating *Ammophila arenarius* (Marram Grass) which shields sand from the wind, binds it together and withstands most minor storm events (Doody 2013: 202-203). Wind-blown sand remains a cause for concern along many parts of the UK's coastline, for example East Sussex (East Sussex County Council 2014), although continual monitoring of risk by government agencies means that these risks are constantly measured, hopefully greatly reducing the possibility of sand inundation posing a threat to the UK coastline (Pye, Saye and Blott 2007: 3-5, 3-6).

2.1 Evidence for the Hazard in the Middle Ages

Within particular geographic areas there are numerous examples of wind-blown sand affecting medieval populations. Rising sea levels throughout the Holocene have led to sand being deposited at many points along the shoreline and subsequently driven inland by aeolian processes (Sommerville 2003: 71). While sand inundation is frequently a factor in site formation processes the action of winds and storms also frequently leads to the discovery of lost sites, although often this process results in stratigraphic mixing

[5] 65% *Pinus sylvestris*.

and renders the site vulnerable to subsequent erosion (Dawson, Lelong and Shearer 2011: 91-92). The fact that significant numbers of unknown sites exist concealed beneath sand and successive vegetation at many points along the British coast has become clear following the storms of 2013/2014[6], signally a hazard, primarily limited to coastal regions but with a widespread geographic influence. Despite the associated difficulties of applying traditional techniques to sand dune environments (Griffiths 2011: 13), a number of examples which have been investigated archaeologically are known from the Middle Ages and great potential exists for future discoveries within these environments.



1 – St Ninian's Isle

2 - Evertaft and Pierowall

3 - Sandhill

4 - Bay of Skaill and Mound of Snusgar

5 - Forvie

6 - Eldbotle

7 - Flixborough

8 - Fuller's Hill

9 - Perranzabuloe and Mawgan Porth

10 - Berrow

11 - Merthyr Mawr

12 - Kenfig

13 - Pennard and Penmaen

14 - Rhossili

15 - Stackpole

16 - Y Ferwig

17 - Newborough and Llys Rhosyr

18 - Meols

19 - Glenluce

Figure 2 – Map of locations affected by wind-blown sand discussed in the text (Created by the author).

[6] For example, as discussed at the 6th MOROL (Institute of Welsh Maritime Historical Studies) conference, 01/11/2014.

Chronologically, the earliest evidence comes from Viking-Age Orkney where a number of sites were affected by the hazard. One of the earliest is the site of Evertaft, a Viking Age settlement site characterized by interspersed sand and midden deposits with dry-stone masonry (Sommerville 2003: 107; Lamb 1983: 30). The various layers of sand could not be linked stratigraphically (Sommerville *et al* 2003: 1091), making it initially difficult to say whether they represented deposition in one or two episodes or a gradual build up over a longer period. OSL dating by Sommerville (2003: 309) demonstrated a distinct phase of sand deposition at the site at 940±110. Taking the different dates obtained in sequence Sommerville *et al.* (2003: 1090) were able to estimate a mean sand deposition rate at the site of 0.5cm/yr although, the disproportionate movement of sand resulting from severe storm events calls into question the usefulness of this figure. The heterogeneous partial bleaching[7] of the sand grains also supports gradual rather than sudden deposition (Sommerville 2003: 316-317), indicating that the hazard posed a continued threat rather than precipitating a decisive cessation to settlement at Evertaft.

Figure 3 - Remains of the chapel below which the hoard was buried on St Ninian's Isle, Shetland. (Photograph by Christopher Gerrard).

A comparable site is the Mound of Snusgar, dating to the early Viking Period[8] (Griffiths 2011: 19; Griffiths 2004: 95). Excavations revealed Viking stone buildings which had been abandoned and consumed by 1-1.5m of wind-blown sand (Griffiths 2011: 19). The site is known locally as the 'Castle of Snusgar' and in 1858 one of the largest known hoards of Viking silver was discovered at the site (Griffiths 2011: 16). Recent finds included a green-banded whetstone, which is known from sites in Norway to be a

[7] Indicating the sand may not have been exposed to enough sunlight to reset the luminescence signal.
[8] 800-1100 AD

high-status object (Griffiths 2004: 95). Although the site may not have been a castle, the evidence points to an elite residence of some kind on the site. It is tempting to view the deposition of the hoard, dated to c. 950-70, as a reaction to the inundation of the site by wind-blown sand and indeed the date of the hoard closely matches C14 dates from midden material deposited to stabilize the sands (Griffiths 2013: 501, 520). A hoard in a comparable context was found on St Ninian's Isle, Shetland, dating from after c.800. A layer of wind-blown sand accumulated at the site in the 11th or 12th centuries when the Norse occupation ended (Barrowman 2011: 187). Following this, a Christian chapel was constructed on the sand (fig. 2), perhaps signalling that the location held long-standing ritual significance. The disparity in date between the burial of the hoard and the onset of wind-blown sand does not preclude a connection, as curation and deposition in a later period is a distinct possibility (Barrowman 2011: 201, 203). While Graham-Campbell and Batey (1998: 243, 246) regard Viking hoards as examples of burial for safekeeping rather than for spiritual reasons, the continued build-up of sand at the site would have made these ill-suited locations in which to inter valuable metalwork if later recovery was the true aim. Due to a lack of evidence however, the connection between environmental conditions and the internment of hoards must remain hypothetical.

Recent excavations at Birsay Links and the Bay of Skaill (very close to the Mound of Snusgar) both demonstrate that sites of importance in the Viking era declined and were covered by sand in the later medieval period (Griffiths and Harrison 2011: 321-324). The clearest dating evidence came from the Bay of Skaill where occupation most likely ended in the 12th or 13th centuries, possibly following the abandonment of a Viking longhouse structure (Griffiths and Harrison 2011: 324). Later evidence of sand movement comes from the Orkney Islands of Pierowall and Sandhill where OSL dating identified wind-blown deposits at 1385±45 (Sommerville 2003: 350), probably indicating increased storm activity at this point.

Further south on the Aberdeenshire coast, the town of Forvie offers a glimpse of a later extreme event. The sand dune system at Forvie has been irregularly advancing north throughout the first millennium (Milek 2012) and must have posed a considerable hazard over this time. This may be indicated by the presence of mussel middens dating to the Pictish period which could be interpreted as a 'famine food' necessitated by the environmental changes brought on by the movement of sand (Milek 2012). A medieval settlement was located at the site from at least the 12th century when the church of St Adamnan was constructed (Kirk 1957: 4). However, in 1413, a storm buried the town under 30m of sand (Lamb 1982: 185). Historical documentation records that the storm came from the south. According to Lamb (1982: 185), this would have caused a reduction in the level of the North Sea which, combined with a coincidentally extreme low tide, would have exposed an unusually large body of sand to fierce aeolian forces. Limited excavations in the 1950s exposed the town's church (Kirk 1957: 4; Kirk 1958: 2), which contained burials from the 13th and 14th centuries up to the point of abandonment. In 1960, further excavations 35m to the east of the church revealed walls and a cobbled pavement together with medieval pottery most likely indicating a portion of the rest of the medieval settlement (Kirk 1960: 2). Evidence of rig and furrow cultivation, as well as field boundaries and drainage ditches have also been detected surrounding the site of the settlement (Milek 2012) and this has led Ritchie (2000: 215) to propose that over-cultivation may have been a contributing factor in increasing the vulnerability of the population. Geoarchaeological investigations of the cultivated area demonstrate that manuring may have been a response to the encroachment of sand in an attempt to preserve the fertility of the soil (Milek 2012). Absolute dating of the relevant soils has not been possible however, and manuring was not new to the site as it was also practiced in the Iron Age (Milek 2014). A current research project of Aberdeen University focuses on Forvie's prehistoric archaeology (Milek 2012), but presumably more of the medieval settlement remains beneath the dunes. Following the event, the population seems to have relocated 6km to the north to Leask, where a new St Adamnan's chapel existed by 1499 (MacGibbon and Ross 1897: 388), which Robertson (1843: 388) refers to as "the parish church of Furvie".

A comparable picture is offered by the medieval settlement of Eldbotle, East Lothian, where wind-blown sand was a component in the community's decline throughout the 14th and 15th centuries. Settlement at Eldbotle appears to have always operated on a delicate balance, resorting to intensive manuring strategies to improve the yields that arable agriculture in chiefly poor soils could provide. To achieve this, turf was stripped from nearby sand dunes for use as fertilizer which, together with other land use decisions, would have exposed the sand to aoelian erosion (Hindmarch and Oram 2012: 282). Large scale harvesting of grasses from the dunes for roofing materials also took place, indicated by a 1230 grant by the landowner, William de Vaux, to the Canons of Dryburgh who were permitted to take as much as they required to roof their buildings (Hindmarch and Oram 2012: 289). Overgrazing by cattle and sheep and the colonisation of the dunes by rabbits (Hindmarch and Oram 2012: 287) would have further contributed to the decay of vegetation and concurrent destabilization of the sands. Once episodes of sand inundation had started to put pressure on the population they may have resorted to unconventional sources of sustenance including shellfish such as limpets which are usually only consumed by humans in famine situations (Hindmarch and Oram 2012: 283). Sand did not cause the collapse of settlement at Eldbotle, which continued into the 18th century, but the peak of activity in the 13th century was very much reduced by the late 14th and early 15th centuries. Repeated outbreaks of disease in both human and livestock populations must have exerted enormous pressure on the surviving population leaving them especially ill-equipped to deal with sand ingress which resulted in the abandonment of a number of buildings following sand inundation (Hindmarch and Oram 2012: 293-295).

The site of Meols[9], Merseyside, may offer an example of a settlement which was almost completely destroyed by the action of the hazard (fig. 3). A vast array of material culture has been retrieved from what is now a sandy beach, of a quantity paralleled only by major settlements with international trading contacts such as London (Griffiths *et al.* 2007: 434). These finds were mostly detected through chance by non-archaeologists, and included numismatic, metalwork, leather and wooden artefacts. Observations made in the 19th century document remnants of structures from the

[9] The Meols place-name is of Norse origin meaning 'sand-bank' (RCAHMW 1982, p. 267).

Medieval period (Cox 1894: 45), although the significance of these structures often went unappreciated and their remains have not been recorded. Their textual descriptions however, point to an early medieval settlement characterized by longhouse structures which developed to a nucleated settlement by the later medieval period, although details of phasing and dating are difficult to disentangle from the surviving accounts (Griffiths *et al.* 2007: 19-21). With evidence of a settlement at the site from Roman times to the later Medieval period, Meols' apparent disappearance at the close of the 15th century has been linked to a natural disaster from the time of discovery, probably an extreme wind-blown sand inundation (Hume 1863, p. 383; Griffiths *et al.* 2007 p. 436). This is indicated by the stratigraphy which records a layer of 'drift sand' above the layer of medieval cultivation and occupation (Ecroyd Smith 1866: pl. II), although coastal erosion may also have played a part (Hume 1863: 383). While a steep decline in the number of coins in the 14th century (Griffiths *et al.* 2007: 435) may indicate problems at Meols before its abandonment, occupation continued, only reaching an absolute cessation in the late 15th century. Archaeological evidence from later periods then shifts to a nearby location known as Great Meols, between 1500 and 1550 (Griffiths *et al.* 2007: 414). Analysis of the field-names and tithe mapping of Great Meols suggests that the losses to sand were made-up for by reorganising more marginal land to the south, probably including a former open field known as the Yard or Old Yard (Griffiths *et al.* 2007: 409-411). That Meols was overcome by sand in one event seems likely given the quantity of material recovered from what was a relatively minor fishing port. This fits well with sudden, unexpected be-sanding in an extreme storm preventing retrieval of many of the objects that have been discovered.

Figure 4 - The modern coastline at Meols with sand dunes in the foreground (© Meols Project, National Museums Liverpool).

Roughly 200 kilometres north-west of Meols at Glenluce, Dumfries and Galloway, wind-blown sand deposition is evidenced between the early 15th century and c. 1495. The dates come from an abandoned house or hunting lodge, probably abandoned prior to becoming covered by sand, and a later coin hoard buried within the layer of wind-blown sand which had accumulated by that point (Jope and Jope 1959: 261-264). While not necessarily a result of the same storm event as the be-sanding of Meols, the sequence from Glenluce does further highlight that sand was moving at that period along the coasts of the Irish Sea. Another hoard in a blown-sand context also adds weight to the hypothesis that they held some ritual significance. The geographic spread of these sites, all from Scottish coastal areas with Norse links, may attest to a pagan tradition which, in the case of Glenluce, permeated into later popular Christian practice. Northern European prehistoric analogous depositions are increasingly viewed as communal offerings to deities for favourable treatment such as protection from natural hazards (Menotti *et al.* 2014: 466) and this would similarly explain these hoard depositions in connection with wind-blown sand.

The Welsh coast offers a wide selection of sites and landscapes where wind-blown sand became a hazard in the medieval period although they are an under-explored archaeological resource (Davidson 2002: 5). The largest example, the town of Kenfig, became covered by sand, most likely in the 15th or 16th centuries. Various archaeological projects have been conducted at the site since the late 19th century and as such, it is a relatively well explored site. The establishment of the medieval burgh was preceded by the foundation of Kenfig Castle in the early 12th century (Gray 1909: 57; Wessex Archaeology 2012: 2) around which a planned walled town soon developed (Wessex Archaeology 2012: 22-23). An extra-mural settlement, which by 1154 contained the town's church dedicated to St James (Higgins 1933: 34), also developed outside the town's walls (Wessex Archaeology 2012: 24). When precisely the town became overrun by sand is unknown but when the antiquarian John Leland visited the site in 1538 or 1539 he described it as "in Ruines and almost shokid and devourid with the Sandes that the Severn Se ther castith up" (1906: 29). Sand may have been beginning to pose a problem by 1262 when a new church was built away from the sands on higher ground and documentary evidence alludes to problems throughout the 14th century (Higgins 1933: 34). The archaeological remains however suggest Kenfig was not abandoned until the 15th or 16th centuries (Wessex Archaeology 2012: 24). While Morris re-tells a story of people having to be dug out from a house so suddenly engulfed by sand that the occupants had no time to escape (1907: 6), other evidence seems to suggest there was time to save building fabric for re-use (Wessex Archaeology 2012: 24) suggesting a high variation in the effect of the hazard across the settlement. The old church of St James appears to have been partially dismantled following the encroachment of sand (Gray 1909: 83-84), with burials and worked stones, including coffin lids, observed and retrieved from the location in the 19th century. At around 1485 a new church dedicated to St James was built at Pyle, roughly one mile from Kenfig, which Gray interprets as a replacement for the old church which must have been buried or at substantial risk from sand by that point (1909: 95).

A number of sites close to Kenfig also fell victim to the hazard. The town of Pennard for example followed a similar trajectory, with a castle constructed c. 1100, next to which a church was built at the same time as the castle was re-modelled in the late 13th century (Higgins 1933: 30). An associated settlement also developed evidenced by a house excavated from beneath the sand (Moorhouse 1985). This structure was destroyed in a fire with the state and location of the ceramics within the building consistent with falling debris as the building burned down (Moorhouse 1985: 5). Interestingly, this is paralleled at Fuller's Hill, Great Yarmouth, where Rogerson (1976: 159) links the evidence for intense burning across the numerous levels of occupation as a product of the pressure of the wind and sand on buildings which collapsed in upon active hearths, a likely scenario for the house at Pennard. The stratigraphic relationship of the peasant dwelling, resting upon layers of existing wind-blown sand, suggests the hazard posed a continued risk throughout the life of the settlement with a layer of midden material and an earlier hearth discovered below the layer containing the house (Lees and Sell 1983: 46-47). This accords well with the documentary evidence which attests to the presence of sand by 1316 with most of the village becoming inundated by 1528 (Higgins 1933: 32). Up until this point, although the sand must have caused considerable problems, the survival of structures and sufficient agricultural land must have prevented the settlement reaching a tipping point, allowing the continued viability of settlement at the site. The Merthyr Mawr area was also affected by the movement of sand throughout the 15th and 16th centuries (Randall and Rees 1932: 41). In addition, a monastic grange of Margam Abbey, Neath Port Talbot, known as the Hermitage of Theodoric, was inundated by sand, dated by Gray (1903: 142) to c. 1300 based on documentary and archaeological evidence. The lack of corrosion on the ironwork and relatively well-preserved state of the structural remains convinced Gray that the structure was buried quickly in one episode, preventing corrosion and decay (1903: 126-143). A re-analysis of the historical documents however, convincingly demonstrated that this grange was still in use by 1535 (Cowley 1963, suggesting the event more likely took place in the mid-16th century, perhaps in the violent storm of 1606 (RCAHMW 1982: 272). Similarly, excavations at the be-sanded medieval church and associated settlement at Rhossili, Swansea, were interpreted, with a degree of uncertainty, not as a case of abandonment in the face of wind-blown sand but as a gradual desertion as people moved a short distance to higher, more favourable ground. An inundation at some point after c.1540 then probably buried the remains of the near derelict church and settlement (Davidson *et al.* 1987: 260-261). Excavations at Llys Rhosyr, Gwynedd, and Stackpole, Pembrokeshire, also identified phases of sand deposition, with the former, a royal-residence of the Welsh princes, probably becoming be-sanded in 1332 (Johnstone 1999: 274) and the latter exposed at some point between the 14th and 16th centuries (Benson *et al.* 1990: 239). The church at Berrow, Somerset, also provides further evidence of sand inundation in the later medival period although very little archaeological work has been undertaken (Rippon *pers. comm.*). These events fit into a phase of wind-blown sand deposition along the Welsh coast which characterized the LIA which Higgins (1933: 64) viewed as a "sharply defined change" from previous conditions (fig. 4).

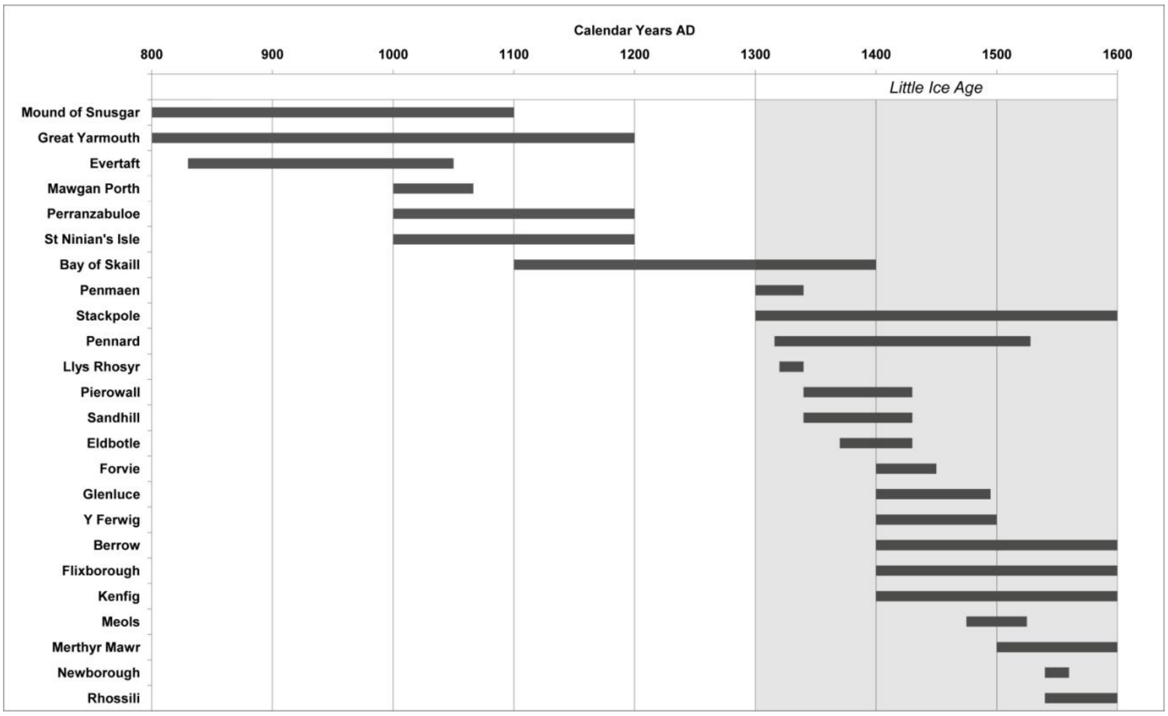


Figure 5 - Timeline of wind-blown sand inundations at sites discussed in the text. The majority can be seen to have occurred post c.1300 in the LIA. (Created by the author, Data available in appendix 1).

Further evidence for the effects of wind-blown sand can be found in Cornwall. At Perranzabulow, for example, the name itself Perran (St Piran) and zabuloe (sabulum: sand), is derived from the supposed burial place of the saint, as well as the presence of sand at the site (Haslam 1844: 27-30; 57). Excavations in 1835 revealed an oratory which was dated to the sixth century (Haslam 1844: 1); although this has been questioned (Orme 2000: 221). The roof had been removed prior to becoming be-sanded (Haslam 1846: 228), suggesting multiple events precipitated abandonment giving time for the removal of features for reuse. Following inundation, the dunes covering the oratory remained a popular burial place due to their relationship with the saint buried below, at least into the 16th century when it was observed by the antiquarian William Camden (Haslam 1846: 227; Haslam 1844: 60). The oratory was covered with concrete in 1910 to protect it from erosion and has been the subject of a recent archaeological project to re-expose the medieval remains (BBC News 2014). The date of this sand movement tallies closely with the abandonment of the nearby settlement at Mawgan Porth, roughly 1000-1066 (Bruce-Mitford 1997: 88-89) which may indicate that Cornwall was affected by either a single storm or, more likely, a phase of stormy weather which precipitated sand movement in the eleventh century, affecting both sites. Following the loss of the oratory, a new church was constructed close-by in c.1150 (Ravenhill 1955: 240). The presence of a stream between the new church and the besanded oratory was thought to provide protection from the sand encroaching any further. This seems to have been the case as sand cannot have been a problem before the post-medieval period as the church was expanded and updated stylistically in 1420 (Haslam 1844: 40-41) suggesting no imminent threat from wind-blown sand was perceived. In the 18th century the stream was diverted and the sand began to progress inland (Haslam 1844: 40-41). Especially in the immediate aftermath of the shrine's inundation, the protection provided by the stream in preventing further inroads by the sand may have been attributed to the power of Saint Piran as it was commonly accepted that saintly relics and holy shrines emanated powerful protective forces (Biraben 1976, p. 83), and this can only have increased the renown of the saint.

2.2 Medieval Mitigation Strategies

Wind-blown sand leaves an identifiable imprint in the archaeological record which can provide important clues in identifying the nature of human interactions with the hazard. The Viking-Age site of Evertaft, discussed above, for example, when excavated revealed layers of sand interspersed with occupation layers signalling a hazard which most likely would have posed a continuous threat rather than a cause for abandonment. Midden material interspersed throughout the stratigraphic sequence was interpreted by the excavators as the attempted mitigation of the encroachment of wind-blown sand through spreading the heavier midden material over the sand which halted further movement (Barrett *et al.* 2000: 21). Midden material was also found at the Mound of Snusgar where it was re-deposited in order to create a good surface for habitation and agriculture following inundation by sand. However, this was only a short-term solution with the heightening effect of the midden material only increasing the ability of the mound to trap blown-sand, creating a vicious cycle that ultimately must have brought on its abandonment (Griffiths 2011: 19).

This practice may be paralleled at a later period along the south Welsh coast at Carmarthen Bay (Higgins 1933: 30) and Pennard (Lees and Sell 1983: 47), an area equally exposed to wind-blown sand, where midden material was also found overlying layers of sand. The effectiveness of this method however is debatable. If it worked at all, it would have required a great deal of manpower as well as a ready supply of midden material to cover large areas of sand threatened by the wind. The Mound of Snusgar and the the Welsh examples, were all eventually overcome by sand and this would seem to prove that if midden material was a deliberate preventive strategy it can only have been a short term solution. Rather than to stabilize, midden material may also have been used to fertilize (Harrison 2013: 100-101), perhaps a requirement of soils which had become mixed with aeolian sand. An analogy for this can be found at Forvie where geomorphological sections indicate that when fertile soils worked throughout the medieval period became covered by sand, manuring may have taken place to maintain the agricultural vitality of the farmland (Milek 2012). A lack of charcoal from these contexts however, has made it impossible to date these soil horizons definitively (Milek *pers. comm.*).

Especially since the available practical measures were ineffectual, spiritual responses were likely one of the first routes down which medieval people would have gone in an attempt to halt the inroads made by aeolian sand. A variety of spiritual responses were probably widespread but the fact that the hazard only affected a relatively small number of settlements where the correct environmental conditions existed means that references in documentary sources are rare. Evidence for this is available however in the work of the 15th century Welsh poet Dafydd Nanmor. His poem '*I Bedrog Sant am Yrru'r Tywod o'r Tywyn*' describes prayers being offered to Saint Pedrog (or Petroc) to drive back sands that had inundated the parish of Verwick[10], Cardiganshire (Roberts and Williams 1923: 15-17, 132). Two facts indicate that this poem has a strong factual basis; firstly, Saint Pedrog was the patron of the local church (Bowen 1955, p. 202) and secondly, archaeological evidence attests to medieval sand inundation (Dyfed Archaeological Trust 2013), perhaps exacerbated by the introduction of rabbits. This illustrates that prayers to local saints were a common response which required no material resources while providing hope and reassurance for those affected.

Where the hazard could not be prevented from encroaching upon human occupation the only possible recourse was abandonment. From the examples above, the most obvious example of this is Meols, where settlement was forced to shift from the original site to the less-vulnerable location known as Great Meols. As the site appears to have suffered total destruction by wind-blown sand all survivors would have been forced to relocate. While Great Meols seems to have been the obvious choice, it is likely that other neighbouring settlements were also settled by refugees from Meols. It is possible that Meols was consumed by a single catastrophic storm event, which may not have been anticipated, although more minor problems with wind-blown sand almost certainly affected the community throughout its history. Kenfig appears to have continued business as usual despite the growing threat of the sand, suggesting the inhabitants may not have perceived sand inundation as an inevitability (Wessex Archaeology 2012: 24). Reuse of building fabric from structures which must have fast been becoming be-sanded and relocation after the event certainly took place however, as the construction of the new church of St James at Pyle demonstrates. On a smaller scale, some of the Orkney examples, such as the Mound of Snusgar and the Bay of Skaill probably fall into this category. While we have little idea to where the survivors moved, James (1999: 771) hypothesizes the presence of a medieval chapel, evidenced by undated burials, remnants of walls and midden deposits, which was deserted and replaced by another church c. 1km to the north in response to sand inundation. The be-sanding of the oratory of Saint Piran at Perranzabuloe also forced a relocation with the construction of a new church, and the absence of any roofing on the oratory suggesting removal for reuse. At Forvie too, relocation seems to have taken place with the establishment of the chapel at Leask in the aftermath of the loss of the medieval town. Therefore, where conditions deteriorated rapidly and medieval populations failed or were unable to act against the effects of wind-blown sand before it was too late, they were left with no option but to abandon and relocate.

2.3 Protection from wind-blown sand in the Middle Ages

Evidence of protective measures against wind-blown sand from the British Middle Ages are limited. Sites from the Netherlands have been identified with wooden fencing, sometimes as long as 100m, employed as ‘sand-breaks’ at sites dating from medieval period (Heidinga 1987: 139). These represent measures to protect fields and structures from wind-blown sand but excavations also identified deep strata of sand over the building remains and the agricultural area indicating these attempts to protect from the hazard were unsuccessful (Van Doesburg 2009: 188-189). Barriers of this nature are unknown from medieval Britain, but this may be due to poor survival in the record or a failure to recognise their significance by

[10] Now Y Ferwig.

excavators rather than because they did not exist. In addition it is also likely that flood defences which are common in coastal areas may have had the dual purpose of protecting land from the movement of sand (Toft 1988: 28). At Stackpole for example a wall dividing the rabbit warren from the land to the north may have been intended, in addition to enclosing the rabbits, to prevent sand progressing inland (Benson *et al.* 1990: 182). Perranzabuloe offers a case where a natural feature, the nearby river, provided protection from the encroachment of the sands. A parallel can be found at Merthyr Mawr, Bridgend, where it is recorded that Sir Thomas Stradling diverted the River Ogmore "to stop the sandes" (Randall and Rees 1932: 119). Although it is not known where these works to divert the river were carried out, Randall and Rees (1932: 163) have suggested that the parish boundary may preserve the original course of the river, and a point where it deviates from the current course of the river may indicate the area where the diversion was inserted (fig. 5). The stream at Perranzabuloe certainly seems to have prevented sand encroaching inland, probably by transporting the sediment and depositing it downstream, and this must have been viewed by some as evidence of the power of Saint Piran. In the correct conditions however, a severe storm would have been able to overcome the limited protection afforded by the river and eventually the additional sediment would likely have caused the mouth of the river to silt up. While rivers and bodies of water can offer protection from the hazard, this cannot be taken for granted.

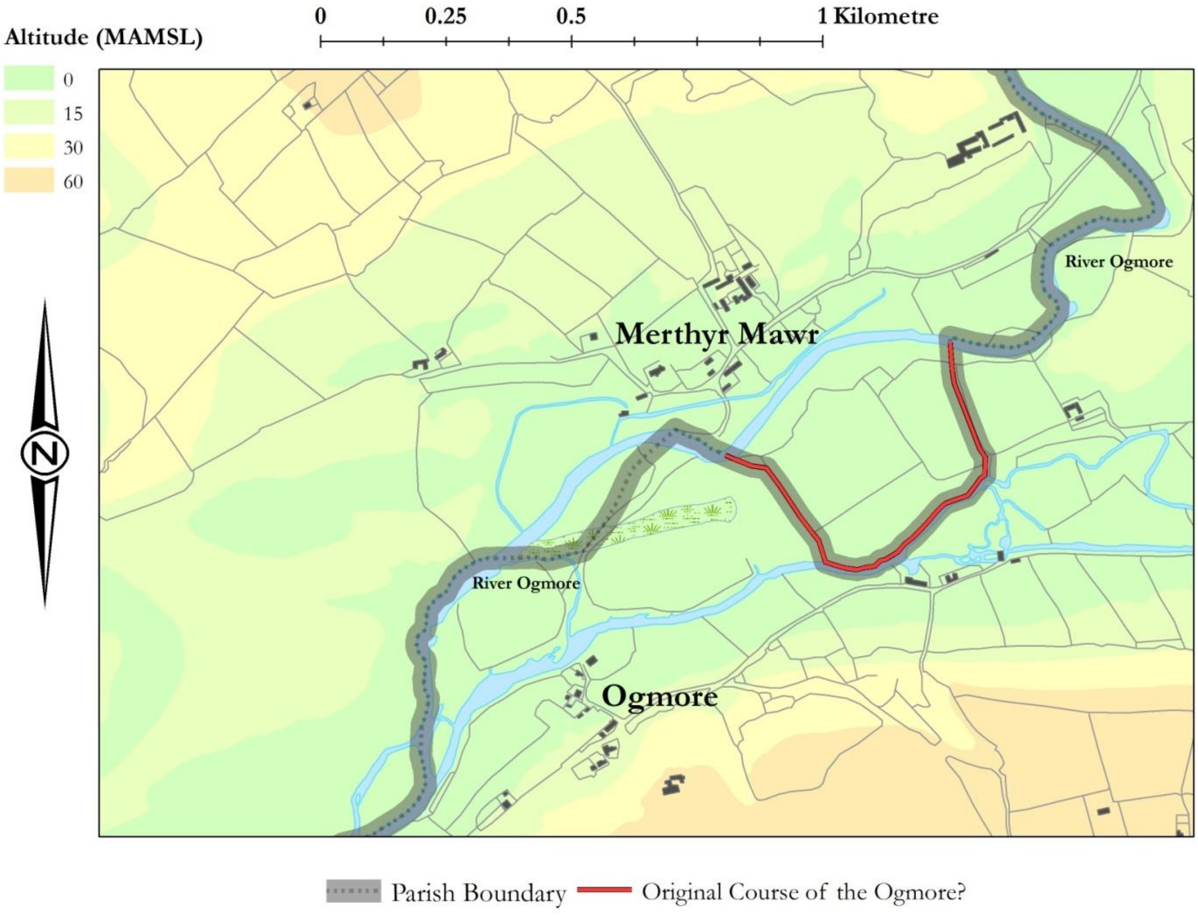


Figure 6 – Map of the Ogmore River at Merthyr Mawr, Bridgend. Documentary evidence records the diverting of the river in the 16th century, which may be indicated by the departure of the Parish boundary from the current course of the river near Merthyr Mawr itself. (Redrawn by the Author after Randall and Rees 1932: Map 1).

The association of be-sanded sites and hoard depositions could be interpreted as ritual deposition in relation to the hazard. It is possible, at the Mound of Snusgar, St Ninian's Isle and Glenluce, where hoards of metalwork and coins were interred, that their deposition may have been intended to procure protection from the elements by appeasing the divine. Although the dates of these hoards and a lack of information on the context of the Mound of Snusgar hoard is a major problem (Griffiths 2013: 504). What remains certain is that the decision to bury treasure in areas prone to wind-blown sand was a poor choice if later retrieval had been the intended goal. It may be that these sites, as well known positions in the landscape that had been transformed by aeolian sand, became foci for deposition in attempts to prevent further losses.

2.4 Adapting to the Hazard

There is good evidence to demonstrate that a phase of increased sand movement occurred around northern Europe following the onset of the LIA (Wilson *et al.* 2001; Wilson *et al.* 2004; Sommerville 2003: 350). Heightened storm conditions, for which substantial evidence exists (Meeker and Mayewski 2002; De Kraker 1999), however, may not have been the only factor behind the sand inundations experienced at many medieval coastal settlements. This is illustrated by the Hoge Veluwe, The Netherlands, where mapping the spread of blown sand deposits demonstrated a correlation with parish boundaries (Heidinga 1987: 145-149). Heidinga's interpretation is that in marginal areas, relatively low human impact meant woodland was more likely to survive, covering and thereby stabilizing the sand, while the concentration of activity in central areas stripped protective vegetation, increasing exposure to the hazard. Whether this holds true for British examples requires further research but it can be similarly assumed that activity contributing to erosion would generally be focused close to settlements, exacerbating risk from wind-blown sand.

Medieval land use strategies were frequently damaging to sand dune environments. The most harmful exploitation strategies in relation to aeolian sand are those that result in swathes of unprotected sand; such as stripping of vegetation, deforestation, overgrazing and erosion from traffic along paths and roads (Doody 2013: 39-40). In the wake of the Black Death this may have been compounded by a switch in focus from arable agriculture to pastoralism across Britain (Campbell *et al.* 1996). Furthermore, it has been proposed that the climatic downturn of the LIA resulted in a shortened growing season with reduced yields (Sommerville *et al.* 2007, p. 635). These two considerations would have forced populations to exploit marginal land, such as sand dunes, to counterbalance the shortfall (Hindmarch and Oram 2012: 287). This is proposed by the excavators as a likely scenario in exacerbating wind-blown sand at Eldbotle (*ibid*). In addition, in the early 13th century the canons of Dryburgh were granted freedom to take as much turf as they required for roofing materials (Fraser 1847: 74) which would have left large expanses of sand exposed to the wind (Hindmarch and Oram 2012: 280). Documentary evidence also attests to widespread grazing and harvesting of marram grass on the sands at Merthyr Mawr in this period (Randall and Rees 1932: 118, 155-56).

Another type of land use that was particularly damaging was rabbiting. As rabbits are not native to Britain, throughout the medieval period they were poorly adapted to the British climate and favoured dry habitats such as large areas of well-drained sand (Bailey 1988: 2). Rabbits were highly valued by landowners for their meat and fur which frequently led to the conversion of marginal or unprofitable land into rabbit warrens. In addition, rabbiting required reduced manpower and offered higher profits compared to cereal agriculture and as the market for meat and fur expanded in the post-Black Death era many landlords decided to make the switch. In order to maximise profit, warrens were artificially constructed (Bailey 1988: 8), destroying protective vegetation, and although they were occasionally afforested with gorse to discourage predators, most warrens were left unvegetated (Bailey 1988: 4). The behaviour of the rabbits would have negatively affected nearby vegetation, heavily affecting the plant coverage in coastal areas where there was plentiful food for rabbits (Sheail 1971: 155, 51) whilst simultaneously creating large deposits of loose sand (Rutin 1992). The problems this created in relation to wind-blown sand are illustrated by numerous post-medieval examples of sand movement on rabbit warrens (Sheail 1971: 55-57). Therefore, from the 14th century, the proliferation of rabbit warrens in Britain spread an extremely unstable land use practice which increased vulnerability to sand inundation in many areas.

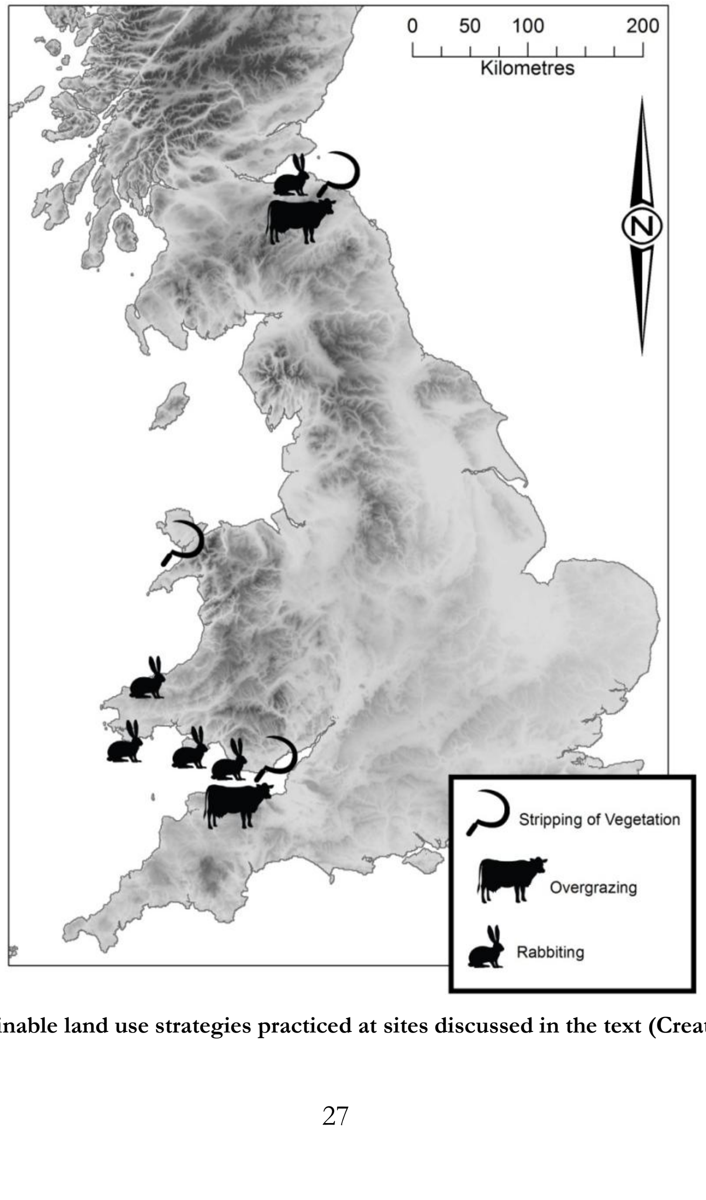


Figure 7 - Map of unsustainable land use strategies practiced at sites discussed in the text (Created by the author).

Extensive rabbit burrows are documented at many sites affected by aeolian sand (fig. 6). At Kenfig for example, documentary evidence records their presence as early as 1314, although only two years later they had become partially inundated by sand (Gray 1909: 23-24). Sand movement at Y Ferwig, Dyfed, could have been initiated and/or exacerbated by rabbit farming. The nearby place name 'Towyn Warren' is indicative of an area that has long been inhabited by rabbits and Davies and Kirby (1994: 80) believe that the warren probably evolved from a seigniorial medieval burrow perhaps belonging to Coedmor or Cardigan Castle. Rabbits were also farmed at Stackpole in the 14th century (Benson *et al.* 1990: 182-184) and at Pennard where a charter from c.1320 grants rights to take animals from the Lord's warren (Clark 1866: 288-289). Further evidence comes from a pillow mound at nearby Penmaen where a medieval settlement may also have become be-sanded by 1320 (Fisher 1920: 298; RCAHMW 1982: 331). At Eldbotle a record from 1300 of the purchase of ferrets from the area by the Constable of Edinburgh demonstrates that rabbit farming was practiced there by this date (Watson 1991: 157; fig. 7) either as a managed burrow, probably belonging to the de Vaux family of nearby Dirleton, or escapee animals from a nearby warren which took up residence in the sands (Hindmarch and Oram 2012: 291). The former is more likely as feral populations were uncommon until the 18th or 19th centuries (Bailey 1988: 2; Davies and Kirby 1994: 80).

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Figure 8 - A depiction from Queen Mary's Psalter of a rabbit warren illustrating the exposed nature of the sand and use of ferrets in rabbiting (© British Library Board, Royal 2 B Vll f84r).

The practice of planting *Ammophilia* (marram grass) to stabilize sand dunes and prevent wind-blown sand dates back at least to the 14th or 15th centuries (Ranwell 1972: 223). Many medieval landowners, as discussed above, failed to appreciate the importance of maintaining vegetation in sand dune environments, but others were less negligent. The island of Voorne, the Netherlands, was planted with marram grass to prevent aeolian erosion as early as 1423 (van der Putten 1989: 20). Comparably, in Denmark from 1539, royal orders restricted exploitation of woodland in the district of Thy due to encroachments by sand onto farmland (Sortfeldt 1920). A number of similar documents exist for Britain. For example in 1554, Queen Mary extended the remit of the Commissions of Sewers to include the prevention of sand inundating coastal areas in Glamorganshire (Bowen 1908, p. 140). A 1561 decree from Elizabeth I to the bailiffs of Newborough, Anglesey, following reports that the town was in danger from wind-blown sand, introduced a fine, or substitute punishment for those too poor, for anyone who had "cut digged rooted up or carried away" *Ammophilia* on sand dunes within two miles of the threatened area (Ellis 1838: 298). In the latter, the phrase "it is thought by **men of experience** that ... permitting the rushes there … to stand and growe will in short time help very much" (Ellis 1838: 298) suggests the benefits of this practice were understood from an early date and 15th century Cornish manorial records support this (Clarke and Rendell 2011: 231).

2.5 Summary

It is clear from the examples above that the environmental changes brought on by wind-blown sand can precipitate extensive losses to human populations. In the British Middle Ages, settlements were abandoned forcing relocation and rebuilding and agricultural lands became inundated requiring coping mechanisms such as manuring and famine foods to survive. Rarely and only in small numbers however can human casualties have been caused by aeolian sand, perhaps by the sudden be-sanding of houses in a storm, as escape to safety would be a natural course of action in vulnerable locations when the meteorological conditions necessary to cause dramatic sand movement arrived. The timeline in fig. 4 demonstrates that the hazard was active over the course of the medieval period but there is an apparent intensification from the mid 14th century. This is probably the result of three main considerations. The growing proliferation and increased survival of written sources provides more accurate dating for the later events, the climatic downturn of the LIA precipitated a marked increase in sand movement and the proliferation of unsustainable land use practices, especially in the post-Black Death era, made coastal communities particularly vulnerable to sand inundation. Medieval communities had few options open to them to defend against sand once it began to move. Midden material and barriers may have been used although the evidence is not conclusive. As with other natural hazards, spiritual responses were likely common although direct references to aeolian sand are rare in documentary sources. This inability to halt the movement of sand made abandonment and relocation the only reliable means of escaping the hazard in the short term. The afforestation and maintenance of plant species such as pine and marram grass in sand dune environments however, can protect sand deposits from the influence of the wind and over the long term this can protect human settlement from the dangers of sand inundation. In the medieval period a variety of sources demonstrate some appreciated the value of this vegetation but only after many settlements had been lost as a result of the hazard.

3.0 Flooding

The rise of water levels in excess of the norms to which communities are accustomed can cause sweeping devastation on a scale equalled by few other natural hazards. Even focussing solely on Britain, the storm surge of 1953 (Rossiter 1954) and more recent weather cycles such as the summer of 2007 (Lane 2008) and the winter of 2013/2014 (Met Office 2014) highlight the lethal and destructive power that flood waters can unleash. A number of scenarios, either together or in isolation, can result in flooding including meteorological influences on the sea, heavy rainfall, snowmelt, changes in river courses, groundwater saturation and blockage or failure of man-made water management infrastructure (Lamond *et al.* 2012: 2; Freer *et al.* 2013: 196-198), although in historic examples it can be difficult to positively identify the impetus behind an inundation (e.g. Haslett and Bryant 2007). The impact of high waters on human populations is more homogenous, washing away people, livestock and property with the danger being exacerbated by a multitude of physical and social considerations. These include: homelessness when waters render homes uninhabitable, the spread of waterborne diseases, pollution, poverty and food shortages (Smith and Petley 2009: 232-233). In addition, the harm caused by floods can extend far beyond the inundated area with disruptions in travel, trade and economic productivity across whole regions (Messner and Meyer 2006: 150). Local vulnerability to the hazard is associated with low-lying ground in areas of poor drainage around coasts and water courses. With the inherent dangers of these regions however, often come resources and opportunities which can make the risks acceptable over the long term (Small and Nicholls 2003). These frequently include access to water for drinking and industrial activities; fish, plants, game and poultry that inhabit aquatic environments; in addition to economic and social incentives such as improved trade links. It is also important to remember that while extreme events cause devastation, the majority of floods are small scale, causing only minor damage while playing a vital role in maintaining the fertility and ecology of floodplain environments (Smith and Petley 2009: 235).

3.01 Mitigation

In modern Britain losses and damage from flooding are mitigated in a number of ways. With adequate forecasting procedures, flood warnings can be issued and people can be evacuated to safe locations where protection from the various risks (e.g. dangerous water flows and disease), food, and shelter are available. The success of these operations requires accurate information to be successfully communicated to those at risk who must understand and trust in its reliability and react rapidly to appropriately protect themselves (Marsalek 1999: 9). Preventing damage to buildings and infrastructure can be more challenging but temporary flood defences such as sandbags and rapidly erected dykes and barriers can reduce damage over localized areas (Environment Agency 2009a). The swift return to pre-event conditions can also be assisted by modern technology, as in Somerset in 2013/14 where pumping from inundated areas back into water courses speeded the dissipation of flood waters (Environment Agency 2014).

Figure 9 – Map of Britain with the main rivers, towns and wetlands discussed marked. 1 = Gloucester, 2 = Durham, 3 = Wisbech, 4 = King's Lynn, 5 = Coventry, 6 = Tewkesbury, 7 = Perth, 8 = York, 9 = Norwich, 10 = Newcastle and 11 = London. (Created by the author).

3.02 Protection

In modern Britain flood risk is a consideration at all stages of planning and construction, seeking to limit the exposure of new developments to the dangers of flooding (Environment Agency 2009b: 13). Modelling can indicate the areas which are unacceptably at risk from flooding, although numerous variables and uncertainties related to the complexity of the hazard can hinder the calculation of an area's risk (Freer *et al.* 2013: 203-205). In ideal conditions permanent structures are not built in areas with substantial flood risk, however the majority of human settlement was established prior to the development of flood risk modelling and pressures on available land often force construction in these areas. As a result, today in England 5.2 million properties, or 1 in 6, are at risk from flooding (Environment Agency 2009b: 6). Defences in coastal and riverine locations to prevent the ingress of water can include dykes, ditches, levees, bunds and walls. In addition, dams can help control flooding by creating an upstream reservoir and allowing control of the downstream flow (Dong *et al.* 2006: 277) although dam breaches have the potential to cause widespread devastation as the water held back is rapidly released (Triana *et al.* 2006). Modern hydraulic engineering can provide extremely comprehensive flood security but negative environmental impacts and high financial costs can make these projects unattractive or unfeasible.

3.03 Adaptation

The need for expensive engineering solutions to protect from flooding can be reduced through adaptation to the hazard. By limiting development in areas that are flood-prone, risks are reduced but as noted above, historic settlement in flood-prone regions together with pressures on available land require the continuation of limited construction in these zones. Developments which do go ahead in these areas can maximise resilience by ensuring flood risk is not increased in neighbouring locations and by adopting flood resistant architecture and construction to minimize exposure to the hazard. This can be accomplished by raising floor levels, excluding floodwater from buildings and ensuring that where damage occurs it can be repaired simply and inexpensively (Bowker and Tagg 2007). In addition, land use practices can either exacerbate flooding or aid in flood prevention due to the varying abilities of different vegetation and soils to hold water and reduce surface runoff (Wheater and Evans 2009), with more flood resilient land use strategies aiding in the prevention of inundations in surrounding areas. Therefore, through 'adaptation' in flood-prone environments risk can be reduced and resilience increased.

Archaeological evidence from around the world demonstrates the extent to which some cultures have adapted to flood risk - a factor which has frequently become intertwined with human survival strategies. The Mesolithic site of Lepenski Vir, Serbia, for example, was exposed to complete inundation, often more than once per year, with evidence suggesting these events held ritual significance for the inhabitants and, rather than being regarded as alarming and destructive alterations to the natural equilibrium, became integrated into their temporal cycle (Chapman 2000: 195). Adaptation can also be seen in the classic example of the Nile flood regime where annual inundations have been central to the development of complex societies sustained by agricultural production since prehistory. Even in this system however, when higher than expected water levels arrived, human settlement, situated on higher ground adjacent to farmland became endangered (Wetterstrom 1995: 194; Brown 1997: 10). In the medieval period too, floods were far from always negative occurrences. Flooding on a small scale could enrich agricultural land and increase natural diversity. Many settlements benefitted from being sited close to wetland environments which were flooded on a seasonal basis. This was the case at Shapwick, Somerset, where the wetlands to the north of the village provided the community with grazing for cattle and plow oxen as well as natural resources including timber and reeds (Aston and Gerrard 2013: 251-252). It is clear, therefore, that the human relationship with floods is multi-faceted. While damaging extreme events are generally cause for fear and alarm, from some perspectives more minor events can be welcomed and are sometimes even relied upon.

3.1 Floods in Medieval Thought

While other cultures, due to their geographic setting, have viewed floods as part of the natural cycle and occasionally as fundamental to survival, this was not the case in medieval Europe. Although Pagans may have venerated inundations, as the the law code of Cnut specifically outlawed this practice (Thorpe 1840: 529), subconsciously or not floods were compared by Christians to the flood that befell Noah (Genesis 7: 10-24) or the waters of the Red Sea which obliterated Pharaoh's army (Exodus 15: 4-5). These were punishments from the divine (Anlezark 2006: 21) with medieval accounts emphasising the suffering and pain experienced by the humans who were not saved by the ark (Putter 1997; fig. 9). It has been argued that not everyone, in particular the laity, subscribed in totality to prevailing Church doctrine with an undercurrent of pagan belief which goes largely unmentioned in contemporary documents (Hanska 2002: 37-39) but the lay population would have become familiar with Biblical floods through multiple mediums, including sermons, theatre (Muir 1995: 72-74) and art. The 14th century stained glass from Greystoke, Cumbria, for example tells the story of *The Acts of Andrew and Matthias* in which Andrew drowns a group of heathen cannibals with a miraculous flood, although the dead are revived when their brethren convert to Christianity (Anderson 1963: 204-207). Death by drowning, as with lightning and earthquakes, was considered appropriate only for heathens or wrong-doers (Daniell 1997: 65) due to the removal of the body which prevented a burial in accordance with contemporary Christian beliefs. It was therefore not a fate for a true Christian. This is illustrated by Gregory of Tours who gives two examples of women who were wrongly accused of crimes and condemned to death by submersion in rivers. In both cases they were saved from drowning through divine influence (Van Dam 1988a: 92-93). Conversely, in the *Life and Miracles of St Modwenna*[11], a man who in some way 'damaged the church' and failed to atone for his sins suffered sudden death in a flood (Bartlett 2002: 211). Additionally, a desire to deny an individual a Christian burial through disposal in water was a component in narratives surrounding historical figures such as Prince Arthur (1187-1203), whose body was apparently sunk to the bottom of the Seine by his uncle, King John (de Gray Birch 1897: 176). Arthur's body however, was apparently retrieved by local fishermen and afforded a proper burial highlighting the fact that a deserving Christian did not go

[11] Written 1118-1150.

unburied. Similarly, when the body of Harold Harefoot, the son of King Cnut, was exhumed by his vengeful half-brother Hardicnut, it was disposed of in the Thames only to be pulled out and re-buried, again by fishermen (Bullough 1969: 310-311). Evil doers were less fortunate and could provoke extreme reactions from water bodies. A legend surrounding Pontius Pilate for instance, a much maligned figure in the Middle Ages for his part in the crucifixion of Christ, holds that his corpse, when thrown into both the Tiber and the Rhône, provoked both rivers to burst their banks (Daniell 1997: 68). In the lives of the saints too, floods were portrayed as unholy aberrations from the natural. For example in the life of Saint Godric, a flood of the River Wear at Finchale, County Durham, is quelled when Godric calls on the power of Christ (Stevenson 1847: 112) and similar holy intervention can be seen in other saint's lives such as Saint Gregory Thaumaturgus (Migne 1863: 930-931). As with other natural phenomena, floods were ominous portents of the future. A well known text throughout the medieval world, Isidore of Seville's *Etymologies*, bears this out, concluding with the words "[floods] signify something yet to happen" (Barney *et al.* 2006: 282-283). When waters began to rise these connections and associations would have strongly coloured perceptions and the belief that floods were controlled by divine forces would have increased the primacy of spiritual responses. Floods were therefore frightening occasions during which the world could be violently transformed from its natural state by the anger of God and the work of the Devil.

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Figure 10 – Detail from the depiction of the Flood in the Holkham Bible Picture Book (1327-1335) which emphasises the suffering of those who God did not save. (British Library Add. MS. 47682 f. 8v)

3.2 Archaeological and Historical Evidence

Despite the alarming and un-Christian associations held by inundations in medieval theology and literature, floods throughout medieval Britain were a common occurrence. Usually these floods were minor in terms of intensity and effect but more occasional floods could have devastating consequences.

This is vividly illustrated by Grafton's (1809: 133) description of a 1483 flood on the River Severn at Gloucester:

"by force of continuall raine and moysture, the ryuer rose so high that it ouerflowed all the Contrie adioinyng, insomuch that men were drowned in their beddes, and houses with the extreme violence were ouerturned, children were caryed about the fieldes, swimmyng in Cradels, beastes were drowned on hilles, which rage of water lasted continually ten dayes".

Although Grafton was writing almost a century later, his description may draw on primary sources and at least serves to illustrate the ability of the most extreme floods to wreak havoc. His reference to children in cradles may allude to the Biblical story of Moses (Exodus 2: 3), highlighting how these events were perceived through comparison to Christian doctrine.

The floods that caused the most severe short-term losses were brought on by extreme rainfall, rapid snowmelt and marine inundations of the coast. Locations at particularly high risk from these events were river floodplains, low-lying coastal locations and reclaimed wetlands: all areas where human decisions situated people, livestock and property at high risk of flooding. Although lists of historic floods exist for some rivers/locations, for example on the Trent (Brown *et al.*. 2001: 76), the compilation of a comprehensive catalogue of flood events from the Middle Ages is outside the scope of this study due to the vast number of inundations over the period. By using case studies however, the exposure of the hazard in different locales as well as the responses and strategies that were adopted to mitigate, protect and adapt to the risk of flooding can be explored.

Most areas where floods affected humans were rural with low population densities meaning that material losses, especially to agriculture, were always a prime concern. Villages were commonly located in valley floodplains enabling exploitation of the surrounding fertile land for arable and pastoral farming. Although long-term settlement would have avoided areas that were flooded on a regular basis, temporary occupation, for industrial or craft activities, and agricultural land would have more readily been situated in these areas. The impact of rainfall and flooding has been a subject for debate in relation to medieval villages. Some, most notably Beresford (1975: 50-54) in the cases of Goltho, Lincs., and Barton Blount, Derbs., argued that the climatic deterioration of the LIA forced inhabitants to adapt, with 'eaves trenches' and 'drains running along the inside walls' to the deteriorating conditions, ultimately abandoning the villages as soil conditions worsened in search of more favourable conditions elsewhere. Similarly, Dudley and Minter (1962-1963: 272; 275) noted the platform house excavated at Garrow Tor, Cornwall, was well adapted to flood prone weather and cite the abandonment of medieval fields as evidence for climatic deterioration. Others however, primarily historians, strongly disagreed with these interpretations, promoting economic rather than climatic explanations for the changes detected at deserted medieval villages (Wright 1976; Dyer 1994: 43). While Beresford and others may have overstated the connection and too readily connected cultural and climatic change, Wright (1976: 149-150) argues that the combined influence of the extreme rains and subsequent agrarian crisis of 1315 combined with the social changes of the Black Death were the main impetus for the economic changes that took place at Barton Blount. Therefore, although the connection was not as clear cut as Beresford argued, weather was probably still an important factor in the changes that occurred there.

Floodplains are highly dynamic environments and significant development since the medieval period has greatly transformed many alluvial environments. Throughout the Middle Ages, floodplains frequently contained multiple channels interspersed with areas of woodland and wetland (Lewin 2010: 276; Brown 1997: 263) as a result of avulsion events. Artificial stabilisation of river channels throughout the later Middle Ages and into the post-medieval period has largely created the environments with which we are familiar today (Cook 2008: 68). In addition, medieval land use negatively contributed to river dynamics. Macklin *et al.* (2010: 1571) have demonstrated that in the centuries from AD c.1000 sedimentation in British river floodplains experienced a dramatic increase. This has been linked to a widespread boom in population, economic activity and settlement between 1000-1300 with concurrent changes in land use to increase agricultural productivity, such as the animal drawn plough, fallowing, manuring and increased deforestation (Macklin *et al.* 2010: 1571-1572; Brown 2009: 104; Dyer 1994: 14). While this broad brush approach has some value, the variety of local conditions with differences in slope, soils and human occupation along individual catchments would have played an important role in determining any rise in the level of erosion experienced by particular stretches of river. Increased sediment entering river systems nonetheless sealed many medieval sites under layers of alluvium, for example a tidal mill (dated to c.1190) at Greenwich (Goodburn and Davis 2010) and a ridge and furrow field system at Redlands Farm, Northants., which was converted to pasture following its loss (Keevil 1992: 183). Changes in alluviation are also evident along the Upper Thames floodplain where an expanding early medieval population grazed livestock along with ridge and furrow farming, maximising drainage through fields aligned at right angles to the river (Lambrick 1992: 222). Following the Black Death, though flooding continued, a decline in alluviation occurred which has been explained as reduced pressure on the landscape as a result of the decline in population (*ibid*).

By their nature, infrastructure and industries in flood-prone areas were particularly exposed to flood events (Whyte 2009: 67). Bridges, for example, were regularly swept away in extreme riverine floods, e.g. Framwellgate Bridge, Durham in a flood of 1400 (Jervoise 1931: 43). Extensively explored archaeological examples further illustrate the frequency with which medieval bridges were damaged or destroyed. The bridge at Kingston-upon-Thames for example, was subject to repeated erosion in flood events which caused damage to piers and in the mid 1300s timber reinforcements were required to prevent total collapse. Documented floods in the 15th century are likely to have been the catalyst for the wholesale reconstruction of the bridge at that point (Potter 1991: 144, 146). On the Trent a succession of three bridges have been excavated with dendrochronological dates covering the period c.1111-1310, each destroyed or abandoned due to river migration and damage from flood events, with at least one episode of repair in between inundations visible on the structure of the earliest bridge (Ripper and Cooper 2009: 38; 222). The damage caused to these structures can be closely correlated with the historical record which documents repeated inundations on the Trent over the period (Brown *et al.* 2001: 76). As one of the few lowland rivers which has seen significant change to its course and morphology in the historic period (fig. 10), floods on the Trent may have been particularly frequent in the Middle Ages (Brown *et al.* 2001: 70). Although many were damaged and a few completely destroyed, medieval bridges were in fact relatively resilient to floods with cutwaters to reduce scouring, flood arches to deal with increased flows and regional adaptations to take account of local conditions with many surviving for centuries (Harrison 2013). Water and tidal mills were also particularly exposed when inundations occurred due to their locations. The establishment of a mill was usually a profit making initiative (White 2012: 51) and, especially in the case of tidal mills, the potential gains encouraged construction in high-risk locations. Historical accounts of mills damaged or destroyed by floods are numerous e.g. a flood in Warwick which rendered four watermills inoperable in 1315 (Langdon 2004: 27). This is reflected by many examples in the archaeological record such as the early mill at Ebbsfleet dating to c. 690 (Goodburn and Davis 2010). Remains of later mills include the mill at Castle Donington, Leics., dating to the first half of the 12th century (Clay and Salisbury 1990: 289) and at West Cotton, Northants., where mill remains dating to c.1100 have been excavated (Brown 2009: 100). The mill at Bordesley Abbey, Worcs., was affected by flooding following the siltation of the Arrow between 1300-1500 precipitating its abandonment and demolition in the early 15th century or just after (Astill 1993: xiii, 54-55). Although many mills were damaged by floods, this was made somewhat inevitable by their proliferation in areas of high flood risk. The financial investment and continued value of mills would have encouraged works to stabilise river channels to reduce risk from flood events (Cook 2008: 68) and the survival of Victorian mills occupying sites recorded in the Domesday survey (Brown 1997: 261) demonstrates that far from all mills fell victim to the hazard.

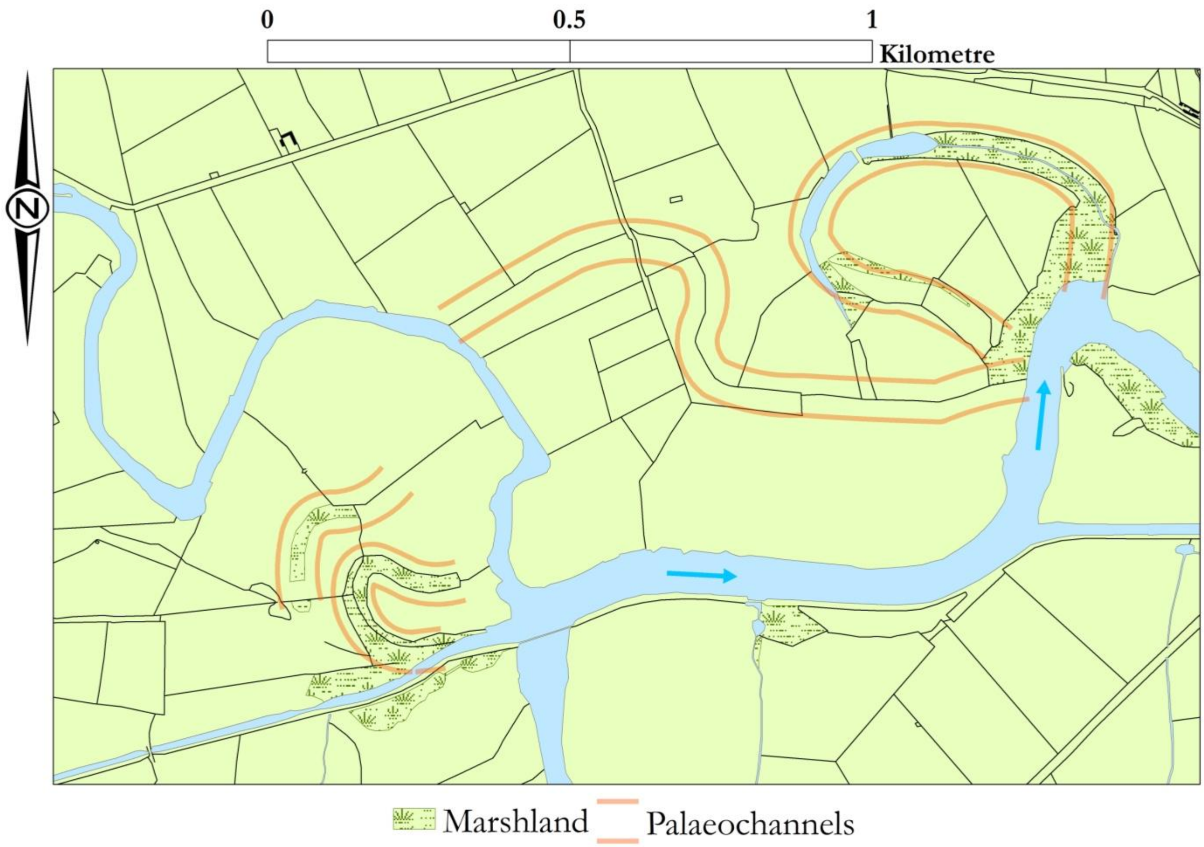

Figure 11 – Palaeochannels in the 19th century on the River Trent near Long Eaton, Derbs., demonstrated by field boundaries and marshland (Brown *et al.* 2001: fig. 1). Although dating these landscape changes is difficult, river migration along the Trent in the medieval period is attested by archaeological evidence. (Redrawn by the author from OS Mapping).

While flooding in rural areas is devastating, the sheer scale of human occupation and investment in towns means that when floods strike, damage to property and human life can be on an even grander scale. Wisbech, Cambs., and Kings Lynn, Norfolk, as two Fenland towns, exemplify the challenges and responses of urban communities faced with continuous flooding. Between the 11th and 13th centuries, the Nene and Great Ouse rivers flowed out through Wisbech until droughts lowered the river's ability to transport silt and the Wisbech estuary become silted-up, diverting the river's course to King's Lynn (Clarke and Carter 1977: 413-414; Hinman and Popescu 2012: 4). Together with North Sea marine flooding linked to storm surges, this was clearly an area at high risk from flooding. From across Wisbech there is evidence for flooding, with at least eight separate layers of flood deposits represented in the sequence from Market Mews (Hinman 2002: 22). The surroundings of Wisbech Castle, a Norman Fortress constructed in 1086, were also exposed to floods which infilled the castle moat (Fletcher 2009: 22; Fletcher 2010b: 17). While these recurrent inundations cannot have forced complete abandonment, as settlement persisted throughout the sequence, the continued pressure from floods may explain Wisbech's lack of expansion (Fletcher 2010a: 12). Radiocarbon dates from Wisbech Castle correspond well to a particularly severe inundation on 12th November 1236 recorded by the chronicler Matthew Paris (Giles 1889: 42) who documented high numbers of human casualties along with structural damage and losses to herds of sheep and cattle. Similarly, a layer of sediment encountered at over twenty sites across King's

Lynn between 3.65m and 4.26m AOD attests to a severe flood that must have inundated a large area (Clarke and Carter 1977: 63). At All Saint's Street, excavations unearthed evidence attesting to the waterlogged nature of the site suggesting only light occupation before drainage activity in the mid-12th century which was probably carried out following two flood events evidenced by layers of blue silt between 1200 and 1250 (Clarke and Carter 1977: 139-142). Just as in rural areas where land use placed greater strain on rivers, human activity in urban settlements also negatively affected flood risk. Jørgensen (2010) has highlighted the important contribution household and craft-related waste made to river courses. In all riverine medieval towns this accumulation of waste and detritus can only have exacerbated the danger of inundations by reducing the capacity of the river channel and this danger was noted at the time, for example, in 1421 reference was made to past blockages of Coventry's River Sherbourne which precipitated floods (Harris 1907: 31).

The longevity of settlement in most towns suggests that inhabitants would have been acutely aware of areas that were at risk from flooding and this would have affected decisions to situate structures in particular areas. Tewkesbury, for example, is sited on an island of river terrace, one of the highest points on the Severn/Avon floodplain (Brown 1997: 44). In Perth too, the oldest and most important buildings such as St John's Kirk, the High Street, the Friaries and the Charterhouse were all located in areas of raised topography where they would have been protected from even the most extreme flood levels (Bowler 2004: 15). Descending down the contours from these prestigious buildings, Bowler (2004: 17-19) theorizes a correlation between the land level and the property owner's wealth, as locations closer to the level of the river would have been exposed to increased risk from the frequent floods of the River Tay. Although based on more recent records, Perth must have commonly experienced minor inundations over decadal timescales (Bowler 2004: 12), only one record of a flood survives from the period, an extreme event of 1209 in which crops and housing were severely damaged and a chapel and the town's bridge were destroyed after a mound was destabilized by floodwaters (Corner *et al.* 1994: 457). Perhaps the frequency with which towns such as Perth were exposed to inundations made only the most severe events noteworthy. The routine aspect of flooding was affected by two chief factors. Firstly, land use decisions, with deforestation along the Tay between 1125-1400 increasing surface runoff, which caused the river channel used by shipping to become increasingly shallow and hazardous as a result of increased sedimentation (Oram 2013: 370). Secondly, climatic changes affecting rainfall, which in Britain has been demonstrated to fluctuate between flood-rich and flood-poor periods over decadal timescales (Lane 2008; Whyte 2009: 64). Even in flood-poor periods however, extreme events are still possible making it problematic to construct a detailed climatic chronology relating to the hazard.

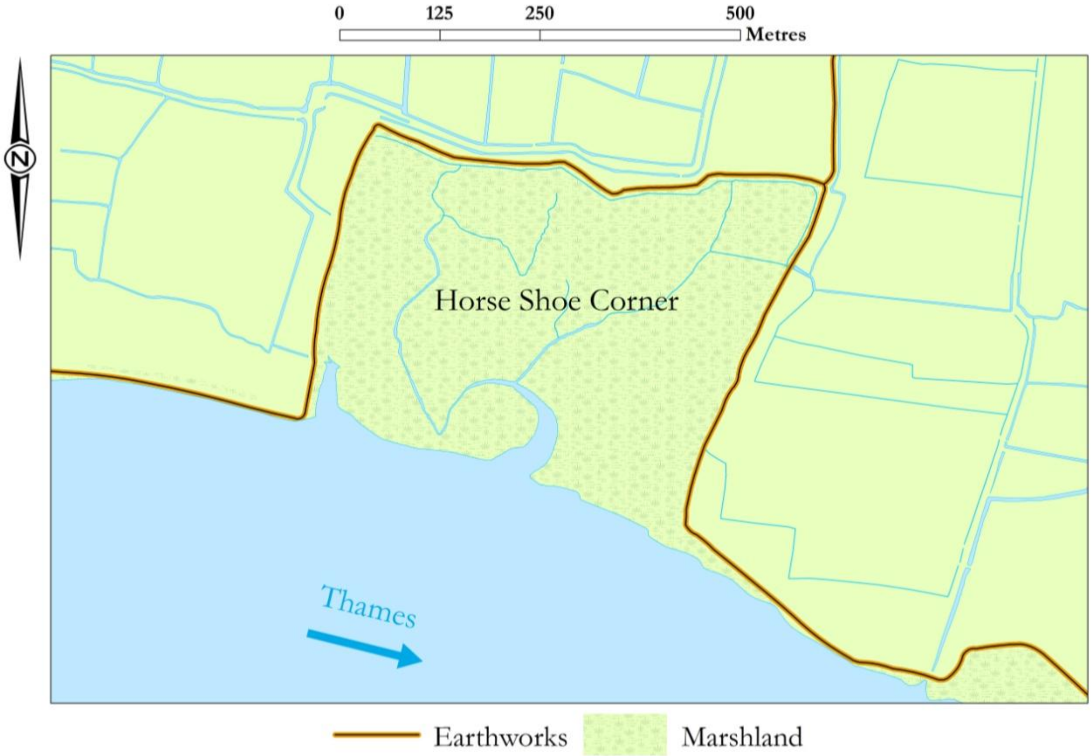

Figure 12 – Horseshoe Corner on the Thames near Dagenham in the 19th century. According to Galloway (2012: 82) it was created when a flood overtopped defences in 1409 (Redrawn by the author from OS Mapping).

Wetlands, as areas that were naturally exposed to regular flooding, were areas where the profits that could be earned from their successful exploitation drove medieval populations to put themselves and property at increased risk. In their undrained state they were valuable and highly productive assets providing pasture, hunting, fowling, fish, plants, timber and salt (Gardiner 2007). The fact that many parishes without direct access to wetland environments shared usage rights with neighbouring parishes (Rippon 2000: 237) further demonstrates their importance. In many cases, a decision was taken to drain marshland in order, at the expense of wild resources, to increase pastoral and arable production which in such fertile soils could be immensely profitable in the short term (Gardiner 2007: 50; Galloway 2012: 70), with reclaimed land usually valued at least double the price of unreclaimed land (Galloway 2013b: 382). Reclamation was conducted in different areas at different dates depending on local socio-economic and environmental considerations. Following Rippon's (2000: 52) model of *exploitation - modification - transformation*, initial occupation took the form of seasonal or temporary settlements characterized by very little alteration to the local environment and the exploitation of only easily available resources (Rippon 2013: 338). Linked to the creation of large estates belonging to magnates, the Church and the Crown, most wetland areas experienced a change in exploitation throughout the 8th and 9th centuries with the establishment of permanent settlements and limited changes to the environment, such as drainage ditches, to allow the cultivation of crops such as barley and legumes and the pasture of sheep (Rippon 2013: 338-339; Rippon 2000: 186). The final stage was the reclamation and transformation of the landscape which generally occurred in the 10th century through the construction of dykes and sea walls to permanently exclude sea water from the marshland. Exceptions include Walland Marsh, Kent, which went unreclaimed until the 13th century due to unfavourable natural conditions, and the wetlands of the Thames estuary which remained unreclaimed until the 12th or 13th centuries (Galloway 2013b: 380) because the captive market for dairy produce in the city of London made nearby unreclaimed marshland, which could be used as seasonal pasture, especially profitable (Rippon 2013: 346). Once sea walls existed, run-off from surrounding uplands became a hazard requiring the construction of embankments where the fen met adjacent drylands as in the Caldicot Levels, Gwent (Rippon 2002: 58). In addition, marshland drainage brings about a marked lowering in ground level as the water content decreases exposing the land more readily to inundation[12] (Gardiner 2007: 36). Physical remains bear this out, for example on the Pevensey Levels, East Sussex, the sedimentological record attests to flooding around c.1400 (Moffat 1986: 85) which Rippon (2001: 20) has linked to a major flood recorded in 1421/2. Storms caused repeated breaches along the Thames estuary leaving behind distinctive 'horseshoe' shaped ingresses where water had broken through dykes with subsequent repairs set back from the failure (Galloway 2013b: 383; fig. 11) which are also seen on Romney Marsh (Barber and Priestley-Bell 2008: 291). Communities which settled in reclaimed areas were also at risk as at Hickling, Norfolk, where a sea flood in 1287 flooded the church up to a foot above the altar and left nine dead (Ellis 1859: 270). At Walpole, Norfolk, St Peter's church was almost completely destroyed and subsequently rebuilt following an inundation in 1337 (Briers 1989: 253) with structural evidence at neighbouring churches suggesting they were also affected by the same flood such as St Andrew's, Walpole and St Mary Magdelene, Wiggenhall (Brandon and Brandon 1848: 107). Despite the frequent flooding associated with wetland environments, the hazard tended to cause losses to crops and livestock rather than people due to the low density of population which permanently inhabited coastal wetlands (Galloway and Potts 2007: 15; Galloway 2013b: 385). Although plentiful evidence attests to the failure of wetland defences, Rippon has argued that where wetland reclamation was achieved through the construction of artificial defences, the resultant reclaimed lands were extremely resilient and sustainable (Rippon 2013: 340-341), only occasionally subject to breaching and inundation. Where wetlands were reclaimed chiefly through natural defences however, as in Romney Marsh where a stretch of shingle provided the main defence against the sea, populations, livestock and property were at high risk especially from extreme storm surge events. As documentary evidence, excavation and retrogressive landscape analysis demonstrate however (Gardiner 1988; Gardiner and Hartwell 2006; Barber and Priestley Bell 2008: 291), breaches in artificial flood defences were far from uncommon in areas such as Romney Marsh. Where breaches resulted in inundations, large scale change was the result e.g. the results of fieldwalking on Romney Marsh demonstrate a marked depopulation throughout the 14th century which although set in the wider context of famine (1315-1317) and the Black Death, must have been significantly influenced by the sea floods of the period (Barber and Priestley Bell 2008: 290). In addition, a discontinuity in the ceramic sequence with a switch from sand to shell tempered wares and an increase in foreign imports suggests widespread disruption to the local pottery industry, very likely a result of the severe floods (Barber and Priestely Bell 2008: 292-293). Although losses to these

[12] This occurs to a greater degree in peat marshes which hold more groundwater than marshes composed of silt.

extreme events were relatively minor compared to in the Low Countries, they must have been episodes of great disruption, destruction and even death for those communities situated in high risk areas.

3.3 Mitigation

Once a flood had occurred, options open to medieval populations to minimise the effect were limited. At the onset of a flood, often the safest response would be to leave the afflicted area and escape to high ground, for example in Terrington, Norfolk, the relative raised topography of St Clement's Church provided refuge in times of flood, e.g. in 1607 (Murray 1870: 301), with similar practices documented throughout the Europe in the Middle Ages (Klápště 2011: 101; Squatriti 2002: 68). A manuscript from Crabhouse Priory, Norfolk, provides a description of how, in the early 13th century the nuns evacuated the nunnery due to a flood, although one nun, Joan, refused to leave choosing instead to become a hermit (Page 1906: 408). Crabhouse's fenland location, with boundaries delineated by dykes against the Ouse, would certainly have left it open to inundation in extreme events. Similarly, the Fransiscan friary at Reading regularly had to be abandoned due to floods which led the friars to request a change of site (Martin 1885: 911-912).

With a lack of reliable material responses to lower flood levels and provide relief, medieval communities consistently resorted to spiritual solutions such as prayer and procession. This is borne out by a miracle of Saint Romanus retold by Gregory of Tours in which a storm caused a flood on the Garonne River, near Bordeaux, which was then made more hazardous by strong winds. After supplication to the saint however, the flood and storm subsided and the flow of the river returned to normal (Van Dam 1988b: 56-57). In extreme circumstances large scale processions bearing saintly relics were regarded as an unrivalled response with the Paris flood of 1206 which subsided following a procession of St Genevieve's relics one of the best known examples (Luchaire 1912: 2-3). In Spain, although more often in response to drought than flood, the ubiquity of these penitential processions, in which God was beseeched to intercede on the behalf of the community, even allows climatic reconstructions from documentary records (Martín-Vide and Vallvé 1995). In Britain smaller scale processions of this type were common, illustrated by two prayers from the widespread Sarum Rite, *Inundaverunt aquae* and *Non nos demergat* (Bailey 1971: 56-57), which call on the Lord for deliverance from floodwaters and would have been sung as part of rogation processions. Hanska (2002: 68) takes the view that these common rogation sermons would have been adapted in times of natural disasters to become 'catastrophe sermons'. In addition, a 1293 letter from the Archbishop of York to one of his officials directs that special prayers for calm weather "*pro serenitate aeris*", a frequent inclusion in prayer books (Thomson 1989: 90), were to be conducted throughout the diocese (Raine 1873: 100-101). In the aftermath, when floods brought communities to the brink, there was often some help available from higher authorities such as the Monarchy, the Papacy or the Episcopate, whose grants or concessions could help ameliorate conditions. Ankerwycke Priory, Bucks., for instance, was granted an indulgence from the Bishop of Ely in 1394 to aid the nun's recovery from flood damage (Gibbons 1891: 399; fig. 12). As a recurrent hazard, local knowledge and memory of past events and recovery would have been critical and Galloway (2013a: 33; 2010: 27) views the Dissolution as an important disruption to water management strategies which may have increased vulnerability through the loss of monastic Orders' expertise in defence and recovery from floods. This can perhaps be glimpsed in the management of the estates of Lesnes Abbey, Greater London, following their seizure by Cardinal Wolsey, where a desire to turn a quick profit seems to have made the maintenance of sea defence a low priority resulting in major breaches and inundations in 1526 and 1529 (Galloway 2013b: 392).

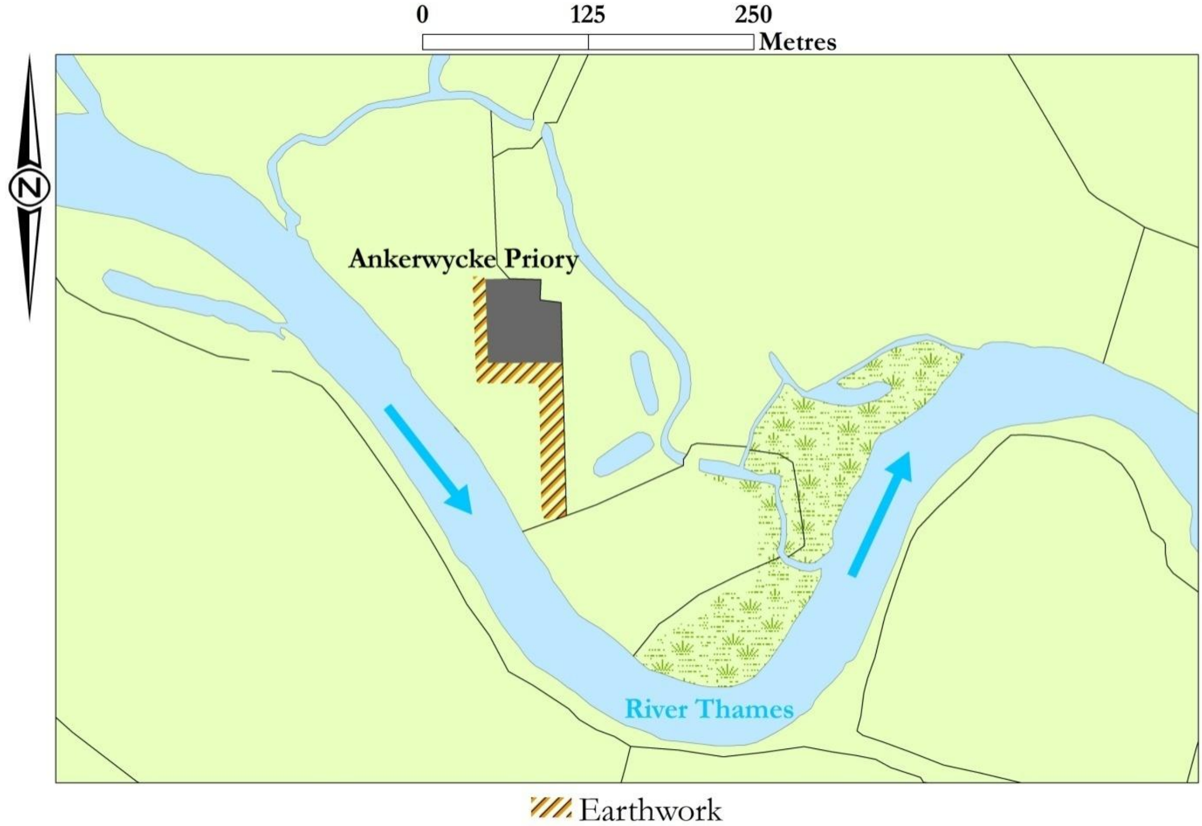

Figure 13 – Site of Ankerwycke Priory with earthen ramparts indicated which may have prevented the priory buildings themselves from becoming inundated (Redrawn by the author from OS Mapping).

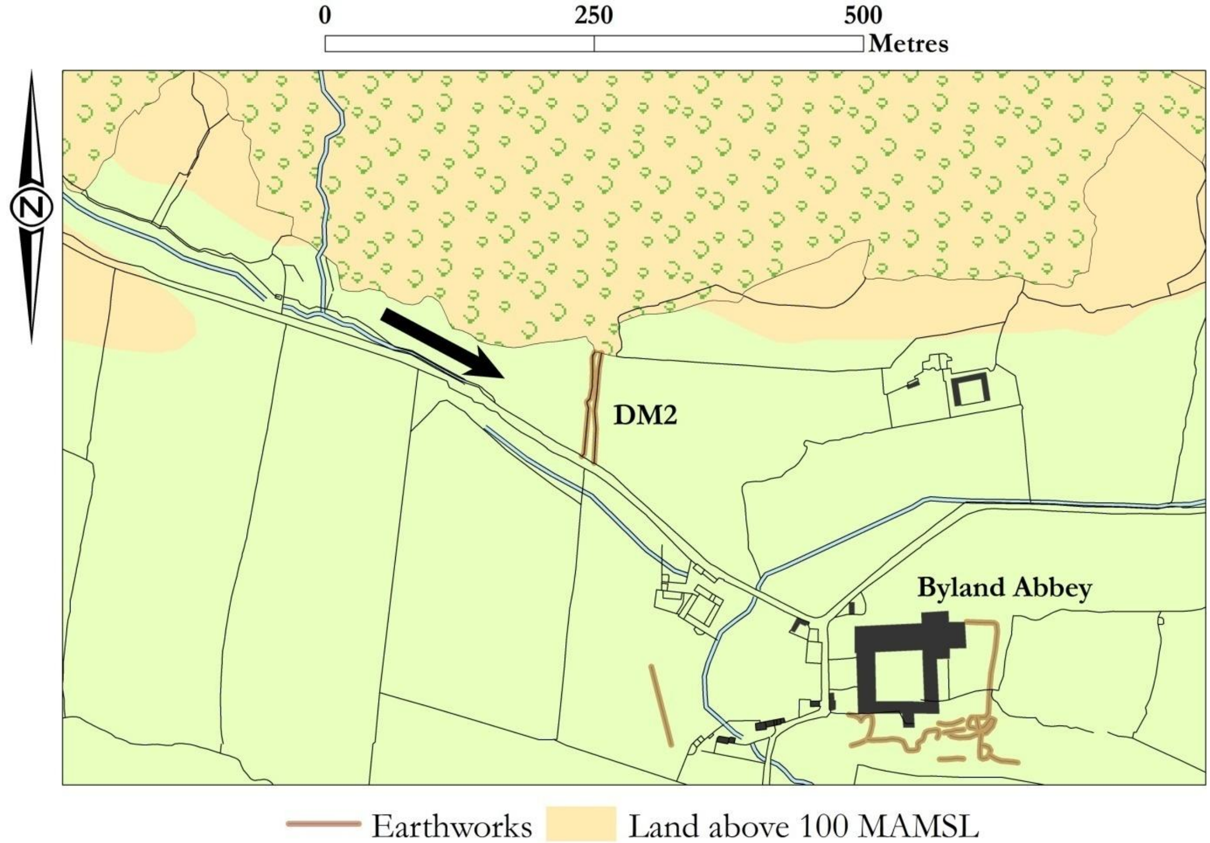

Figure 14 – Map of Byland Abbey, N. Yorks., with flood defence feature DM2 and the predominant direction of water flow from surrounding uplands indicated by arrow (Redrawn by the Author from OS Mapping).

3.4 Protection

In relation to other natural hazards and because of its recurrence, physical defences against flooding were common constructions. Examples are abundant with monastic landowners especially fervent investors in flood protection. For example, defences to protect reclaimed lands from rivers and the sea were a considerable expense for the monks of Canterbury Cathedral (Smith 1969: 166-189). Smaller scale constructions include those at Drax Priory, N. Yorks., where strong banks and a moat were required to keep the site dry from frequent inundations caused by the site's location close to the confluence of the Derwent and Ouse rivers (Burton 1758: 100). At Byland Abbey, N. Yorks., flooding was a high concern with the site requiring drainage even before construction could commence (Jecock *et al.* 2011: 80). The feature DM2, which has traditionally been related to fishpond creation, is re-interpreted by Jecock *et al.* (2011: 82) as a flood defence constructed in response to major flood events resulting from high-rainfall or snowmelt and subsequent surface runoff from the surrounding uplands (fig. 13). The embankment also provided a causeway across the water course and may have incorporated a sluice to enable any water from floods or high precipitation trapped behind it to be drained (Jecock *et al.* 2011: 82). Access to protection from flood waters was not always equal. For example the town of Ramsey, Cambs., as a result of its fenland location was exposed to frequent inundations as demonstrated by the archaeological evidence (Spoerry *et al.* 2008: 175). The Benedictine community of Ramsey Abbey on the other hand were protected from the frequent floods by defences including drainage channels, or lodes, which kept the abbey precinct itself safe and dry (Spoerry *et al.* 2008: 179, 200).

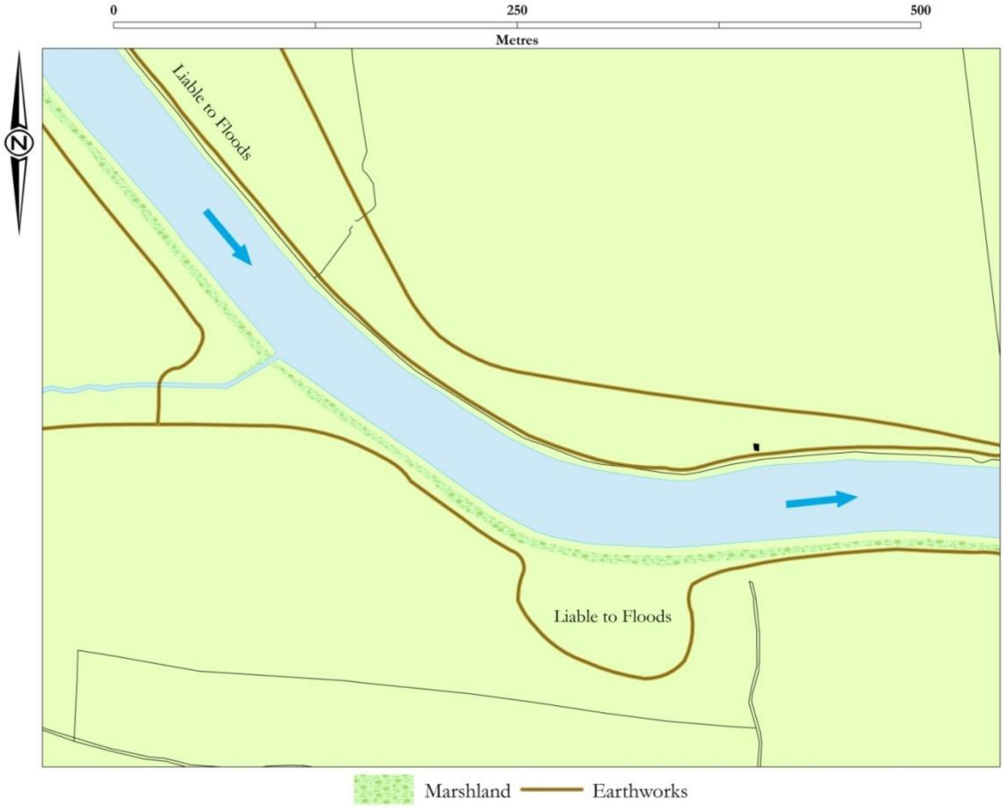

Figure 15 - An area along the River Ouse near Riccall, N. Yorks., in the 19th century. The semi-circular section on the south bank may have been set back and re-embanked following an inundation (Redrawn by the author from OS mapping).

These defences however, were not always successful in their role. Stratigraphic analysis of historic cartography can often reveal changes which may have occurred or been exacerbated by floods (figs. 14, 15, 16). More comprehensive archaeological study reveals further evidence of flood defences being overtopped, for example at West Cotton, Northants., where a bund constructed around c.1100 to protect from floods and increased alluvial deposition began to let in water. Together with other factors, this precipitated the decline and abandonment of the village during the 14th century (Brown 2009: 100). Excavations at Thornton Abbey, Lincs., uncovered a bank of compacted earth interpreted as a medieval flood defence, however two layers of alluvium demonstrate that the defence was overtopped at least twice by inundations (Willmott and Townend 2012: 19). Similarly, at Bordesley Abbey, an earthen flood bank between the abbey precinct and the River Arrow (Aston 1972: 134-135), which must have provided protection from most flood events prior to the siltation of the river, was unable to protect against the increased height of floodwaters which repeatedly overtopped the defences. One inundation damaged the floor of the south transept attested to by broken and misaligned tiles sealed by river mud (Rahtz and Hirst 1976: 70). A maximum height of these flood waters can be estimated by the fact that they did not inundate the higher floors of the choir. In the period following this flood, the floors were raised by 20-26cm, almost to the same level as the presbytery, to protect from further damage (Hirst *et al.* 1983: 54-55). Similar responses were adopted at the hospital of St Bartholomew, Gloucester, where documentary evidence records rebuilding in the early 16th century upon higher foundations to raise it above the level of winter floods (Herbert 1988: 352-353), and at the abbey of Bury St Edmunds where a flood of 1439 provided an impetus to raise the floor levels of the new bell tower to hopefully avoid future inundations (Gage 1831: 332).

As urban settlements focus populations, structures and resources, systems of protection are especially important. From the available evidence, riverine and sea floods appear to have been the most common categories of inundation to have affected medieval towns and defences were developed to guard against these threats. The available evidence suggests that the risk of inundation was well understood. Rivers flowing through towns frequently became blocked by the waste of the local population which could intensify floods. Town councils, as in York, Coventry and Norwich, responded to this problem through legislation against depositing waste in rivers, which was punishable by fines and enforced by inspectors, and citizens were required to contribute physically or financially towards unclogging the river channel. This assisted in alleviating flood risk but the primary aim was often to create a waterway with reduced pollution which was easier for shipping to navigate (Jørgensen 2010). Archaeological evidence also attests to physical defences built against inundations in towns, as at Newcastle-upon-Tyne. Historical floods are recorded in 1320, when reportedly over 120 people were drowned (Bourne 1736: 142), and in 1339 when the Tyne Bridge was damaged, becoming the subject of piecemeal repairs over the following century (Brand 1789: 41-44). In response to these floods, Bourne (1736: 142) describes how ballast was used to raise the level of the quayside in order to protect it from further floods after 1320, and Gray (1970: 51) records how ballast was used to heighten the ground level, together with a high stone wall to prevent future inundations. These accounts are verified by the archaeology, with a rise in the ground level dating to the 13th century (O'Brien *et al.* 1989: 200). In York, while layers of alluvium evidence a series of minor floods between the 9th and 10th centuries and major floods appear to have occurred between the 12th and 14th centuries defences to protect riverside buildings may not have been in place until the 13th century (Hudson-Edwards and Macklin 1999: 811-812). A clay and brushwood embankment with associated drainage ditches was initially dated to the Anglo-Danish period (Richardson 1959: 59-61) but a re-interpretation has tied it to the damming of the Foss to flood the moat of William I's castle (Hall 1991: 181), suggesting that it was not intended to protect against naturally occurring flood events.

In contrast to urban settlements, wetlands were only sparsely settled but land use intensified following reclamation which required material protection to deny access from naturally occurring inundations. These defences were usually composed of clay, soil from the marshes, rushes, brushwood and timber, or whatever could be obtained locally (Galloway 2013b: 382). Due to expense, stone was rarely used as a material for sea walls unless abundant supplies were available, such as in the Thames area where chalk was frequently used (Galloway 2013b: 382-383). To further reduce flood risk in reclaimed wetlands, compartmentalising walls were often employed so that if floods broke down the defences in one area, much of the remainder would still be protected. This was the case on Foulness Island, Essex, where internal walls divided the marsh into thirteen separate units (Smith 1970: 26). Provisions were also organized to maintain flood defences to further reduce the likelihood of inundations. This can be seen in Somerset by the 13th century with parishes employing 'wickmen' who were responsible for the maintenance of the sea walls (Elton 1891: 39; Williams 1970: 45). Similarly, common walls in Romney Marsh were maintained by contributions from all nearby tenants while the maintenance of flood defences on an individual's estate could consume considerable financial resources (Gardiner 1988: 117). In addition, lords frequently required their tenants to provide labour for the repair and upkeep of flood defences, especially following severe events (Williams 1970: 45). Just as often however, investment in the maintenance of flood defences was lacking, in areas of the Netherlands this was particularly the case where land was owned by absentee landowners (Vanslembrouck *et al.* 2005: 61-62), with the result that floods often broke through defences.

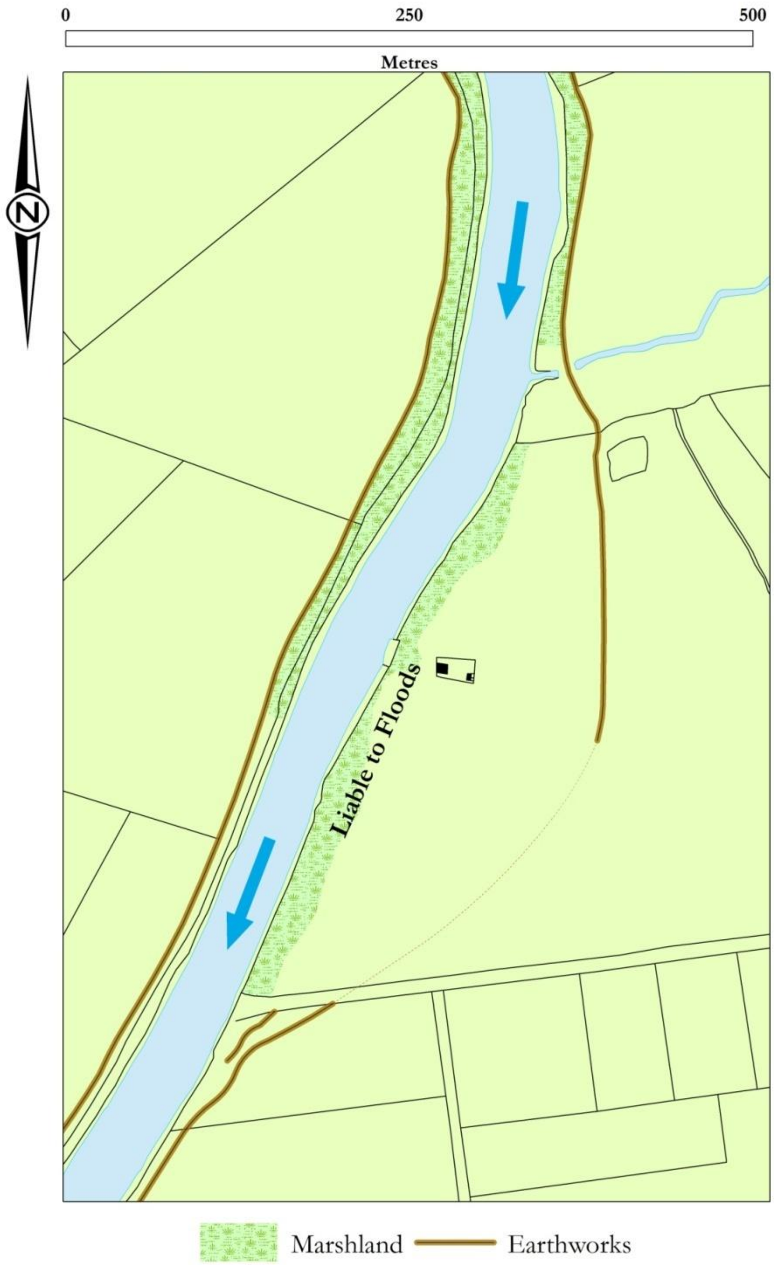

Figure 16 – A break in the dyke against the River Ouse near Riccall, N. Yorks., at an area which the 1st Series OS Map describes as "liable to floods". Likely, this represents a case of a dyke being overtopped in an inundation (Redrawn by the author from OS mapping).

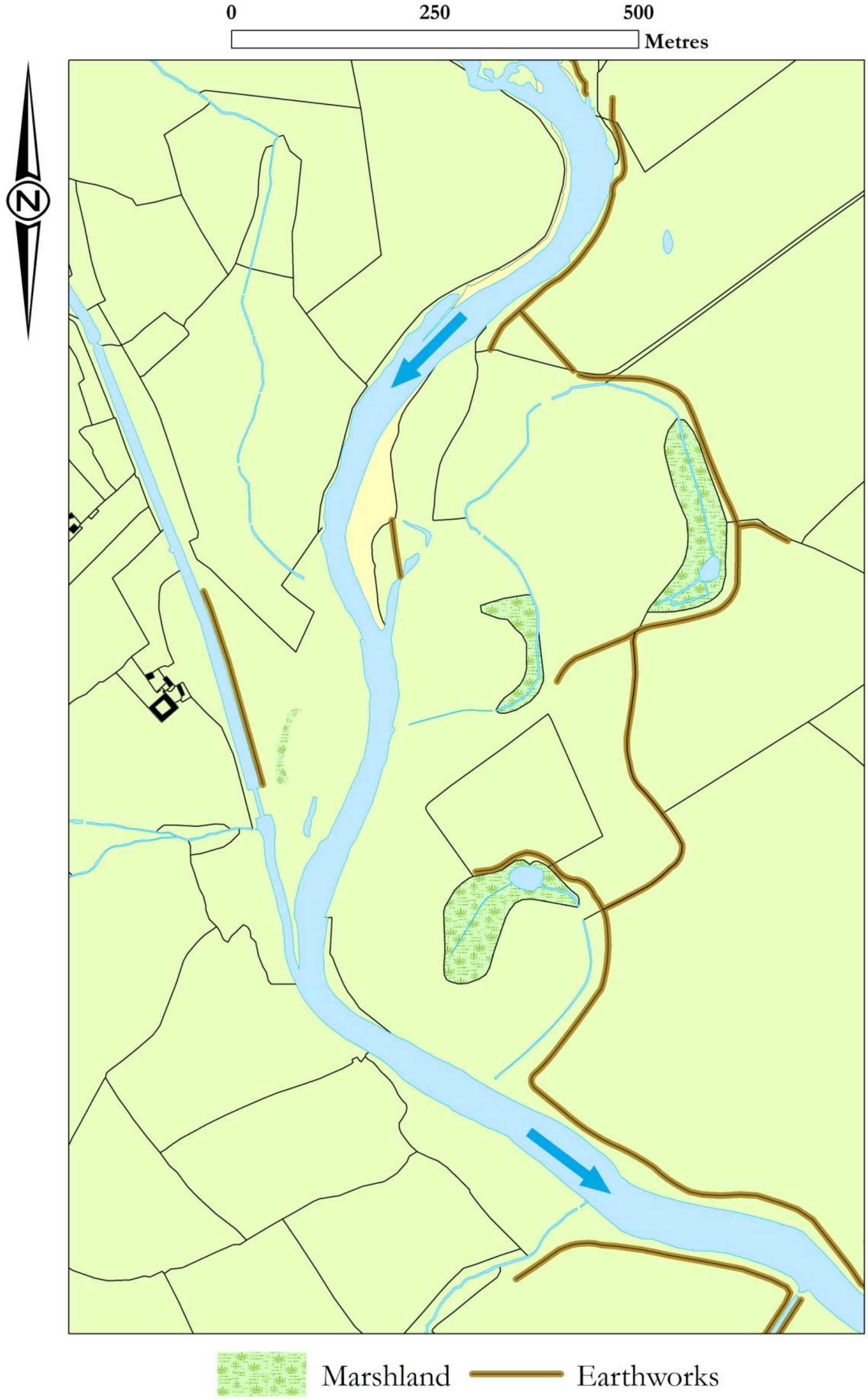

Figure 17 – An area along the River Ure southeast of Ripon, N. Yorks. in the 19th century, where the dykes on the right appear to have been constructed in line with a previous course of the river. Subsequent migrations were clearly met with adjustments to the course of the dykes (Redrawn by the author from OS mapping).

In wetland areas especially but along all river courses, the fragmented nature of landholding played a role in increasing vulnerability to flood events. Three inquisitions[13] recording land ownership along various stretches of river in the Fens (Wells 1830: 1-17), demonstrate how the course of a river could run through lands owned by many different entities and that failure on the part of a single party to maintain their stretch of river, by repairing dykes and unblocking drains, could lead to the inundation of neighbouring estates (Darby 1956: 2). This reduced the incentive to carry out necessary works as the failure of neighbours to invest in water management could result in flooding despite expensive precautions taken by individual landowners. This situation, in which flood defences commonly went un-maintained was remedied to a certain extent by the establishment of Royal Commissions *de walliis et fossatis* (on walls and ditches), later the Commission of Sewers, which investigated and rectified decline in local conditions brought on by flooding. These commissions were composed of prominent local landowners as well as royal officials (Galloway and Potts 2007: 376) with powers to ensure the completion of work required to protect land from flooding; order or conscript workers to carry out the work; and bill the party deemed responsible (Darby 1956: 1). In the 1370s for example, workers were conscripted to repair flood defences in the lands of Barking Abbey with the Abbess footing the bill (Galloway 2012: 73). An increase in the number of Royal Commissions in the Thames area from c.1350 has been attributed by Galloway and Potts (2007: 377) to the social disruption linked to the Black Death, particularly its impact on the labour market. A labour shortage created by the sharp plummet in population gave the survivors greater freedom to reject employment opportunities. Whereas in earlier times a swelling population had ensured there was always sufficient manpower to conduct repairs, unpopular jobs, such as the maintenance and repair of flood defences in wetland areas where malaria bearing mosquitoes were common (Gowland and Western 2012: 309), now frequently required the coercive powers of Royal Commissions to ensure the completion of the work. The commissions *de walliis et fossatis* were always however, a reactive rather than proactive, organized to reverse inroads made by floodwaters rather than to prevent hypothetical future events (Galloway and Potts 2007: 376).

Just as divine intervention could speed the recession of flood waters, the saints and the Almighty could also provide spiritual protection. What spiritual responses pre-Christians turned to is not well documented. It has been theorized that depositions in water bodies and wetland environments may have played a role in accruing protection from flooding and other hazards (Aberth 2013: 19; Ellis Davidson 1988: 134). A myth from the Icelandic *Landnámabók* hints that the god Thor may have also assisted in providing protection from floods (Ellis Davidson 1988: 137, 205). Christian practice, for which we have more evidence, was surprisingly diverse; while prayers and processions were a common response to mitigate the effects of floods, these strategies also provided protection as can be seen in a 1289 decree from the Bishop of Chichester which encouraged parish priests not to hesitate in conducting prayers and processions whenever adverse weather conditions loomed without seeking prior permission from the archdeacon (Powicke and Cheney 1964: 1086). Particular saints might also be invoked as defenders

[13] Two from 1395, the other from 1530.

against flooding, for example St Gregory Thaumaturgus who was credited with stemming a flood on the River Lycus, probably in modern day Turkey, by planting his staff in the ground where a tree emerged that prevented future inundations (Migne 1863: 930-931). Churches or shrines might also be built to prevent future floods. This occurred following a flood on the Wear at Finchale in the 12th century when the hermit Saint Godric built a new church dedicated to St John the Baptist in thanks for his survival and to protect against similar future events (Stevenson 1847: 112).

3.5 Adaptation

Responses to the losses and environmental changes that floods brought about were diverse. One of the greatest concerns of medieval populations was the success of their agricultural produce which floods could endanger. In some areas this could be minimised by the organisation of the agricultural year. As most inundations occurred in the winter, sowing in spring could provide protection from floods as this allowed the seed to benefit from the enrichment of the floodplain from alluvium while reducing the likelihood of the crops being drowned or washed away. The exposure of livestock too could be minimised. When heavy rains made floods inevitable it would have been common practice to relocate livestock from flood prone areas to higher ground (Whyte 2009: 70). The location of winter shelter would also have avoided areas vulnerable to flood as the security of such structures was a high priority, and with individual sheepcotes often housing c.300 animals, losses could be severe[14] (Whyte 2009: 70; Dyer 1995: 151). Inevitably, this system fell apart when the weather was erratic. Sudden floods could destroy arable crops and carry away livestock, and it is these floods that could not be anticipated which Rohr (2005: 77) views as the most threatening to humans and livestock. The extreme rains of 1358 for example, precipitated great losses to crops concentrated in low lying areas prone to flooding in the Lothians (Oram 2013: 372). Frequent flooding created a familiarity with the hazard which engendered the development of recovery strategies. Individual peasants buffered themselves from the risk of their crops being destroyed through membership of village fraternities, in which the other members would contribute to offer financial assistance in times of need (Richardson 2005: 391). At Wisbech and King's Lynn the reuse of timbers from inundated buildings deeply buried by silts may have been an adaptation to the frequent recurrence of flood events. Due to a shortage of wood in the Fens (Fletcher 2010a: 73), when possible, these structural timbers were pulled out of the river deposits and re-used in the construction of new buildings (Hinman 2002: 25, 36, 73; Clarke and Carter 1977: 65). In addition, in flood-prone medieval towns, especially vulnerable areas were used for temporary, often craft-related and polluting, activities rather than as sites of permanent settlement due to their frequent exposure to the hazard. A regularly inundated marginal area within King's Lynn was exploited as a meadow or pasture ground due to the inhospitable conditions until its reclamation in the 16th century (Clarke 2010: 17-18). Similarly at North Bridge, Doncaster, a riverside area with evidence for regular flooding episodes was used for a combination of watering livestock, as a refuse dump and as a craft area for butchery and metalworking

[14] e.g. Forty sheep were lost in 1380 when a building providing shelter caught fire in Bishop's Itchington, Warks. (Dyer 1995: 151)

(Carrott 1997: 69). Particularly extreme events could be the catalyst for far-reaching changes, for example at Godstow Nunnery, Oxon., in the aftermath of a flood that cast masonry downstream, buildings were rebuilt along new orientations suggesting a large-scale re-organisation of the site (Ganz 1972: 151).

Single devastating floods were rarely grounds for abandonment but repeated inundations more commonly forced communities to permanently relocate. This is particularly clear from the historical records relating to the monastic orders who frequently occupied 'green-field' sites rather than ones with greater longevity which may have adapted to floods over time. In comparison with other monastic orders, the foundations of the Cistercian Order appear to have been exposed to greater flood-risk, in no small part because their reformist doctrine expressly favoured wasteland such as forest, agriculturally exhausted wasteland or low-lying marshes. These lands constituted relatively insignificant portions for a magnate to cede from his estate and this resulted in the proliferation of many monastic orders, but Cistercian foundations especially, in less than ideal topographical locations (Hill 1968: 46, 48). In some ways they did not help themselves however, as the Cistercians' enthusiasm for increasing land under the plough and clearing woodland according to Lewin (2010: 295) meant that their foundations in valley bottoms endured problems with increased sedimentation. To a lesser extent, other monastic orders experienced similar problems with unsuitable sites and unsustainable land use as many of the examples below exemplify. A small cell of Ely Abbey founded in 1150 at Waterbeach, Cambs., for example, wrestled with continual flooding which by c.1160 had caused the monks to decide to move a few miles to the north to the less vulnerable site of Denny Abbey (Wright and Lewis 1989: 244). Records of a chapel, perhaps belonging to the Abbey of St Mary Graces on the Isle of Dogs, describe repairs alluding to continued problems with flooding which came to a head in 1449 when the Thames burst its banks and the chapel was abandoned (Hobhouse 1994: 375). The Cistercians at Stanlow, Ches., were forced to move to Whalley, Lancs., following inundations by the sea in 1279 and 1289 (Hulton 1847: vii). The low-lying and flood-prone ground between two streams at Otteley, Oxon., also made another Cistercian foundation impermanent with the community relocating after just three years[15] to the more suitable site at Thame, Oxon. (Fergusson 1983: 78; Donkin 1978: 35).

When the costs of protecting areas from flooding outweighed the returns that could be accrued from exploitation, changes in land use or a retreat to less flood-prone ground became the only viable option. In coastal marshlands a frequent adaptation was the switch from cereal farming to legumes, which are not only relatively tolerant to heavy soils and high salinity but also provide excellent fodder for livestock (Rippon 2001: 30-31). Additionally, marine resources would have always been important with excavations around Lydd on Romney Marsh suggesting marine foods made up the mainstay of the diet with their income augmented through the less dependable mixed agricultural regime (Barber and Priestley-Bell 2008: 289). In more extreme cases, the impact of floods often forced a shift from arable to pastoral agriculture. At Redlands Farm, Northants., for example, land that had been settled and cultivated in the early medieval period by the later medieval period was devoted solely to pasture as a result of

[15] 1137-1140

continued inundations (Keevil 1992: 183). While switches of this type were common, with reversals in the prices of grain and wool (Rippon 2001: 27) and a general retreat from marginal lands from c.1300 (Dyer 1994: 14), the tipping point in flood prone regions was reached far in advance of less vulnerable locales. This decision was also framed by the sharp decline in population of the 14th century, as pastoral farming requires a fraction of the manpower of arable cultivation (Gardiner 2012: 111). With adversity for some came opportunity for others, for example some areas where floods made inroads into reclaimed land became important for supplying resources such as reeds for thatched roofing and the continued inundation of wetlands along the Thames favoured the growth of a thriving fishing industry (Galloway 2012: 82; Galloway 2013b: 393).

3.6 Summary

For many populations in medieval Britain, although theologically they were frightening occasions, floods were a frequent reality which had to be endured. Although only extreme floods resulted in casualties or destruction on a large scale, repeated smaller-scale inundations exerted continuous pressure on crops, livestock, homes, infrastructure and industry. Local conditions display wide variation; when there was sufficient manpower and financial capital available, inroads made by floods could usually be reversed. This allowed land gained through wetland reclamation to remain viable as arable land. Ironically, this ability to transform the environment and intensify land use caused increased erosion and sediment run-off and put increased pressure on water courses lowering the threshold at which they flooded. Extreme events were still capable of causing considerable damage and when the social upheaval of the Black Death was accompanied by worsening climatic conditions, in many areas it became uneconomic to maintain flood defences to the same degree. This created a vicious cycle of degrading defences and diminishing resources which made future flooding and exposure to storms increasingly damaging - a cycle that was not reversed until the post-medieval period. Responses were constrained by the technological abilities and spiritual beliefs of the period. Other than evacuation until waters naturally receded, there were few effective courses of action to affect any lowering in flood levels which made spiritual supplications integral to medieval mitigative strategies. Material flood defences could be seen to offer genuine protection which made sea walls, bunds, ditches etc common constructions across the landscape, although these are often extremely difficult to date accurately. The knowledge that these defences were not unbreachable however meant that spiritual help was also sought in ensuring the material protective measures repelled flood waters. When a deluge did break through, adaptation could make it possible for occupation in a particular location to persist, for example, changes in agricultural exploitation such as a shift from cereals to legumes or from arable to pastoral, the intentional avoidance of permanent settlement in flood prone areas in towns, and the reuse of building materials when structures became deeply entrenched in alluvium. In the face of repeated severe inundations however, it could became untenable for occupation at a site to continue and complete abandonment and removal to a less flood prone locale was far from uncommon. The various options open to medieval populations, encompassing hugely diverse situations, are summarised in fig. 17 viewing floods as a continual inevitability, unless sufficiently secure material defences can be constructed. This cycle can only end with abandonment of the settlement but adaptation and material protection can increase resilience providing sustainable long-term protection.

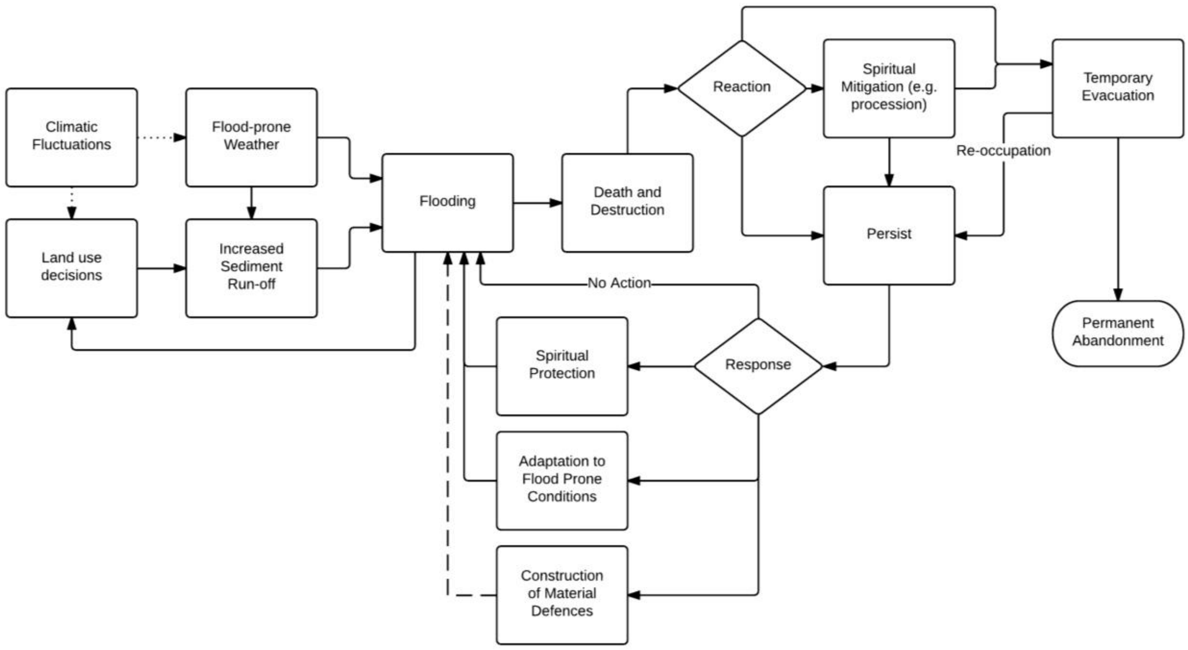

Figure 18 – A flowchart diagram summarising the principle processes related to the onset of floods and the responses open to populations in the Middle Ages. The diagram is too simplistic however, as the connection between climatic fluctuations, weather patterns and flooding is not a simple relationship. It also fails to show that floods were far from always a negative occurrence for nearby populations (Created by the author).

4.0 Lightning

Lightning is a powerful and dangerous atmospheric phenomenon which poses an often underestimated risk to society. While the physics of lightning are complex, essentially it occurs when a difference in electric charge between a cloud and the Earth's surface is equalized through a discharge, producing lightning (Rakov and Uman 2003: 9-10). While the majority of lightning flashes result in no personal or material damage, when they do strike they can be extremely harmful to people and property with risks from a variety of associated hazards. Individuals struck by lightning can experience amnesia, damage to the central nervous system, heart disorders, cataracts, deafness and of course death (Golde 1976: 1175-1176). Lightning can directly endanger individuals in a number of ways including direct strikes, contact with conductors struck by lightning (which can include the ground) or from 'flash-overs' from a nearby conductor when the path of least resistance is found through the air to the person or animal (Golde 1976: 1170-1171; Elsom 2001: 326-327). Quadrupedal animals are at particular risk because their hearts are located in the gap between their legs which increases the risk posed by electric current (Golde 1976: 1174). In addition, animals tend to look for shelter in a storm which often brings them underneath trees or against fencing which can cause group casualties if the tree or fence is struck (Swan 1960: 157). Flammable material struck by lightning can ignite causing buildings or natural features to burn down and collapse creating further risks from fire, smoke inhalation, falling structural material and trees. Casualties and damage are likely to increase as recent research concludes that, due to climate change, lightning strikes will increase by up to 50% by 2100 (Romps *et al.* 2014).

4.01 Mitigation

The type of damage caused by lightning can be diverse requiring varying mitigation strategies. Lightning could result in a farmer losing livestock, or in a building burning down, two scenarios with drastically different consequences. Carcasses can negatively affect water quality and attract unwanted scavengers so their removal is a priority. Fire damage can be mitigated if the fire can be extinguished before it runs out of fuel. In the present, technology and social organisation mean that fire fighting is very effective. Between 2011-2012, 380 people died in Great Britain as a result of fire (DCLG 2012: 19). To put this in perspective, John Stow estimates that at least three thousand were killed in the London fire of 1212 (Kingsford 1908: 24). Even if only ten percent of those deaths actually occurred, a more believable figure, it is clear that our ability to prevent deaths from fire has been immeasurable enhanced over the last millennium. Further results of a lightning storm could include fallen trees or telephone poles which require removal to prevent obstruction to infrastructure, as well as the restoration of any damage caused by their fall.

4.02 Protection

Lightning itself cannot be stopped but there are methods to manage and reduce its effect. Since Benjamin Franklin's invention of the lightning conductor in 1752, the risk of buildings being damaged by lightning has been greatly reduced (Rakov and Uman 2003: 2; Uman 1987: 7) and behavioural adaptations reduce the exposure of humans to the hazard.

4.03 Adaptation

When lightning strikes, or if weather patterns suggest an oncoming thunderstorm, behavioural adaptations can reduce the risk of lightning induced injury or death. These could include: staying indoors or inside a vehicle in a thunderstorm and avoiding contact with conductors which are likely to be struck, not using telephones or sheltering under trees (NYDH 2007).

4.1 Lightning in the Middle Ages

4.11 Perception

Lightning held a special place in the medieval mindset. It had been associated with the gods throughout prehistory and many pagans followed deities that controlled lightning. Prehistoric pendants in the form of hammers or axes symbolized lightning (Shetelig and Falk 1937: 412), a practice which continued into the historic period with the Norse weather god Thor. In particular, he was associated with thunder and lightning and the popularity of his cult is demonstrated by the widespread occurrence of amulets depicting his hammer across the Viking world. These were thought to offer protection from the meteorological forces within his power (Abram 2011: 66-65; 69). A fear and fascination for atmospheric electricity persisted following Christianization. Many medieval sources stress the terror that lightning stirred in onlookers. A sudden thunderstorm in 1287 at Bury St Edmunds for example "terrified spectators not a little" (Gransden 1964: 87-88). For medieval Christians, being struck by lightning was a particularly terrible way to die as it was clear that God had singled an individual out for failing to follow a Christian life, a fact borne out in a number of stories and accounts from the period. Lightning was often interpreted, as a sign from the divine, as an ominous indicator of things to come, e.g. Matthew Paris, in hindsight, viewed the lightning at St Albans as a fore-warning of the death of Abbot William in 1235 (Riley 1867: 299-300). More directly, lightning was a punishment, for example in Jacobus de Voragine's *Golden Legend* the carter Peter decided to work as normal rather than observing the feast day of Saint Mary Magdalene for which he and his cart were punished by being struck by lightning. This caused his leg to be torn from his body but this was restored to him after he went to the local church and was visited by the Virgin and Saint Hippolytus in a dream (Caxton 1900b: 232-233). This is further illustrated by a section from the life of Saint Andrew in which a mother maliciously accuses her son of trying to be incestuous with her. Following a prayer from Andrew she is struck down by lightning and reduced to smouldering ash while bystanders all around are stunned by an earthquake (Ryan 2012: 15). Symeon of Durham, in his *Historia Regum*, similarly tells how Thunor, who had murdered the two princes Ethelbert and Ethelred to guarantee the throne for his master, was killed by lightning and immediately engulfed by the earth (Arnold 1885: 11). As these stories demonstrate, a further reason why lightning was feared was because it brought sudden and instant death. This was alarming for Christians because a successful ascent to heaven required preparation with repentance, the administration of last rites and burial, which could not be achieved if lightning incinerated the body (Daniell 1997: 71). Therefore, in medieval literature, death by lightning, in common with other natural hazards e.g. drowning, earthquakes etc, was a fate associated with non-Christians (Daniell 1997: 65).

4.12 Historical and Material Evidence

There is no shortage of historical accounts describing lightning and its effects throughout the middle ages. A non-exhaustive list of events involving physical damage caused by lightning in Britain has been compiled for the period through a search of medieval literature. This has produced a list of 57 events from across Britain. When plotted overlain against estimated lightning strike density data from the present (Anderson and Klugman 2013: 6903; fig. 18), the medieval data appears to mesh well with modern estimates, with more in the south than in the north. It must be noted however, that the areas with more lightning strikes were also areas of higher population, with more structures for lightning to strike, and more people to witness and document the effects.

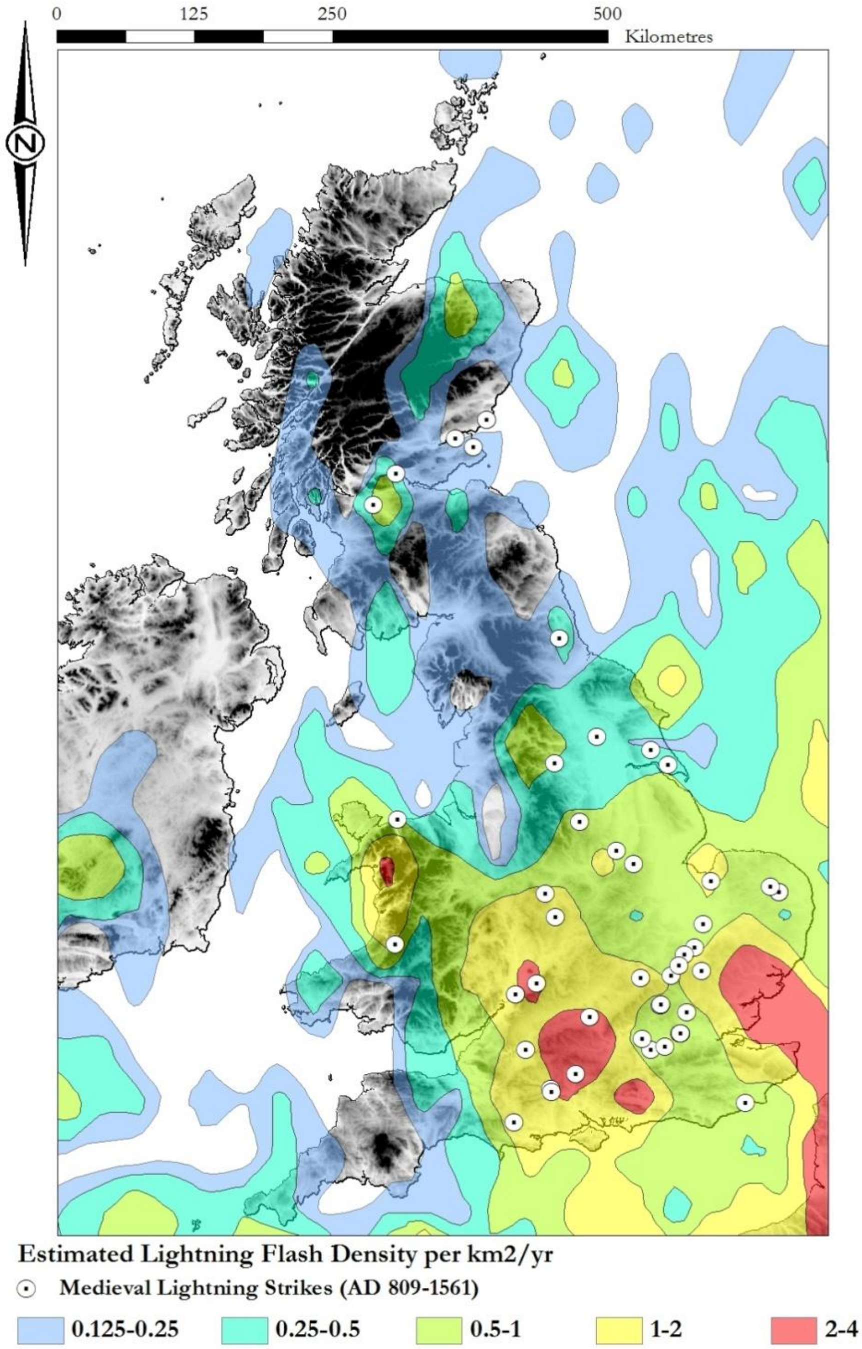

Figure 19 – Historical lightning strikes from the medieval period overlain against modern estimates of lightning flash density (Created by the author, lightning flash density from Anderson and Klugman 2013: 6903, Data from appendix 2).

While some historical accounts record personal injury, such as the death of Gabriel d' Eylston who was struck by lightning in 1187 in the porch of Elston Church, Nottinghamshire (Thornton 1797: 339), and agricultural damage, for example the burning of crops by lightning in 1233 (Lyte 1905: 178-179), the vast majority document damage to structures, mostly ecclesiastical properties. While churches and cathedrals with their tall towers and spires were at greater risk from lightning (Morris 1989: 329-330), there is certainly a bias in the documentary record as the literate clergy were more likely to record such events than the largely illiterate peasantry, and these documents had a greater chance of survival. In structures, lightning primarily results in fire damage but so many fires began through carelessness, accidents in kitchens and warfare (Kerr 2008: 10) that it is impossible to identify lightning damage through the archaeological record alone. While relict lightning strikes are detectable through magnetometry (Reindel and Wagner 2009: 68-69), these cannot be closely dated. Archaeology however, can verify and augment the historical sources, with structural clues often able to shed light on pre-event conditions. At Châlons Cathedral in France, for example, analysis of the present window-glass configuration proffered clues to the changes in internal layout following a destructive lightning induced fire in 1668 (Lillich 1996: 476-478). The identification of the impacts of lightning in the archaeological record is thus a different methodological challenge when compared to the effects of wind-blown sand and flooding. While these hazards can be independently identified through archaeology, evidence for lightning is reliant on textual evidence. The next step therefore is to evaluate the archaeological evidence for each historic reference.

With some of the accounts, this is not possible. For example, one of the earliest recorded cases of lightning damage supposedly took place in the mid 5th century when the heathen tyrant of Arthurian legend, Vortigern, was consumed by 'heavenly fire'. If this was lightning, it apparently took place following the prayers and fasting of Saint Germanus outside Vortigern's fortress of Guorthigern, at an unknown location along the river Towy in Wales (Walker 1844: 212; Charles-Edwards 2013: 444). An early example is also documented at Doncaster, where the antiquarian William Camden (1637: 690) relates how a fire from heaven burned down the entire town along with its castle in c.759. This however, perhaps represents either a folk memory or a fabrication as archaeologically there is no evidence for a significant settlement or fortress at Doncaster at that date (Buckland *et al.* 1989). While any truth in these examples is dubious and unverifiable, other examples are more plausible. Despite this, due to a lack of standing remains in the present, owing to post-event remodelling, the destruction of the Protestant Reformation and other damaging forces, many of the events recorded in the chronicles remain tantalizingly unverifiable. An example is Deganwy, Gwynedd, which is recorded as being struck by lightning and burnt in 812 (Williams 1860: 11). A further entry in the *Annales Cambriae* records that in 822 (Williams 1860: 12) the castle was destroyed by the Saxons, hence the lightning strike cannot have caused the site's total destruction and abandonment. Alcock's (1967: 198) excavations in the 1960s found no definitive evidence of 9th century occupation although it was conceded that ceramics could belong to that period, a view re-emphasised by Dark (1994: 11). Therefore, the archaeology probably demonstrates occupation up to the time recorded in the texts. Any more concrete evidence has been erased however, by the construction of a later medieval castle and subsequent rabbit burrowing on the site (Alcock 1967: 198). An equally unverifiable account comes from the *Chronicle of the Reign of Edward II* which records how Woburn Abbey, Bedfordshire, went up in flames following a flash of lightning (Stubbs 1882: 278). Any evidence that might have survived attesting to this event however, disappeared when the abbey buildings were pulled down at the Reformation to make way for the new stately home of the Duke of Bedford (Page 1912: 459).

One of the few secular buildings with documented lightning damage offers no more concrete evidence. Queen Eleanor's chamber in Windsor Castle which, according to Matthew Paris, was struck on Saint Dunstan's Day[16] in the summer of 1251 by a particularly violent thunderstorm (Giles 1853: 465) which threw the Queen's bed "to the ground, crushing it to powder, and shook the whole house" (Giles 1853: 465). This would have been a chamber added c.1240 by Henry III, and although some structural remains survive (Brindle and Kerr 1997: 34), the lightning damage as recorded was certainly too ephemeral to leave any lasting evidence.

Many churches and cathedrals offer more conclusive evidence. One of these may be St Peter's Church, St Albans, the central tower of which is recorded as being damaged by lightning in 1254 (Page 1908: 419). While major alterations to the building's fabric occurred in 1893 obscuring the structure's previous history, observations made at the time of this remodelling and documentary evidence, attest to the construction of the original church in the late 10th century which was succeeded by a Norman structure. At some point in the 13th century, alterations were made to the west end, most notably the addition of a 13th century doorway (Carey Morgan 1897-1898: 140). Although the timing meshes well, whether these changes were required due to damage caused by lightning is unknown, and perhaps more likely is that these changes were simply made to update the church stylistically. While lightning damaged the spire of Lichfield Cathedral in 1550 (Greenslade and Pugh 1970: 168), only two metres of medieval fabric remain on the west side, with the rest post-dating the English Civil War when the spire must have been nearly completely destroyed (Rodwell 1996: 91). In the same year, the spire of the church of St Peter and St Paul, Coleshill, Warwickshire, was destroyed and repaired to a height 4.5m less than the original (Salzman 1947: 54), perhaps owing to a lack of available funds. With Lichfield only separated from Coleshill by c. 22 km it is tempting to suggest these two events occurred as a result of the same thunderstorm although this cannot be proved. The Cathedral of Old Sarum is recorded as being struck by lightning in 1092 only five days after it had been consecrated by Bishop Osmund (Stubbs 1889: 375). St John Hope's (1913-1914: 102) excavations in 1913 identified considerable evidence for this event with "scorched and reddened stones and pieces of moulded work, used up as rubble in the later walling of the church". Another church which received considerable damage from a fire initiated by a flash of lightning was St Edmund's Church, Taverham, in 1458-1459. Archaeological evidence from excavations in 1989 corroborates this, with burnt remains uncovered beneath the nave and south aisle (Sims 2000). While

[16] 19th May

structural damage occurred, much of the structure's fabric remains standing, including an early stone tower, and stained glass from the original east-window which survived the fire to be re-used in the nave (King 1977: 387). Lightning could lead to formerly decorative masonry being re-appropriated for structural repairs as at St Mary's Abbey, York, in 1377, when a flash of lightning is recorded setting the tower on fire, destroying the relics along with much of the transept (Galbraith 1970: 95). From this description, Whittingham suggests (1972: 125) that the crossing must have been used as an extension of the choir, as at York Minster, as this is the only scenario which accounts for the fire destroying the relics. Further structural damage is demonstrated by the discovery of a fragment of sculpture, the waist of God the Father, which most likely came from a depiction of the Coronation of the Virgin, shattered and straight-away re-used in the repair of a buttress damaged by the lightning (Whittingham 1972: 125). Although little survives of the Abbey due to its destruction in the Dissolution (Norton 1994), it seems that few later modifications were made to the church (Whittingham 1972: 125) making any repairs relatively easy to identify.

Some structures were completely razed to the ground by lightning induced fires. An example is Milton Abbey, Dorset, which was burnt to the ground in 1309 and subsequently rebuilt with only two Norman arches in the chancel of the new church attesting to the existence of the previous structure (Pentin 1933: 5). Excavations in the 1950s revealed burnt floor levels and show that both the church's size and location were altered in the rebuilding (Wilson and Hurst 1957: 151-152). The fire resulted in a sharp decline at the monastery despite its Bishop encouraging donations and assistance to help with reconstruction and the King granting exemption from contributions he required towards his Scottish campaign. By 1344 the Abbey was bankrupt and external royal agents took control (Luxford 2005: 116). The church at Great Eversden too seems to have experienced near total incineration following a lightning strike in 1466 (Cotton 1997: 101). This made necessary the construction of a new nave, chancel and tower, erected in the new perpendicular style.

The Abbey of Strata Florida, Ceredigon, became a victim of lightning in 1284[17] (Christie 1887: 115-117). While the documentary evidence would lead one to believe the abbey church was burned to the ground with only the choir surviving, the archaeological evidence tells a different story. The structural fabric suggests much of the earlier church survived the fire (Robinson 2006: 271) although the roofing was destroyed and other damage was substantial. This is demonstrated by the archaeological evidence with moulded masonry reused as quoins (Williams 1889b: 34), layers of charred material (*ibid*: 41) and a broken grave marker (*ibid*: 32) all linked to the fire. The description from the *Annales Cestriensis* records how the lead roof melted covering large areas of the church fabric with molten metal (Christie 1887: 117). Pleasingly, Williams' (1889a: 153) excavations at Strata Florida in the late 19th century recovered "pieces of lead ... which had melted and trickled down from the roof into the interstices of the walls". A particularly large piece of lead was recovered from the presbytery which preserved a cast of the stone arches upon which it had solidified and remains of charred wood were found across the site underneath

[17] or 1286 according to the *Annales Cambriae* (Williams 1860: 109).

later flooring tiles (Williams 1889a: 153-154). While the chroniclers appear to have exaggerated the scale of the damage caused to the church, the details of the account appear to have been accurate.

That the towers and spires of major cathedral churches were frequently victims of lightning is illustrated by the standing remains at Durham and Norwich. The central tower of Durham Cathedral was struck by lightning in 1429 and again in 1459 (Cambridge 1992: 96; 116). The first strike destabilized the Norman tower forcing episodes of repair which took place principally between 1433 and 1436 (Cambridge 1992: 96). This repair however cannot have solved the underlying issue that the tower was in generally poor condition and the second strike seems to have been the catalyst for the whole scale rebuilding of the tower (Snape 1974: 72). Modifications appear to have been made to the plans throughout the rebuilding with the belfry, a late addition, perhaps a replacement for a steeple that had originally been planned to cap the tower. The repairs to the tower were completed soon after 1488 (Snape 1974: 73). Norwich Cathedral, the victim of at least two flashes over the period, was more heavily damaged by lightning. Severe damage first occurred in 1271 when a flash of lightning hit the tower (Britton 1816: 20). Together with fire damage from rioting in 1272, extensive repairs were required which led to the erection of a leaded wooden spire over the tower in 1297 (Gilchrist 2005: 76; Feilden 730). This spire was blown down in 1362 in a severe windstorm, which fell on top of and destroyed much of the eastern clerestory. Its replacement was struck by lightning in 1463 (Gilchrist 2005: 76), igniting a fire that destroyed this spire causing considerable damage to the cathedral. In many places the Caen stone of the walls turned pink due to the high temperatures (Gilchrist 1998: 118). Burnt stones in the north transept were re-used for repairs and alterations such as the blocking of a doorway, but Gilchrist has linked this to a later fire in 1509 (1998: 126) rather than the 1463 blaze. Similarly, burnt stone in the tower may have been a result of the 1272 riots (Gilchrist 2001: 296-297). Scorch marks in the presbytery, which had been rebuilt following the 1362 windstorm however attest to the significant damage propagated by the 1463 fire, which necessitated the refacing of the masonry (Woodman 1996: 193-194). Among the losses at Norwich were the church bells, which required replacements that survive to this day (Gilchrist 2001: 291). A third spire was built between c. 1472-1485 and its fabric bears signs of budgetary concerns, built in a manner requiring minimal scaffolding and utilizing brick faced with stone (Gilchrist 2001: 297; Feilden 1996: 730). While it has traditionally been thought that the roofing of the nave, which had previously been wooden, was replaced with stone vaulting following the fire (Rose 1996: 368) this may in fact have occurred before the event (Woodman 1996: 187) although the former remains a possibility.

Another frequent victim of lightning was London's original St Paul's, the spire of which was struck in 1230, 1341, 1444 and 1561 (Saunders 2001: 16). The flash of 1230 struck on the feast of the conversion of St Paul[18] when the cathedral was full of worshipers and apparently only shocked those inside rather than causing any structural damage (Kingsford 1908: 131). The later strikes however, permanently damaged the spire which required repair. The 1444 thunderstorm, which occurred on the 1st of February (Noorthouck 1773: 93), also hit the church of Kingston-upon-Thames (Anderson 1818: 73)

[18] 25th January

and similarly, in 1561, St Martin's Church, Ludgate, was struck just before St Paul's (Thornbury 1878: 241-243). London's church steeples were clearly at great risk when a thunderstorm passed over. The blank slate created by the Great Fire of 1666, destroyed any structural remains of St Paul's which may have preserved evidence of these strikes although several depictions of the cathedral survive from the Middle Ages which allow the major changes to the cathedral to be visualized (fig. 19). The earliest spire appears to have been topped by an orb surmounted by a cross, while the repaired spire was capped by a weather-vane (Saunders 2001: 16). The fire caused by the lightning strike of 1561 completely destroyed the spire as well as all the cathedral's roofing, with additional damage caused to the stone vaulting by falling roofing timbers (Keene *et al.* 2004: 171-172).

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Figure 20 - Three views of old St Paul's which illustrate the changes to the spire caused by lightning: The 1341 strike damaged the apex causing the orb and cross to be replaced with a weather vane, and the flash of 1561 started a fire that destroyed the whole spire. (Left and Centre, Keene *et al.* 2004: 154 & 112; Right, Saunders 2001: 18).

Scotland's two most major cathedrals, Glasgow and St Andrew's, may have both been set on fire by lightning in the late 14th - early 15th centuries. Glasgow Cathedral was definitely affected by lightning at some point before 1406 which ignited its wooden spire (Lewis 1851: 496; Durkan 1975). Durkan (1975: 91) has gone some way to reconstructing the progress and extent of this fire, with the timber spire initially set alight by a flash of lightning which then spread to the choir, the north choir aisle and from there into the vestry and the chapter house. Extensive archaeological excavations within the cathedral from 1988-1997 failed to detect either significant evidence for rebuilding in the 14th and 15th centuries (Driscoll 2002: 8; 161) or layers of burning, which probably disappeared when the floor was relayed in the 18th

century (Driscoll *pers. comm.*). The standing remains however, support the documentary evidence (Fawcett 1996: 65; 70; fig 20). While the roof bosses in the south choir aisle predate the fire, from the time of Bishop Wardlaw, those in the north choir aisles date from 1508-1523 and only the lower levels of the chapter house are from the 13th century, with later reparations above. The vestry, now gone, was located above the treasury which was built in the 13th century on the north side of the Cathedral. This location is consistent with the pattern of damage as well as structural and documentary evidence which supports its repair at a later date (McRoberts 1966: 40-42). This suggests a strong wind from the south-west, Glasgow's prevailing wind, spread the flames from the central spire to the north east of the cathedral (Durkan 1975: 90-91). Following the fire, the steeple was rebuilt in stone by 1425 and the chapter house was reconstructed by 1454 (Ralegh Radford 1970: 22-23). More piecemeal repair work is evidenced across the chancel with later ribs and vaulting inserted over the bays of the north aisle (Ralegh Radford 1970: 23) perhaps attesting to only minor damage by the fire in these areas.

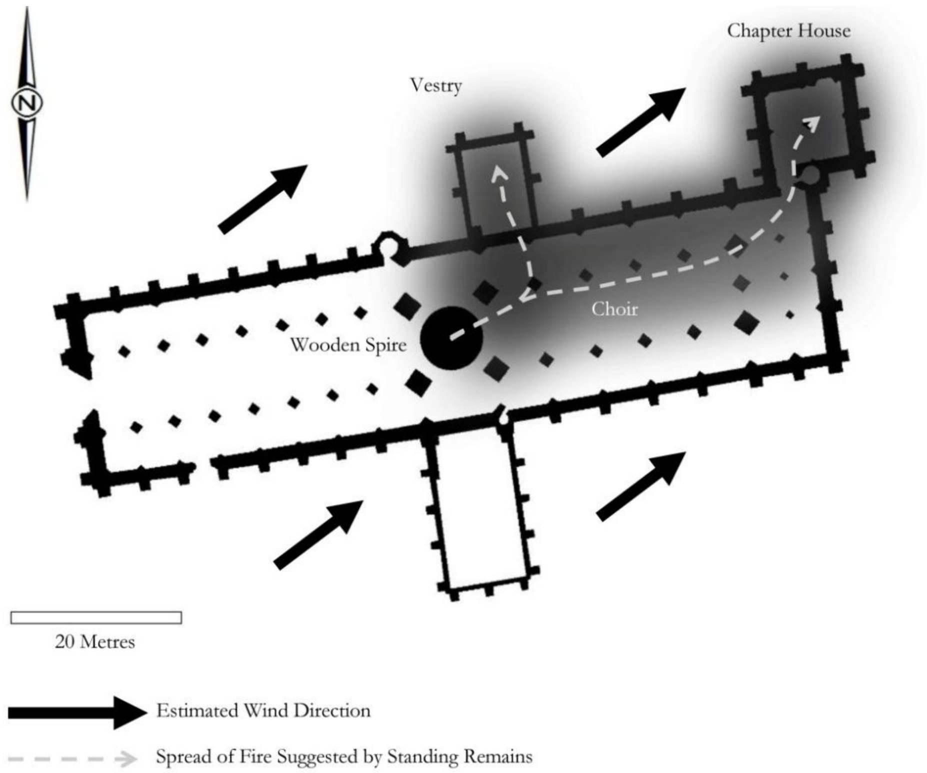

Figure 21 - Schematic diagram of the fire (shaded area) at Glasgow Cathedral with the estimated wind direction marked. (Prepared by the Author; Plan of Glasgow Cathedral after Driscoll 2002: 7)

At St Andrews a fire occurred in 1378 but it is unclear whether or not lightning was the cause. Hector Boece, writing more than a century later, varyingly attributed the blaze to lightning, a bird carrying a burning twig into its nest and a plumber leaving a hot iron in a crow's nest (Batho and Husbands 1941: 340; Bellenden 1821: 455). Lightning is probably the most likely candidate from these possibilities but there is no way of knowing for sure, with fires from other sources equally common (Greene 1992: 98-101). The fire seems to have caused great damage across the cathedral (Amours 1908: 309-311) with a 1381 grant from the Papacy "for the rebuilding of the church, which has been destroyed by fire" (Bliss and Twenlow 1902: 244). Although it would have been in the interests of the clergy at St Andrews to exaggerate their problem to the Papacy, the fire certainly precipitated the replacement of almost all of the roofing, the rebuilding of one side of the central tower - which involved careful engineering, the replacement of pillars in the transepts, the renewal of much of the nave and west front, and repairs and modifications to the east end (McRoberts 1976: 29-31). A silver lining to the fire perhaps, was that the rebuilding allowed changes to be made, such as an enlargement of the choir made necessary by changes in liturgy (McRoberts 1976: 65; fig. 21). If lightning did cause the fire, a strike to the central spire would explain the spread along the roofing, affecting almost the entire cathedral, which resulted in ongoing reconstruction work at least forty years after the event. Tracing the fire in greater detail is hindered by a lack of remaining structural features as a result of the cathedral's ruination since the Protestant Reformation.

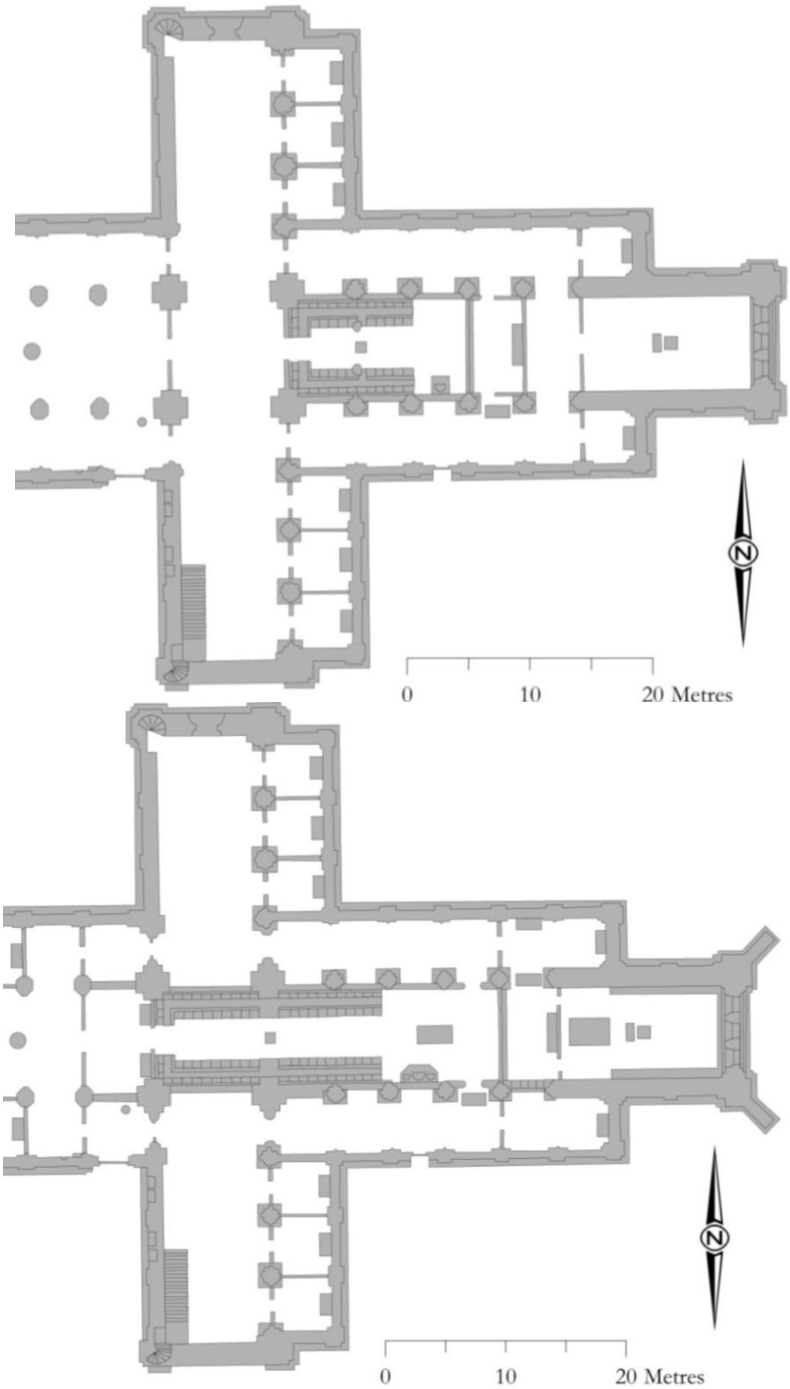

Figure 22 – The layout of the east end at St Andrews Cathedral. Above: A conjectural reconstruction prior to reconstruction the work between 1393 and 1443. Below: The changes made to the internal organisation of space in the reconstruction. (Redrawn by the author after McRoberts 1976: 179).

4.2 Mitigation

Once lightning had struck the most effective strategy to mitigate damage was to extinguish the fire as quickly as possible. This required an awareness of the fire as well as the skills and resources to successfully tackle the blaze. Medieval fire-fighting was not particularly advanced relying on makeshift community intervention with buckets of water and ladders rather than a professional fire brigade. Writing in 1662, the surveyor and teacher of mathematics George Atwell (1662: 95) lists the most effective fire-fighting tools, including pikes, forks, ladders, buckets, wet blankets, sand, ashes, horse manure, dust and dirt. These would similarly have been applied in earlier medieval conflagrations, with their rudimentary nature making it understandable why a reliance on spiritual defences such as saintly relics also developed (Snoek 1995: 334). Even when fire damage had been considerable however, there were still ways to mitigate the consequences. When Lacock Abbey was struck by lightning in 1447, affecting the bell-tower, bakehouse, brewery, two hay barns and Abbey property at Chitterne (Maxwell Lyte 1909: 86), the Abbess negotiated relief from taxes for forty years which allowed the monastery to successfully recover within thirty years (Pugh and Crittall 1956: 313), in contrast to the sharp decline of Milton Abbey following the fire of 1309. Clearly the success of local responses owed much to individual initiative as well as good fortune.

4.3 Prevention

Medieval preventive strategies were intrinsically flawed as they had no understanding of electricity, electirc charge or current flow. The lightning conductor was not invented until long after the close of this study and so no effective prevention could take place. Fire, lightning's most damaging associated hazard, could be prevented or minimized through the construction of buildings in fire-proof materials, e.g. roof slates rather than thatch (Jope and Dunning 1954: 214), and while legislation was enacted in certain towns to enforce this, as in London in the early 13th century (Riley 1860: 86-88), medieval settlements, which were often overcrowded with buildings with thatched roofs and wooden chimneys (Thomas 1971: 15), remained extremely vulnerable as demonstrated by the 1507 fire in Norwich in which 718 houses are said to have been incinerated (Blomefield 1806: 182). More widespread however were the numerous and diverse spiritual defences employed in defence against lightning. Probably since before the Middle Ages, Stone Age tools, fossils and sea urchins had been regarded not as anthropogenic or natural remains but as products of lightning strikes (Blinkenberg 1911: 1-3). As Gilchrist (2012: 247) discusses, their seemingly miraculous appearance from the earth imbued these objects with magical powers and curating them beneath floors, in roof-spaces or wearing them as pendants bestowed protection from lightning as well as providing other benefits (Blinkenberk 1911; Marbode 1996: 48-49). A variety of plants are also known to have been regarded as effective protection from lightning strikes. Sempervivum or houseleeks are mentioned in the 17th century Antiquarian John Aubrey's collection of miscellaneous folklore as "defensative against lightening and thunder" (Britten 1881: 167). Although most commonly found in post-reformation contexts, burn marks in structures may have also served as a blessing against fire and lightning, particularly amongst the lower social classes (Lloyd *et al.* 2001). Explicitly Christian material culture could also grant protection as Matthew Paris describes at St Albans, where a Papal Agnus Dei was placed atop the tower to prevent lightning strikes but its failure to prevent lightning striking the tower led to him at least losing faith in not only the power of the Papacy but the saints themselves (Riley 1867: 313). Jacobus de Voragine, Archbishop of Genoa, writing in c. 1275 describes how church bells were rung to banish the evil spirits and demons that call up lightning and storms (Caxton 1900a: 105). A variety of evidence for this practice can be found in Britain, for example the great bell of Saint Adelm at Malmesbury Abbey is documented as being wrung to disperse thunder and lightning (Britten 1881: 22) and church warden's accounts from Spalding, Lincs., document the payment of bell-ringers to drive away a storm (Peacock 1895: 37). Church bells from the period are also commonly inscribed with words relating to their ability to dispel lightning such as ‘fulgura frango’ - break lightning (Weever 1767: 119). In common with other hazards, it was also widely believed that personal protection could be obtained by calling on the saints for assistance. St Barbara in particular was invoked for protection against lightning and sudden death because her father had been consumed by heavenly fire (Thurston and Attwater 1956: 488; Buzwell 2005: 17). Holy water was also seen as a viable protection as in 1543, during a thunderstorm, the sprinkling of holy water on houses by parishioners of Northgate, Canterbury, was branded as heresy by the reforming Protestants (Gairdner and Brodie 1902: 300).

4.4 Adaptation

Medieval populations had to accept the fact that they were vulnerable to lightning and plan for the consequences. This can be seen on the death of the Bishop of Winchester, Nicholas de Ely, in 1280 when his executors provided for a marble cross to be erected to his memory in the village of Froyle, Hants., which was to be replaced if struck down by lightning (Baigent 1882: 27-28). With such a seemingly direct connection to God, it must have been testing to see some of the largest ecclesiastical buildings in the land severely damaged, or even incinerated, by the hazard. While lightning fires may have caused some to question their faith, their strength of belief required them to rebuild and maintain religious houses. These examples illustrate an acceptance that the effects of lightning, as a divine force, could neither be controlled nor prevented but subsequent recovery and rebuilding was possible.

4.5 Summary

While it has been extremely difficult to trace structural and archaeological evidence for lightning in medieval Britain, the few examples where good evidence exists; Glasgow, Norwich, Strata Florida, St Mary’s York etc; allow the process of disaster recovery, repair and restoration to be glimpsed from the archaeological record. The sources give the impression that human casualties were rare but that material losses could be extensive. Lightning prompted repairs to some of the largest and most expensive structures in medieval Britain which were commonly ongoing for at least half a century, placing great financial burden on the community. In these cases however, lightning induced fires were not disasters which caused people to lose hope as the eventual repair of all these examples demonstrates, although it took time to amass the resources to begin restorations and new liturgical requirements, tastes or financial considerations often called for alterations or modifications to the pre-disaster design.

5.0 Windstorms

While winds are an everyday occurrence, particularly stormy conditions, corresponding to winds of 10, 11 or 12 on the Beaufort Scale or winds above 25 m/s, have the potential to cause major and widespread damage and are often accompanied by other meteorological hazards such as heavy rain, hail, thunder and lightning. Studies of storm occurrence in the UK over the last century demonstrate that storm activity has varied naturally over decadal timescales (Dorland *et al* 1999: 515; Lamb 1991: 33) although recent increases in frequency and intensity could be related to anthropogenic climate change (Donat *et al.* 2011). Britain and north western Europe are threatened by severe cyclones all year round as a result of the contrast in temperature between polar and sub-tropical masses of air over the Atlantic which generate extra-tropical cyclones along this frontier (EEA 2012), although only a small proportion of these produce gale force winds (Leckebusch *et al.* 2007). When the force of these high winds become greater than the ability of buildings and infrastructure to resist, damage to human settlement can be severe (Dobrovolný and Brázdil 2003: 105). Between 1962 and 1999 there were 509 casualties in the UK as a result of wind storms (Sanders and Phillipson 2003: 214). Among the most frequent material losses in storm events are electrical distribution systems, transportation and communication infrastructure and vulnerable structural components (such as lightweight roofing) as well as structures and property hit by falling trees (Field *et al.* 2012: 257).

5.01 Mitigation

In order to mitigate losses, both material and human, accurate forecasting is necessary. This allows emergency services, contingency planners and the general public to prepare for adverse weather conditions. If homeowners are given reliable information in advance of a storm hitting they can take action to reduce damage such as boarding up windows, securing external vulnerable objects and parking cars safely in garages. The Met Office's accurate forecasting of the storm on 28th October 2013 for example caused people to choose to work from home rather than travel and trains were cancelled to avoid the danger of fallen trees (Met Office 2013). Precautions such as these reduce human casualties, material losses and costs to insurers.

5.02 Protection

The main method by which society protects itself from the impact of storm damage today is through insurance. According to the reinsurers Munich Re, storms, such as 'Lothar' in December 1999 (Leckebusch *et al.* 2007), were the costliest natural hazard to affect Europe between 1998 and 2009 (EEA 2012) and global insured losses to weather-related natural catastrophes have increased more than tenfold since the 1970s (Schwierz 2010: 487). The scale of damage that windstorms can precipitate however, combined with the high uptake of insurance in Britain represents a volatile risk to the insurance industry which requires reinsurance to prevent insurance companies becoming insolvent in the face of widespread damage from severe storms (Ulbrich *et al.* 2013: 109).

5.03 Adaptation

Adaptation to the threat of windstorms requires that structures are designed cohesively to withstand the forces of high winds. The enforcement of suitable building codes should ensure that structures are built to a standard that can weather an extreme event although there is evidence that many UK buildings are damaged in wind-speeds below those for which the building codes are designed and climatic changes may require regulations which protect against increased wind speeds (Sanders and Phillipson 2003: 215).

5.1 Medieval Theology and Literature

In the medieval period high winds with the potential to cause damage were not only feared for their destructive potential but also as troubling signs of things to come. Many entries from the *Anglo-Saxon Chronicle* bear this out, for example, the first Viking raid on Lindisfarne in 793 was heralded by "excessive whirlwinds and lightnings" and in 1117 a violent storm followed by an eclipse provided an omen which was seen as a forewarning of an earthquake in Lombardy (Giles 1914: 40, 184). Similarly, the deaths of prominent figures were presaged by stormy weather, for example the death of Pope Paschal II in 1118 was heralded by stronger winds than could be recalled in living memory (Giles 1914: 185) and the passing of the Archbishop of Canterbury, Ralph d'Escures, in 1122 was foreshadowed by high winds and sightings of ghosts throughout the land (Giles 1914: 187). Additionally, according to the chronicler Gervase of Canterbury, unusual winds and rains were seen as portents of God's dissatisfaction with the reign of Edward II (Stubbs 1880: 67). While it is impossible to ascertain the veracity of such accounts regarding weather patterns, they are at least a valuable source for understanding contemporary beliefs surrounding inclement weather. The inevitability of misfortune meant that, in hindsight, such weather could always be seen to precede negative events thereby reinforcing the belief that adverse weather conditions were ominous portents. That winds were often viewed as divine punishments can be seen in the allegorical poem *Piers Plowman* in which the storm of 1362 is described as a result of the sin of pride (V, 13; Bloomfield 1962: 114). Witchcraft was also a component in beliefs surrounding storms. As early as the late eighth century, the Anglo-Saxon writer Cathwulf wrote to Charlemagne giving advice on the prevention of the dark magic of *tempestarios*, or those who summon up storms (Dümmler 1895: 504). It was only by the late 15th century however, that this view became accepted Church doctrine and waves of witch persecutions took place across Europe - a development which Behringer (1999) has linked specifically to the climatic downturn of the Little Ice Age.

5.2 Archaeological and Historical Evidence

While contemporary accounts confirm that winds did indeed cause havoc, thus "on St Thomas's day, [1118], there was so exceedingly high a wind … and this might be seen everywhere from the state of the houses and the trees" (Giles 1914: 185), material evidence that has survived into the present is rare. After rubble has been cleared and buildings rebuilt the physical signature of a windstorm is almost completely erased. As a result, identifying archaeological evidence for human interaction with the hazard is not an easy task. Some proxies left behind by windstorm events however, can be studied. Wind-blown sand is one such indicator and is discussed fully in chapter two. In rare cases, other landscape features can attest to windstorm events such as the abundant mound and pit features at Minchinhampton Common, Glos., which have been demonstrated to be the result of widespread tree toppling in a late medieval windstorm (Allen 1992: 339). It would be useful if the gaps in the archaeological record could be plugged with documentary evidence however, unfortunately, for the medieval period the historical record in relation to storm activity comes with a multitude of problems related to provenance, reliability, accuracy and calendrical differences. It is also impossible to know what medieval sources have left out. Pfister *et al.* (2010) have illustrated in relation to post-medieval European storms that only the most damaging events survive in the cultural memory with the socio-political situation at the time of the hazard being an important factor as to whether or not they are remembered. The medieval event with the most historical and archaeological evidence for example, a storm of 1362, came amid a renewed outbreak of plague (Horrox 1994: 85-86), and was still remembered around a century later when the historian John Capgrave included it in his *Chronicle of England* (Hingeston 1858: 221). As a result of these various methodological issues most catalogues such as the one compiled for the Czech Republic by Dobrovolný and Brázdil (2003: 110-115) begin in the post-medieval period. The reliability of historic sources, however, can be demonstrated if standing building or archaeological evidence, usually in the form of phases of damage or swarms of repair, can be found to support the textual description. This allows the reconstruction of particularly detailed structural biographies in relation to windstorm events although the number of identified cases is small and can be considered in no way a comprehensive record of windstorm activity throughout the period.

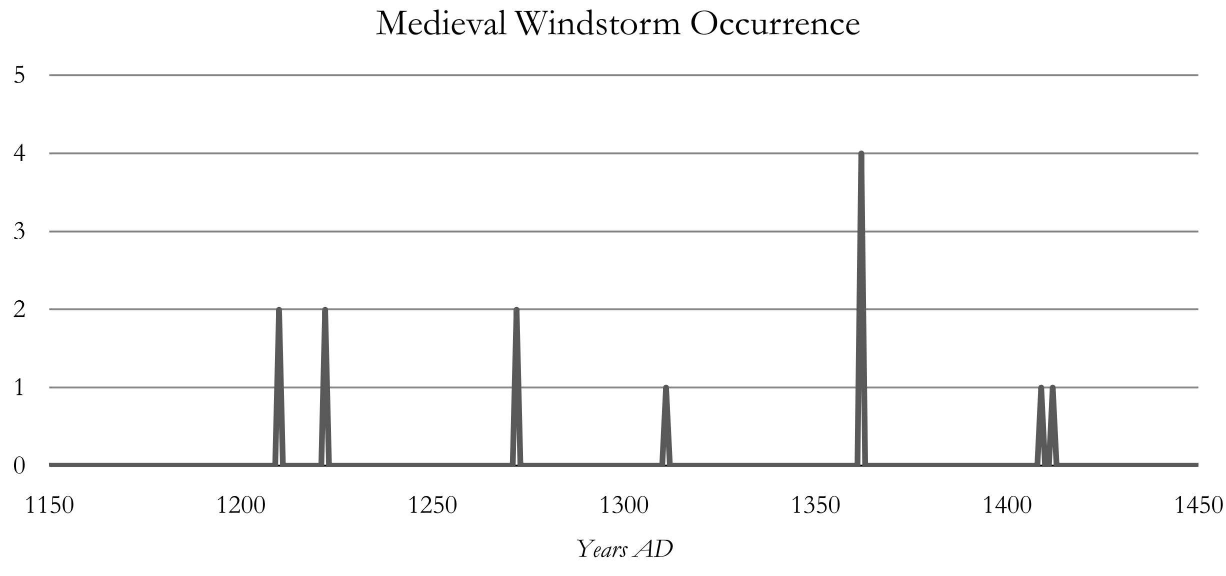

Figure 23 – British medieval windstorm events with archaeological evidence. Vertical axis indicates the number of unique archaeological indicators for each event. Data available in appendix 3.

The impact of a windstorm on a medieval settlement would have been far from uniform which in turn has influenced what has survived into the present. For example, low status dwellings of the peasantry were more likely to have been constructed of timber or wattle and daub rather than stone, although there was much regional variation, and as a result they would have been particularly vulnerable to extreme wind speeds. Consequently however, these buildings have survived in only very limited numbers into the present, with those that survive unlikely to have sustained considerable damage, and rarely with well documented building histories. Seigniorial and, particularly, ecclesiastical structures on the other hand are more likely to have had memorable and calamitous events such as extreme winds recorded and these documents are more likely to survive into the present. This permits a limited picture, biased by the nature of the evidence, to be constructed of damage from windstorm events in selected medieval structures.

One category of secular structure which was placed at particular risk from high winds, and due to seigniorial ownership are often accompanied by documentation recording damage and repair, were windmills. The tower mill at Turweston, Bucks., for example was damaged in 1316 most likely as a result of high winds, repaired again in 1324, only to be damaged again in 1326. Subsequent repairs were carried out in 1330 but by 1344 the mill was described as 'destroyed and eradicated' and no identifiable remains have survived into the present (Langdon and Watts 2005: 708). In this case it may be that the repeated damage precipitated by storms made it unprofitable to continue maintaining the mill, forcing subsequent abandonment and decay. Similarly, a windmill on the manor of Ivinghoe, Bucks., was rendered inoperable as a result of strong winds in 1389-90 (Langdon 2004: 38). These may represent especially well documented cases of bad luck but it is likely that comparable damage would have affected the numerous windmills throughout Britain at regular intervals.

The category of building for which the most evidence survives of damage from high winds are churches which, with their tall towers and spires, proved especially vulnerable. St Andrews Cathedral, Fife, for example, fell victim to storm damage in the 1270s when, just after the church had been completed, the west front was blown down in a storm (McRoberts 1976: 23; Goodall 1775: 360-1). This was probably the same event recorded in 1272 at Arbroath which had the force to "*overturn houses, smother those sleeping within and flatten high buildings*" (Watt 1990a: 385) and may have brought down one of the towers of the Abbey church and precipitated a lightning induced fire causing widespread damage (Miller 1860: 102-103). Although the exact original plan for St Andrews Cathedral's west end is unknown, the reconstruction differed slightly from the original, located two bays further east, creating a narthex from the pre-existing nave walls (McRoberts 1976: 23). Damage was again felt at St Andrews on 13th January 1409 when high winds caused the collapse of the south transept, which sent rubble falling through the roofs of the chapter house, dormitory and transept chapel-aisle, fatally injuring one of the canons (McRoberts 1976: 31; Watt 1990b: 75). The surviving structural evidence attests to this event. Buttresses, visible in fig. 21, were added to the east end, perhaps in response to the recent storm, and a non-original cylindrical respond dating stylistically to the 15th century was presumably inserted during the repairs. (McRoberts 1976: 31).

The Cathedral at Old Sarum, Wilts., similarly seems to have frequently fallen victim to strong winds and stormy conditions. According to William of Malmesbury, in 1092, five days after being consecrated it was struck by lightning which scattered the roof of a tower (Stubbs 1889: 375). The storminess of the location is further demonstrated by a Papal letter from 1217 which describes how the church was "so shaken by the wind and storm that it daily needs repair" (Bliss 1893: 46) and this was probably a contributory reason for abandoning the site in c. 1227 (St John Hope 1913-1914: 102). In addition, a document from 1315 records damage inside the nearby castle to one of the chambers and St Nicholas' chapel which cost £20 to repair (Lyte 1916: 51). Although no archaeological remains survive, this chapel was probably situated on the first floor of the Bishop's palace where it would have been more exposed to storm damage than another chapel presumed to have been situated beneath on the ground floor (Shortt 1965: 31). Occupying a similarly exposed position on the floor above the east gate (Shortt 1965: 30), another of the castle chapels, the chapel of the Holy Cross, was damaged in a storm in 1365 (Pugh 1962: 60).

A widely referenced storm occurred in October 1091 at London (Luard 1865: 202; Luard 1869: 12) with some sources describing the damage or destruction of c. 600 houses as well as severe damage to the church of St Mary-le-bow when roofing was blown off, sending rafters deep into the ground below and killing two (Thorpe 1849: 29). This description has led researchers at TORRO (the Tornado and Storm Research Organisation) to recognise this event as the first recorded occurrence of a tornado in Britain (Elsom *et al.* 2001: 24-26). By their reckoning the textual description involving wooden-framed houses and their contents being dispersed over long distances and stone or brick houses being irreparably damaged corresponds to a T8 tornado, with wind speeds greater than 96 m/s (Elsom *et al.* 2001: 25). Unfortunately, the church of St Mary-le-Bow was damaged in the Great Fire and subsequently completely rebuilt by Sir Christopher Wren (Keene and Harding 1987: 212) and other archaeological evidence from across London is likely to have also been erased in the many interim phases of damage, repair and rebuilding. In such circumstances no archaeological verification is available for this event.

An event which appears to have affected multiple churches can be found in the *Annales de Dunstaplia* (Luard 1866: 32) recording a windstorm in 1210 which toppled towers at Evesham Abbey and the Abbey of Bury St Edmunds while at Chichester Cathedral two towers were blown down. That one of these was the central tower is strongly supported by the fact that Willis (1861: 32) dates the fabric above the Norman arches to c. 1225-1250. In addition, analysis of the tower fabric conducted following the collapse of the main spire in 1861, noted that Norman ornamental mouldings on the tower's arches did not properly match together and voussoirs of Caen stone had been inserted to replace damaged masonry and strengthen the arches (Willis 1861: x-xi) perhaps indicating structural repairs undertaken following the 1210 event. The 13th century alterations made to the south west tower, including a completely new upper storey (Tatton-Brown 1996: 49) strongly support the identification of this tower as the second tower damaged by the storm of 1210 (fig. 24). Enlarged buttresses on this tower were also added at this time signifying an attempt to increase resilience from similar future events. While the structural evidence at Chichester accords with the description in the *Annales de Dunstaplia,* the *Chronicon Abbatiae de Evesham* records the tower there collapsing in 1207 (Macray 1863: 224), causing great destruction in the presbytery where the altar itself, ornaments, nearby tables and the treasures of Saint Wystan were all damaged. Documentary evidence relating to the fall of the tower at Bury St Edmunds agrees with the date given in the *Annales de Dunstaplia* but there is disagreement over the cause of the collapse with one account describing the fall as spontaneous and unconnected to a storm or high winds (Arnold 1892: 19) while another repeatedly mentions the violence of the storm (James 1895: 203-204). James (1895: 204) believed the documentary evidence favoured the collapse of the central bell tower which he believes was not rebuilt for over a century. The abbeys at Evesham and Bury St Edmunds were both almost completely destroyed at the Dissolution and as a result standing remains are unable to assist in proving or disproving the conflicting sources. The disagreement in the sources and the lack of any geographic clustering in the locations of the three sites (fig. 23) does not preclude the possibility that a severe Atlantic storm toppled all four towers but neither does it strengthen the case. That two towers fell at Chichester seems however to suggest at least there a storm was the catalyst with the lack of standing remains making it impossible to verify with greater clarity the events at Evesham or Bury St Edmunds.

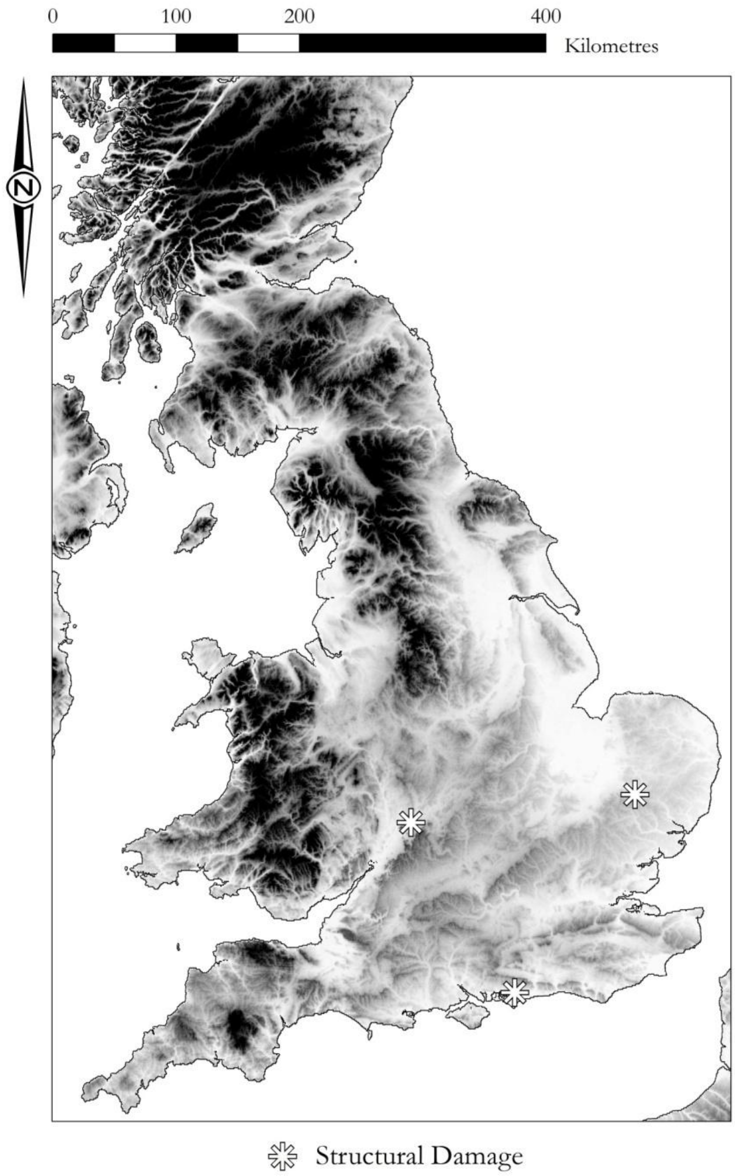

Figure 24 - Map of structural damage recorded occurring in the 1210 storm event (Created by the Author).

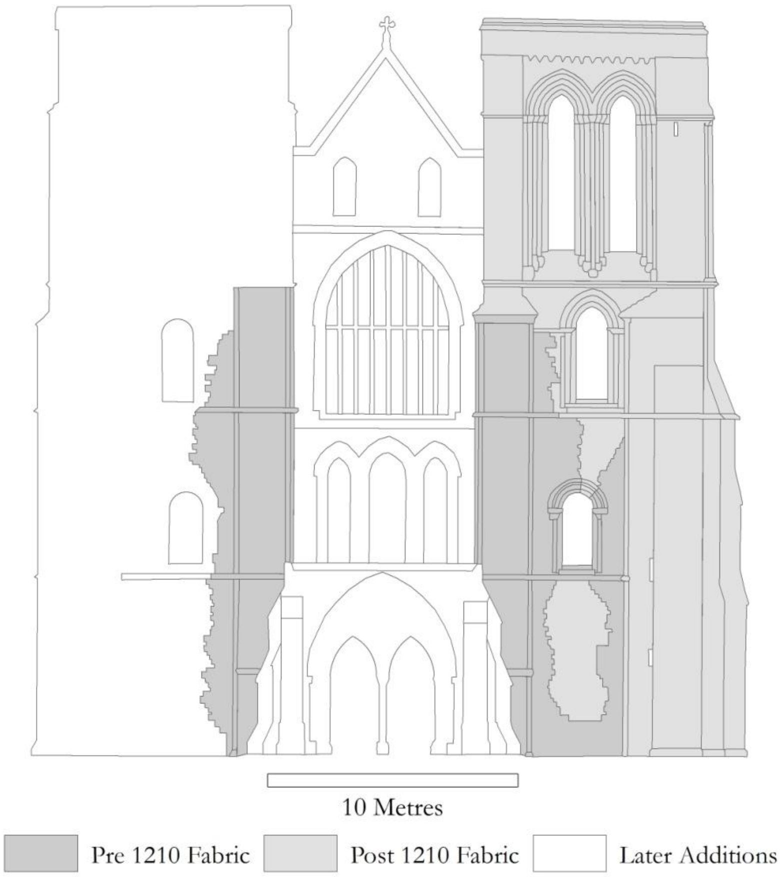

Figure 25 - Phases of damage and repair relating to the 1210 event visible on the west front of Chichester Cathedral (Redrawn by the author from Tatton-Brown 1996: 49).

Similarly, a series of windstorms in 1222 seem to have caused damage at Pilarton Hersey, Warwickshire; Dunstable Priory, Bedfordshire; and Worcester Cathedral, Worcestershire. That these three locations were all affected by the same storm event is strengthened by their spatial alignment which fits well with an Atlantic storm travelling east (fig. 25). The *Annales de Wigornia* describes this event with the words "a mighty tempest of wind, rain, and thunder arose on the feast of St. Andrew [30th November]" (Luard 1869: 415). The chronicler, Roger of Wendover describes how a house belonging to a knight in the town of Pilardeston (Pilarton Hersey), Warcks., collapsed in the storm killing 9 (Giles 1849: 442). Wendover also adds that storm winds were again experienced on the eve of St Lucy [13th of December]. At Dunstable, two towers were brought down, one of which collapsed into the Prior's hall and the other fell into the church itself (Page 1912: 364-365). Only the north-west tower was reconstructed, perhaps because it had been the bell tower but documentary and archaeological evidence do not provide further insight into the post-event recovery. At Worcester Cathedral the documentary evidence records that the storm "threw down the two small towers of Worcester (Luard 1869: 415)". Willis (1863: 91) describes foundation walls visible in the crypt of the cathedral which he thought could have been those of a tower, suggesting that the Norman apse at Worcester originally had two side towers as at Canterbury Cathedral. Beginning in 1224, work began to completely remodel the east end of the cathedral, only two years after the storm. While Singleton (1978) views this as a move instigated primarily in order to create a lady chapel or additional space for shrines, given the probable location of the two towers flanking the apse, the catalyst for this long-term goal may more likely be ascribed to the damage caused by the 1222 storm event.

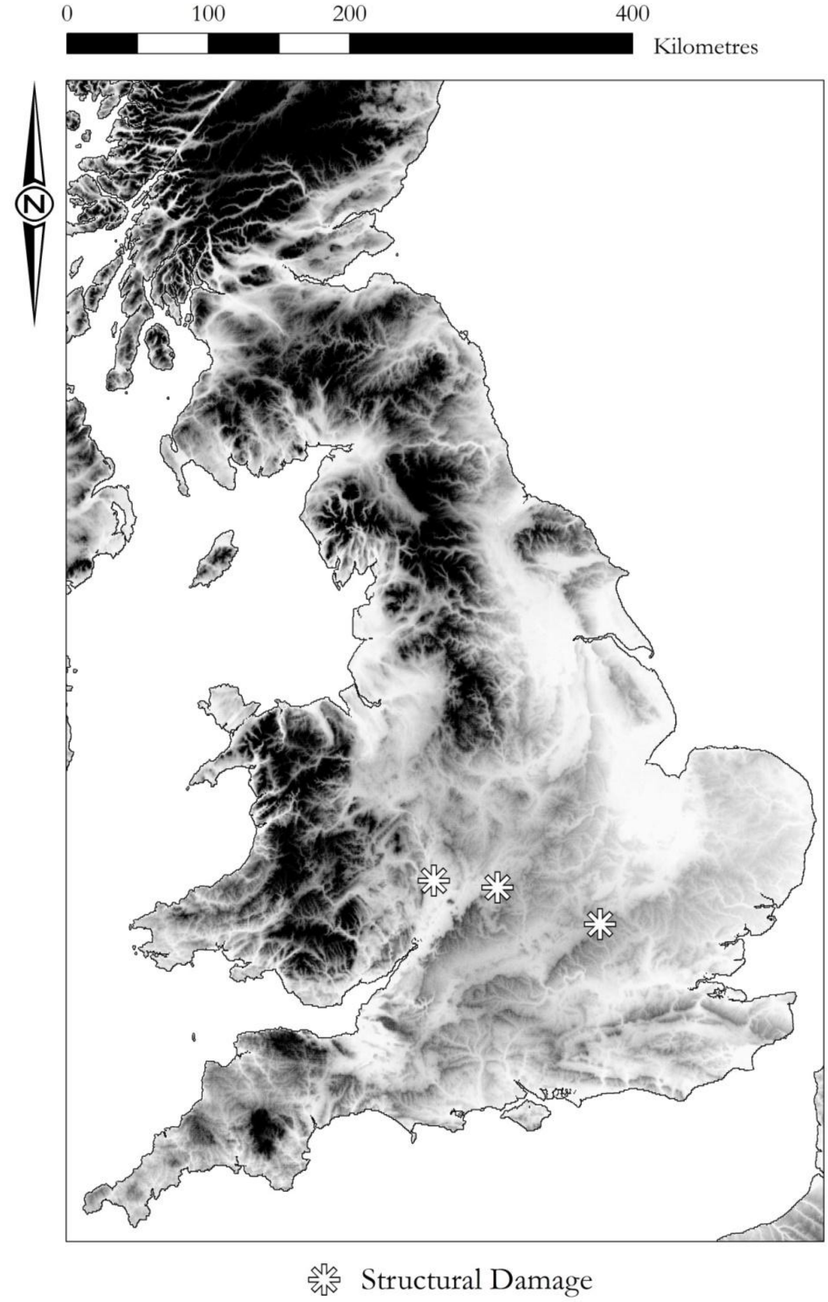

Figure 26 - Map of structural damage recorded occurring in the 1222 storm event (Created by the Author).

Other more localized storm winds are apparent through documentary evidence. An inquisition dated 1314 regarding Winchester Castle for example includes damage to the roof slates by storms as one of the issues for which money was sought to carry out repairs (Lyte 1916: 43). Likewise, the chronicler Thomas Walsingham (Riley 1863: 126) records a storm of 1311 which brought down bell towers in Somerset at Modeford (Mudford) and Gaveltone (Yeovilton). The church at Mudford was subsequently completely rebuilt in the perpendicular style in the late 14th or early 15th centuries (Pevsner 1958: 251) while at Yeovilton the tower was rebuilt in 1486 (Pevsner 1958: 357-358), in both cases obscuring the structural evidence but perhaps also indicative of long recovery periods in these rural parishes. In 1412 a strong wind blew down the bell tower of the church at Cawston, Norfolk (Cozens-Hardy 1952: 339). Heraldic evidence at the base of the tower (wall mounted shields pre-dating 1412) suggest the collapse only affected the top portion of the tower indicating only the top portion was affected by the storm (CVMA 2010). Repairs were however not fully accomplished 71 years later in 1483 when 10 marks were granted to cover the costs of a new bell (Cattermole and Cotton 1983: 243), again highlighting the long term impacts of such catastrophes on small rural communities.

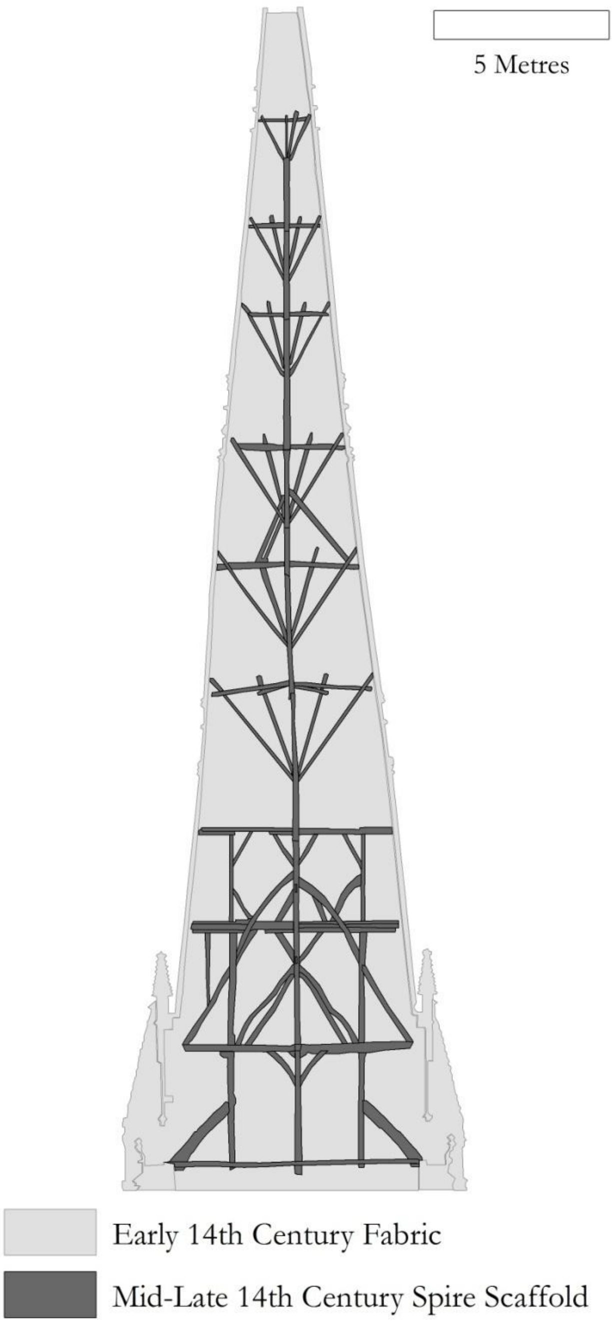

Figure 27 – The internal scaffolding at Salisbury Cathedral inserted following the event of 1362 (Redrawn from Miles et al. 2004: 51, Fig. 6)

One of the storms of greatest intensity from the period occurred in January 1362 as a result of a strong wind from the southwest. This storm is known as both the Second Marcellus Flood and the Grote Mandrenke (great drowning) in the Low Countries where a storm surge resulted in devastating flooding (Meier 2013: 99-100). It fits into a wider series of severe storms which have affected the south of England with comparable events in 1662, 1703, 1987 (Rowe 1988). The storm's effects in Britain were recorded in many different forms including, as discussed above, the poem Piers Plowman (Bloomfield 1962: 114) as well as in the Annals of the Franciscans at King's Lynn (Gransden 1957: 275) and on a graffito in St Mary's Church, Ashwell, Herts. (fig. 27). The *Annales de Bermundeseia* describes "intense and terrible winds throughout the whole of England prostrating churches, towers and many buildings, particularly in the east of England" (Luard 1866: 477). Damage was felt in Salisbury, London, St Albans, Bury St Edmunds, and in Norwich (Lamb 1991: 17; fig. 28). At Salisbury the belfry, which is no longer extant, and up to 9m of the spire were damaged (Miles et al. 2004: 21). In order to secure financial resources to fund repairs, the Bishop and chapter turned to the Pope for assistance in 1363 (Bliss 1896: 463) and this money may have been spent installing internal timber scaffolding as bracing against future storms in the spire (fig. 26). This interpretation is based on the felling dates of the timbers from the spire scaffolding, dated using dendrochronology to 1344-1376. This post-dates the construction of the spire (1310-1330) by at least 10 years and meshes well with the date of the storm (Miles *et al.* 2004: 20). In London the windstorm brought down the steeple of the house of the Austin Friars at Broad Street which was subsequently repaired, although this replacement was taken down in the 17th century (Hugo 1864: 9, 17-18). At St Albans Abbey the gatehouse was heavily damaged by the storm (Niblett and Thompson 2005: 254). Abbot Thomas de la Mare constructed a new gatehouse with a strong lead roof on the site of the almonry, which had presumably also been damaged in the storm (Riley 1869: 387). Re-used 13th century ribs in the vaulting of one of the ground floor chambers of de la Mare's gatehouse probably came originally from the old gatehouse and almonry and are the only known material remains of these structures (RCHAME 1982: 31). The mention of the lead roof in the documentary sources could indicate that the previous roof had fared especially badly in the storm event and the new roof was intended to be more resilient. A proclamation by the Abbot also forbade roof tilers from increasing their prices from pre-storm levels in response to the increased demand caused by the destruction of the storm (Riley 1869: 46-47). While damage was felt at Bury St Edmunds, as the prior had to manage repairs (Rouse 2004), the fact this goes unmentioned in other sources may suggest the damage was not particularly severe. It is unclear whether the central tower had been fully rebuilt by this time after the collapse in 1210 as there is no date to the account of rebuilding by John Lavenham (James 1895: 167-168). At Norwich Cathedral however, structural damage attests to the severe destruction caused by the storm. The spire was blown in on top of the presbytery destroying both the roof and the Romanesque clerestory. Reconstruction work in the new gothic style took place between 1364 and 1386 but the new spire did not last for much longer as it was again destroyed when it was ignited by lightning in 1463 (Woodman 1996: 179, 192). Another possible candidate may be St John's Abbey, Colchester, as in 1363 a letter from the Papacy records the fact that the abbey church had been damaged by storm, flood and fire (Bliss 1896: 444) although more concrete evidence is lacking and the structural remains were largely destroyed as a result of the Dissolution and the English Civil War.

Figure 28 – An extract of the medieval graffiti from St Mary's Church, Ashwell, Herts., describing the storm of 1362. Roughly translated the graffito reads: "In the end a mighty wind in this year [on St] Maur's [day] thunders in the world 1361". Note: January 1361 in the medieval calendar corresponds to January 1362 in the modern style (Redrawn by the author).

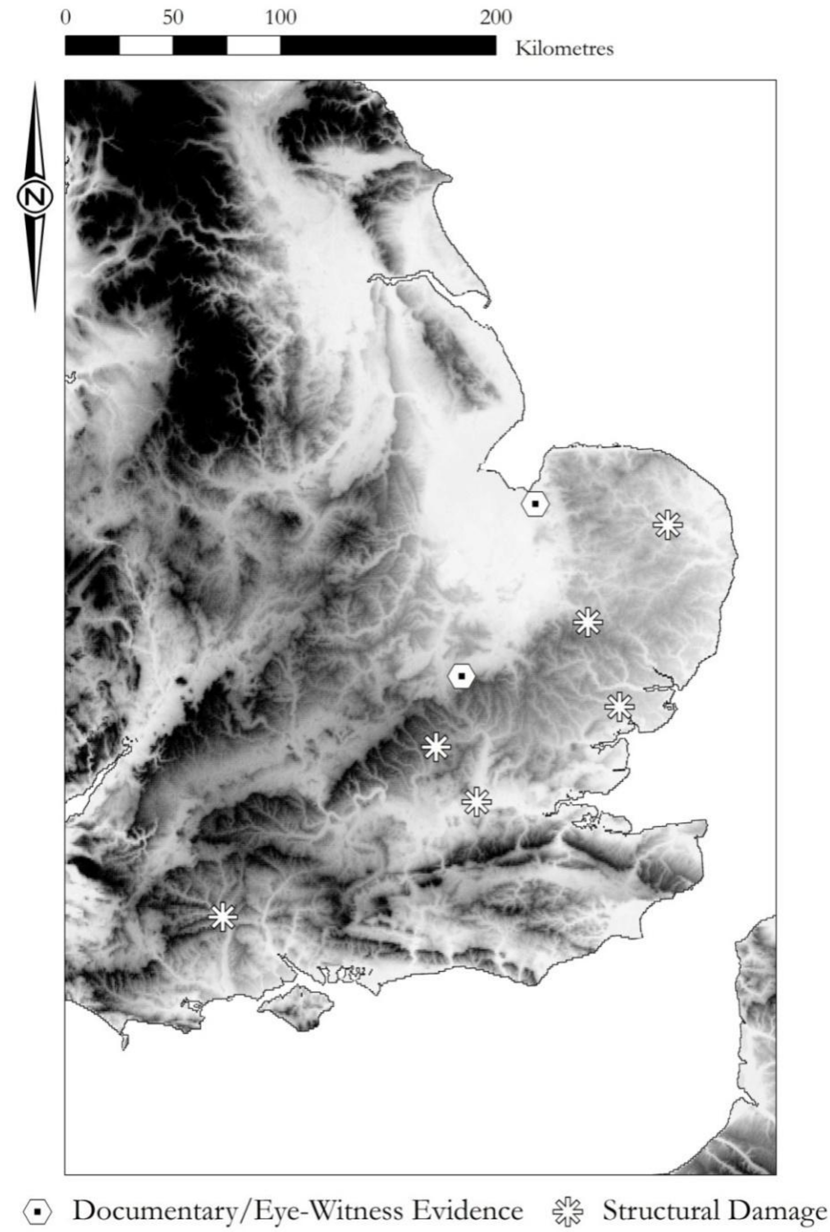

Figure 29 - Map of the documentary evidence and structural damage from the 1362 storm event (Created by the Author).

5.3 Mitigation

Practical measures to reduce damage in storm events are likely to have been largely too ephemeral to have left any lasting imprint in the archaeological record. Historical evidence may attest to some attempt to mitigate damage to windmills as the damage wrought by strong winds could be minimised if the wind-catching canvas could be removed. To do this, brakes were required to bring the windmill to a halt. Historical evidence attests to windmill brakes from the late 14th century in the Low Countries although evidence for contemporary British windmill brakes is inconclusive (Langdon 2004: 123-124).

There is no practical way to halt a windstorm. This however did not prevent medieval populations from trying. Calling on particular saints or God for assistance was a common method of accruing protection which took many forms. An extreme wind at Burton, Staffs., documented in the *Life and Miracles of St Modwenna* illustrates one of the methods in which saintly power could put an end to a storm:

"*We have seen on one occasion at Burton a gale greater than we have ever witnessed, with winds so strong that the waves threatened to shatter the glass and to throw the water from its course at any moment and everything threatened to cast down the monastery in ruin. As soon as the shrine of the holy virgin was placed on the ground, as if the saint was prostrating herself and humbling herself before the Lord on behalf of the church, all that wild storm abated immediately in a wonderful manner and grew calm without a moment's delay* (Bartlett 2002: 211)."

Similarly, the guidelines of Abbot William of Hirsau, from the late 11th century, proscribe that in the event of a storm the sacristan should bring out and set up the processional cross along with saintly relics and holy water at the side of the monastery's cloister nearest to the approaching storm (Herrgott 1726: 524). This is echoed by Jacobus de Voragine who elaborates that the cross must be brought out so that the demons driving the storm can see the symbol of Christ which will cause them to flee in terror, thus preventing the onset of the storm (Caxton 1900: 105). A resemblance to this practice can also be seen in a story retold by Gregory of Tours in which a 'whirlwind' that was fanning the flames of a fire in Le Mans, France, was brought to an end along with the conflagration when the Bishop, Victorius, made the sign of the cross against it (Van Dam 1988b: 62). As storms inevitably subside, it comes as no surprise that this sometimes occurred soon after people had carried out a ritual which was of significance to them and it is these events which must have appeared miraculous and were written down and remembered. For the medieval mind this physical reinforcement of the power wielded by the saints in the physical world would have increased the renown of particular cults and the likelihood of people resorting to them in times of crisis and hardship.

This would have led to religious sites, such as chapels and parish churches, becoming focal points in bringing an end to a particularly bad storm. It has been suggested that religious sites situated in areas affected by a natural hazards were important in accruing communal protection (Meier 2005: 278). This may have been true of windstorms, perhaps most overtly in Britain at Cowrie, Aberdeenshire, where a chapel in an exposed coastal location was dedicated to St Mary of the Storms in 1296 (Geddes 2001: 17).

It is likely from the dedication that this chapel played a role in averting storms reaching the community, perhaps with prayers being said when storm clouds were sighted on the horizon as occurred at the chapel of St Blaise at Subiaco, Italy (Roth 1915: 7). More generally, it is probably true that lay people turned to a saintly protector, perhaps their local patron saint, when an impending storm approached.

The ubiquity of trusting in the power of God or the saints in a storm can be seen in the foundation myths of some monastic houses. Hailes Abbey, Glos., for example was founded in 1246 when Richard, Earl of Cornwall found himself at sea in a terrible storm and vowed that he would found a monastery if he survived (Page 1907: 96). Similarly, Vale Royal Abbey, Ches., apparently owed its foundation to a vow made by Edward I in a storm on his return from the Holy Land. The date of the first charter however, 1270, is from before he set out on crusade perhaps suggesting rather that the foundation was intended to protect him on his journey (Denton 1992: 124). Sailors at sea were at particular risk from storms and dominate accounts of miracles and saintly intercession in the face of meteorological hazards. When the Pope canonised John of Bridlington in 1401 for example, he enumerated a number of miracles attributed to the new saint, one of which was walking on water out to the rescue of several men in a rowing boat who were caught in a storm (Bliss and Tamlow 1904: 458). Storms could also be mitigated through ritual use of artefacts, it was common practice, for instance, when caught in a tempest to fold a penny and make a vow to a saint who would then cause the storm to clear. Duffy (1992: 184) views this as a 'contract' between supplicant and saint which can be seen in many miracle accounts. This is illustrated by one story in which sailors at sea in a storm beseeched many saints for deliverance but their prayers were only answered after all the sailors had folded coins while invoking Saint Wulfstan (Finucane 1977: 94). The folding of coins was not exclusively employed for the mitigation of severe weather, also providing benefits such as good luck or cures from illness, but their widespread distribution, comprising almost 1 in 100 of all coin finds, demonstrates the general acceptance of their efficacy (Kelleher 2011: 1499). Another method by which this 'contract' with the saint could be paid was by leaving some of the threatened ship's cargo at the shrine of the saint (Finucane 1995: 96-98). Quelling storms using similar means has a long history as demonstrated by a miracle of Saint Aidan retold by Bede in which, between 642 and 645, Aidan prophesied that a storm would befall a priest named Utta on his return journey from Kent and gave him a vial of oil which Utta was to pour into the sea. When the storm arrived and the oil was administered, calm weather returned as predicted (Sellar 1907: 166-167). The focus on storms at sea in accounts of saintly miracles is however, viewed by Hanska (2002: 97), following the work of André Vauchez, as a hagiographical convention based on chroniclers preference for saintly miracles to match stories from the Bible rather than because meteorological hazards more frequently provoked calls for saintly intercession at sea than in other situations. It is therefore likely that all of the above methods were similarly employed against storms in terrestrial settings.

5.4 Protection

Just as the saints could be relied upon in the moment of disaster, they were also called upon at regular intervals to prevent and give protection from storms. This, again in relation to sailors and ships, can be seen through votive offerings which are recorded being left at shrines which commonly included candles with wicks measured to the length of the ship, miniature wax or silver ships or anchors (Finucane 1995: 95, 98). A relationship between graffiti depicting ships in churches has also been postulated in connection to chapels of St Nicholas who was regarded as a protector of mariners. Blakeney church, Norfolk, for example contains ship graffiti covering a period of two hundred years focused on a pillar opposite a niche that was dedicated to St Nicholas and a comparable pattern is found at St Thomas', Winchelsea, East Sussex (Champion 2013: 112-113). The distribution of these carvings signals that they were more than a coastal community's artistic inscriptions, in fact representing material manifestations of prayers for safety at sea or in thanks for a safe return. Although less evidence exists, it is probable that offerings and prayers were also commonly made in relation to storms on land, especially in connection to agriculture, for example vegetation, usually yew, box or willow, blessed as part of the Palm Sunday procession were believed to hold apotropaic powers (Duffy 1992: 23), including the ability to protect against storms (Wilson 2000: 33), and were often kept within the home or applied to the fields to provide protection (fig. 29). Widespread finds of *ampullae* from rural agricultural land with use-wear marks suggesting ritual deposition (Anderson 2010: 197-198) also indicate that these too may have offered protection from natural hazards such as windstorms.

While insurance is the chief method by which people shield themselves from windstorm damage today, the concept of insurance was largely unknown in the medieval world. The first recognisable insurance contracts appeared in mid-14th century Italy covering shipping (Nelli 1972), although informal networks would have permitted pooling of resources and borrowing in medieval Britain (Bekar 2000) and this was no doubt important in times of hardship. Physical protection can be obtained to a certain degree by using barriers to prevent the full force of the wind from reaching vulnerable buildings and this was clearly understood in medieval Britain as trees were frequently planted or maintained in churchyards to insulate church buildings from storm damage. A statute believed to date from the reign of Edward I describes this practice: "trees oftentimes are planted to keep away the force of the wind for hurting of the churches (Wood 1870: 131)". This statute also specifies that in the event that a church was damaged the wood from these trees in the churchyard should be used to repair the building. Trees were also used as wind-shields for orchards by farmers who feared stormy weather as it could rapidly destroy their livelihoods (Zadoks 2013: 117, 135). Similarly, the Byzantine agricultural manual *Geoponica*, describes how lentils naturally resisted strong winds and using them as a companion crop could protect other more susceptible crops (Needham 1704: 48; Zadoks 2013: 136). Whether or not British farmers used lentils or other crops in this way is unknown however.

Figure 30 – An olive branch tied to a balcony balustrade in Aragon, Spain, where the belief that vegetation blessed on Palm Sunday protects homes from storms is still practiced (Photo taken by the author).

5.5 Adaptation

Evidence for medieval adaptation to windstorms is scarce. Some buildings affected by the hazard show identifiable signs of reinforcements and changes in design taken in the rebuilding stage which may have been intended to reduce exposure from high winds in the future. This can be seen at the south western tower at Chichester which was reinforced with buttressing, the redesign of the gate at St Albans and the strengthening internal scaffolding at Salisbury. At the other end of the scale some rural churches had to wait close to a century for funds to become available to repair damage, and this void in time probably meant deliberate adaptations to prevent future damage were forgotten. More ephemerally, medieval architecture was influenced by a desire to build resilience to the wind. This can be seen both in the orientation of structures to shield entrances from the prevailing winds as in Pembridge, Herefs. (James 2003), as well as in church architecture where the evolution from pyramidal church spires for example to polygonal and conical forms may have been driven by their reduced exposure to stress in high winds which made them more resistant to storms (Baker 2007: 846-847).

5.6 Summary

From the discussion above it can be seen that, just as today, storms caused large scale disasters across medieval Britain. Although archaeological evidence for the hazard is limited, major events such as the 1362 windstorm have left a material signature traceable through analysis of surviving medieval buildings set alongside documentary evidence from the period. The experience of storm events in the Middle Ages differed markedly from today with no forecasting to give an idea of what could be expected to allow preparations and precautions and no insurance to protect property and investments from rapid destruction. Instead, medieval populations were forced to rely chiefly on the protection and intercession of the saints, increasing their chance of gaining successful protection by participation in a variety of rituals, pledges and prayers.

6. Discussion

As the previous chapters demonstrate, medieval society was beset by the consequences of meteorological hazards at regular intervals. Two main lines of enquiry can be drawn from the discussion of the hazards above. Firstly, the impact that these hazards exerted on medieval populations and secondly, the responses which they adopted in order to mitigate loss, defend against recurrent hazards, and adapt to new conditions. In addition, whether the picture this research creates corresponds to previously proposed models to distinguish between 'industrial' and 'pre-industrial' societies will be assessed.

6.1 Impact

Northern Europe is vulnerable to meteorological hazards, with flooding and windstorms among the hazards posing the greatest risk to modern society (WEF 2014: 16). The archaeological and historical evidence prove that this was true throughout the medieval period as Britain frequently experienced harsh conditions. Extreme examples such as the inundations of aeolian sand at Forvie, Meols and Kenfig demonstrate that meteorological conditions sometimes permanently drove populations from their homes, forcing them to move to safer locations. Lightning induced fires which burned down cathedrals such as Norwich, Glasgow and Durham, as well as monastic houses such as Strata Florida, St Mary's Abbey, York and Milton Abbey also had far-reaching consequences, often causing damage which was still being repaired over half a century later. Similarly, the windstorm of 1362 was an event that greatly affected communities, unroofing homes, severely damaging important structures and adding to the sense of dread that surrounded a resurgence of plague (Horrox 1994: 85-86). Its memorial in documentary sources (Hingeston 1858: 221) as well as in graffiti (fig. 27) proves that it severely affected the people who lived through it. While these extreme events were rare, other more recurrent hazards could have similarly devastating consequences. While people living in flood prone areas, where inundations occurred on a more or less annual basis, were relatively well adapted to the hazard, sudden and extreme conditions displaced populations, disrupted movement – especially when bridges were washed away - and wider economic activity. Less extreme sand inundations exerted considerable stress on populations by reducing agricultural yields and routine storms and lightning activity frequently threatened individual livelihoods, for example in the destruction of crops, homes or important structures such as windmills. While it is unhelpful to exaggerate the effect of natural hazards on past societies, the fact remains that these events, then as today, occurred relatively often and when they did they often caused great damage.

6.12 Population

Natural hazards only become disasters when they come into contact with human populations. As natural hazards do not occur uniformly across the surface of the Earth, the risk faced by medieval populations can only be assessed if the population density throughout the British Middle Ages can be characterized.

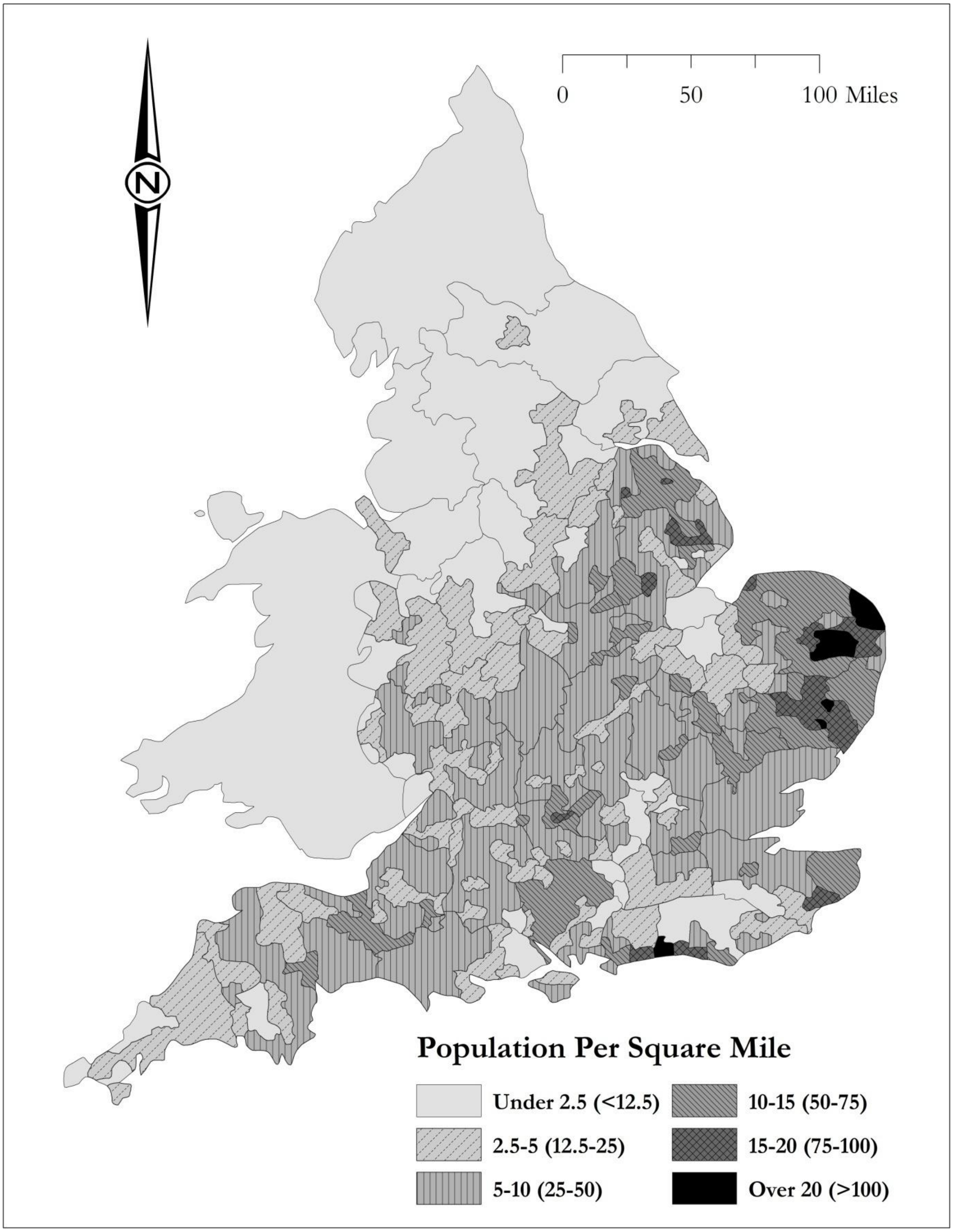

Figure 31 – Population per Sq Mile in England in 1086. The first value corresponds to recorded population while the number within the brackets has been multiplied by 5 to give a more accurate representation of actual population as recommended by Darby (1977: 92) (Redrawn by the author from Darby 1977: 91).

Figure 32 - Population per Sq Mile in England in 1290. Compiled from a variety of tax records including the poll tax of 1377 and the lay subsidy returns of 1290. (Redrawn by the author from Campbell 2008: 929).

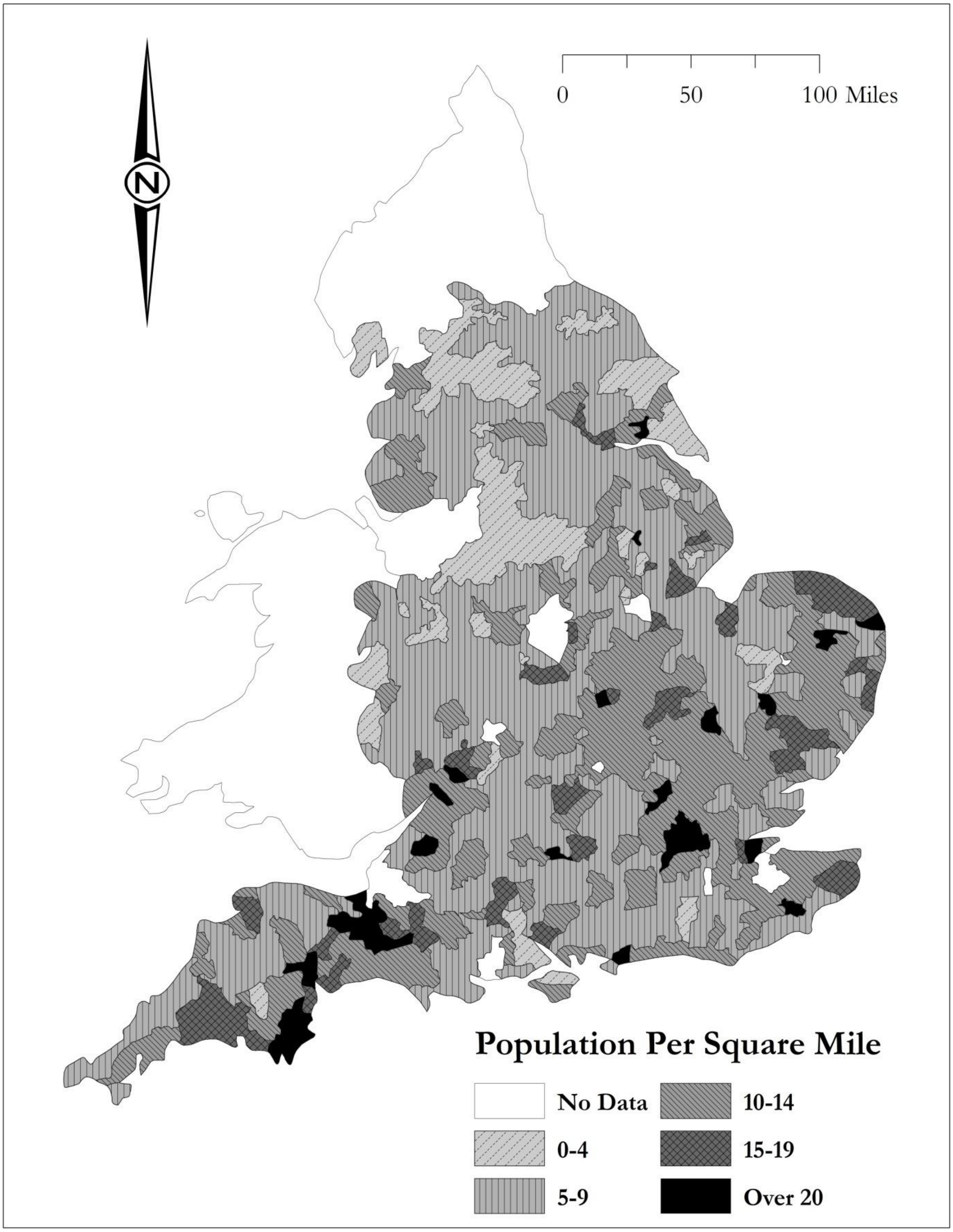

Figure 33 – Recorded population per sq mile in England in 1540 from the lay subsidy surveys of 1524-25 and 1543-45. This map shows only recorded population - the population that paid tax – and so it can only be used to give an indication of relative population spread rather than to give an accurate number of people in a specific area (Redrawn by the author from Sheail 1972: 119).

While it is becoming clear that a simple relationship between population density and vulnerability is non-existent (Reide 2014: 351), it remains the case that denser population in an area affected by a hazard is likely to experience greater losses than would be the case in a more scarcely populated region (Royal Society 2014: 41). Due to a lack of accurate census data, estimating population in the medieval period is a difficult task. Luckily, surviving documentary evidence has allowed fairly reliable reconstructions of population density. The Domesday survey provides data for c. 1086 (Darby 1977: 91), Campbell (2008: 925) has estimated the population at c. 1290 using a variety of taxation records and Sheail's (1972) study of tax records from the 1520s and 1540s provides evidence for population density at this date. These allow three 'time-slices' to be estimated with a good degree of accuracy. The data from 1290 is close to the peak of population over the period before the rapid decline brought on by the various calamities of the 14th century, such as the famine of the 1310s, the Black Death and further outbreaks of plague. Unfortunately, there are many problems particular to each study, for example scribal errors are evident in the Domesday survey, for example the number 16 in one version of the text was rendered as 116 in another (Darby 1977: 58). In addition, because the necessary volume of documentary data only exists for England, insufficient data exists to accurately estimate the population of Scotland and Wales, although they probably had similar population densities to comparable parts of England such as Northumberland, County Durham, Westmoreland, Cumbria, Yorkshire and Lancashire (Campbell 2008: 930). As a result these maps do not present precise data, only estimates of population density throughout the medieval period.

The resulting maps from these three sources of data (figs. 30, 31 and 32) create an impression of the spread of population at intervals of between c. 200-250 years which can be interpreted in relation to the hazards considered above. Coastal communities were obviously the ones which were most vulnerable to wind-blown sand but the locations where this occurred were almost all in areas of low-density. The picture provided by these maps lacks the resolution to assess the risk from wind-blown sand at particular sites, and indeed many of the events took place in Wales and Scotland for which we have limited information. The archaeological evidence demonstrates that the hazard primarily affected areas of human settlement, where population density would have been of a higher concentration than the 'broad-brush' average densities displayed here. This could mean that more people would have been exposed than the maps initially seem to suggest. Flooding is a hazard across Britain, although an issue which is hugely dependent on local conditions and, in common with wind-blown sand, the population density presented here is probably not detailed enough to permit any meaningful conclusions. It might be noted however, that the relatively high density of population around the east coast of England in Norfolk, Suffolk and Kent would have placed those communities at particularly high risk from marine inundations. Lightning strikes do not occur uniformly across the surface of the Earth, and on average in the present, lightning activity in Britain is concentrated in the south and east. This pattern correlates well with medieval lightning strikes (fig. 18) suggesting this pattern has not changed significantly. Population across all three of the 'time-slices' was concentrated in this area, although it appears to have shifted from a particular concentration in the mid-south east of England in c. 1086 and to a diminishing extent in c. 1290 to a more even spread, with obvious urban areas, in 1520/1540. Throughout the period therefore, the south and east had both a relatively high population and increased occurrence of lightning which would have made this area especially vulnerable. Windstorms could theoretically affect any region in Britain, although their impact is heavily related to the local topography, but the medieval examples for which we have the most archaeological evidence appear to have chiefly affected from the Midlands down to the southern coast of England, with evidence for a limited number of events on the east coast of Scotland. The mid-south of England, as the most populous area of Britain, therefore represented the area of greatest risk in relation to windstorm damage, and by comparing the damage patterns of the storms of 1210 (fig. 23), 1222 (fig. 25) and 1362 (fig. 28) with the closest population map, that of 1290, it is clear that these storms, especially the major 1362 event, must have caused severe and widespread damage far in excess of the limited evidence preserved in either the historical or archaeological records. It must be acknowledged that there is a circularity in this reasoning however, as increased archaeological and historical evidence for hazards in regions of higher population could be related to the higher density of settlement, which meant a hazard was more likely to leave an imprint in the archaeological and documentary record than would have been the case had it occurred in an area of low population density, such as the Scottish Highlands.

6.11 Climatic Setting

The LIA is thought to have brought an increase in storminess over northern Europe from c. 1300 until the post-medieval period (Meeker and Mayewski 2002; De Kraker 1999; Clarke and Rendell 2011). Widespread evidence from across northern Europe attests to increased sand movement in the LIA compared to the preceding MWP. In the UK, such evidence has been found along the coasts of Northumberland, Northern Ireland, the Orkney Islands and the Hebrides (Wilson *et al.* 2001; Wilson *et al.* 2004; Walsh 1993: 145; Sommerville 2003: 350; Dawson *et al.* 2004; Dawson *et al.* 2011). While wind-blown sand was undoubtedly affected by these climatic changes, it is less clear what the impact of the transition from the MWP to the LIA was for other hazards. When the individual events considered in this study[19] are examined together against time (fig. 33), while wind-blown sand events experienced an obvious increase which is contemporaneous with the onset of the LIA, the clustering of the other hazards does not display an obvious rise in frequency. While lightning and windstorm activity are high from c. 1300-1450, they were similarly active for at least the preceding century. That being the case, the two events for which we have the largest volume of evidence, and are thus likely to have been the most severe, the 1362 windstorm and the thunderstorm of 1444 both occurred after the onset of the LIA. Set against the wind-blown sand evidence, this may indicate that during the LIA meteorological hazards did not occur with any discernible increase in frequency but when they did occur they were likely to be of greater intensity, a conclusion which finds support in the work of (Trouet *et al.* 2012) which found that the LIA was probably characterized by more severe rather than more frequent storms.

[19] Flooding was not included because the volume of data placed it outside the scope of this study.

There are problems with this approach however. Whereas sites affected by wind-blown sand are dated mainly through archaeological evidence, the evidence for lightning and windstorm activity are informed and dated using the historical record. As a result, the evidence for lightning and windstorm activity is biased by a number of factors: what people at the time chose to document, how accurately this occurred and what historical texts have survived into the present. In addition, while most of the events can be confirmed through standing building evidence, it is not normally possible to accurately check the date given in the historical texts, and with dating a common area for confusion (Brázdil *et al.* 2005: 373-374) due to calendrical differences, scribal errors and vague descriptions, this could introduce errors into the picture presented in fig. 33. The accuracy of this picture could further be improved and checked with the addition of more historical and archaeological evidence, perhaps from surrounding regions and countries such as Ireland, Scandinavia, Germany and the Netherlands.

Furthermore, to allow longer-term comparisons, the record should ideally be extended further back in time. This is impossible with hazards such as lightning and windstorms as the historical record becomes increasingly patchy and unreliable prior to the Norman Conquest and would only provide isolated and questionable data for the early medieval and Roman periods. With wind-blown sand however, a hazard which can be tracked using primarily archaeological and palaeo-environmental data, it would be possible to extend the record further back into earlier periods allowing a greater understanding of any climatic forcing affecting hazards. The lack of historical records to inform on land-use practices and provide accurate dating in these periods, however, would be a considerable issue.

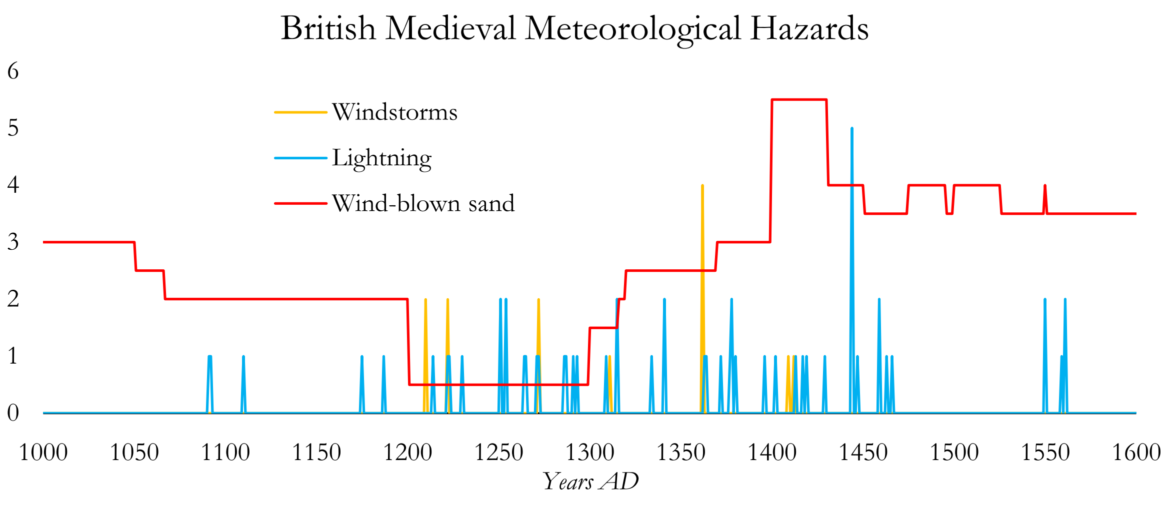

Figure 34 – British medieval meteorological hazards with archaeological evidence. Vertical axis indicates the number of unique archaeological indicators for each event. While lightning and windstorms are dated using documentary sources, providing exact years, wind-blown sand is dated through a number of archaeological techniques, usually providing a range of dates. To make the data more comparable, the number of wind-blown sand events has been divided by two.

While the climatic changes of the LIA may have increased the intensity of meteorological hazards, another factor which negatively affected vulnerability were the concomitant social changes which came in the wake of the Black Death. This is most certain in the case of wind-blown sand, which in many locations around Britain influenced the uptake of unsustainable land use practices such as rabbiting, overgrazing and the stripping of vegetation. The Black Death also affected the ability of threatened communities to protect against floods with reduced manpower available to maintain dykes and other flood defences. Therefore, although the LIA may have exerted considerable pressure on populations from c. 1300 onward, the social changes of the Black Death and the crises of the 14th century placed additional stress on vulnerable settlements. This combination of climatic and social factors meant that not only were medieval populations met with increasingly severe hazards at a time when they were least prepared to deal with them but in some instances this increase in pressure also drove them to adopt land use practices which increased their own vulnerability. Together, these factors must have made meteorological hazards especially damaging during this period.

6.2 Responses

6.21 Material Measures

Attempting to curb the disastrous potential of a natural hazard to prevent further losses once it had started to occur was the most obvious time for medieval populations to take action. Invariably at this stage however, it was also too late to prevent most of the damage that hazards held the potential to unleash. Communities were ultimately helpless in the face of a windstorm with no material means to halt a storm and stop damage occurring. Similarly, once aeolian sand had begun to move it could not be slowed or diverted as it is driven by wind activity. In a flood there was little that could be done practically, with the best option to evacuate to higher ground and wait for flood waters to recede. Reike (2014: 351) suggests that population displacement, temporary and permanent, is one of the major ways in which individuals and communities respond to perceived hazards and this can certainly be demonstrated for wind-blown sand and flooding in medieval Britain. Lightning damage could be mitigated if the fire could be brought under control but medieval methods were rudimentary, often leading to blazes burning out of control. Due to the fact that damage from all of these hazards was fundamentally beyond the means of medieval populations to prevent through practical measures, other than by relocating to areas of safety, religious responses were the only methods which could be relied upon.

When it came to ensuring buildings, settlements and agricultural land were protected from recurrent natural hazards in the interim period between events, there was more that could be done in the material world. For action to be taken however, there had to be a perception of risk from future events which, in turn, required the survival of communal memory of past severe events. The archaeological record attests to protective steps instigated to prevent future damage for most of the hazards considered. For example, although they do not appear to have been employed much against wind-blown sand in Britain, barriers could be erected to temporally control the advancement of sand. In two cases, Perranzabuloe and Merthyr Mawr, rivers performed this role, protecting sites from sand movement. There are numerous examples of physical reactions taken to prevent flooding including dykes against sudden torrents from surrounding uplands, such as those at Byland Abbey, or from nearby rivers as at West Cotton and Thornton Abbey. Floor levels were raised following floods at Bordesley Abbey, St Bartholomew's Hospital, Gloucester and Bury St Edmunds and barriers were constructed against floods at Newcastle-upon-Tyne. The extent to which communities reacted to worsening environmental conditions has been the subject of intense debate, with the impact of climatic deterioration on DMVs a particularly controversial topic. It is certain that many monastic communities re-located because of problems with flooding but whether any villages such as Barton Blount were abandoned as a direct result of flooding and climatic decline remains unproven and contentious. In the case of lightning, due to its seemingly unpredictable and indiscriminate nature, there was little that could be done other than ensuring that buildings were as fireproof as possible - a concern which was definitely acted upon through legislation in towns such as London (Riley 1860: 86-88). Similarly, material protection from windstorms was mainly limited to making sure structures were strong enough to resist high wind speeds, although there appears to have been some appreciation for trees as wind breaks to prevent the full force of storms hitting buildings (Wood 1870: 131). What these methods have in common is that they were all comparatively costly, time consuming and still far from guaranteed to provide adequate protection. Spiritual protection, which could be gained through many routes and applied in many forms, offered an additional approach, which could complement material strategies, in preventing natural hazards affecting individuals and communities.

6.22 Religious Responses

The basic causes and effects of some natural hazards are easier to understand without specialist knowledge than others. High-rainfall for example, one of the most common causes of flooding, produces an observable rise in water level which can inundate areas that were formerly high and dry. This is the conclusion drawn by Rohr (2005: 74; 82), in connection to late-medieval Austrian floods, who states: "Floods did not need a supernatural explanation, because they were obviously part of nature". As it was relatively easy to understand how protection could be achieved through the construction of dykes or the raising of floor levels therefore, these became common responses. In comparison, without an appreciation of the nature of electricity, protecting a building from flashes of lightning is an impossible undertaking and without accurate weather forecasting at a global scale there is no way to anticipate the arrival of an extreme windstorm or strong winds able to cause inundation by aeolian sand. This lack of understanding necessary to appreciate the multitude of factors which influenced meteorological hazards, the reasons they occurred, and in some cases how they could be prevented, fostered the interpretation that these events were caused by the divine. For the majority, natural hazards were the result of heavenly influence in the physical world. This was reinforced through Church doctrine with episodes from the Bible, such as Noah's Flood (Genesis 7: 10-24), providing an example, albeit an extreme one, of God's ability to bring about drastic changes in the natural world. In addition natural hazards featured prominently in tales of the lives of the saints, often in such a way that it was clear the events had occurred due to divine influence. It is therefore unsurprising that medieval Christians turned to religion as one of the surest sources of help in the face of natural hazards. In *Sociology of Religion,* the sociologist Max Weber regards bringing about change in the material world as one of the prime reasons for behaviour motivated by religion (Weber 1920: A.1.b). Medieval spiritual responses to natural disasters certainly fit into this model as they were believed to either provide protection from hazards or speed the return of natural conditions to their accepted norms. These spiritual responses took a number of forms including processions, prayer and personal rituals as well as the protective powers of artefacts and their ritual deposition.

Processions became an accepted form of defence against natural hazards from an early date. Rogation processions evolved out of Roman pagan practice to protect agricultural produce (Hanska 2002: 35) although early Christian archetypes became well known and offered examples of what to do in a calamity. In the 5th century for example, Bishop Mamertus of Vienne held fasting and prayers to combat earthquakes and heavenly fire in his diocese (Caxton 1900: 103) and in AD 590, Gregory the Great, just before assuming the role of Pope following the death of Pope Pelagius II due to plague, led a procession through Rome in which the participants repeated prayers for the plague and floods of the Tiber to subside (Brehaut 1916: 227-228). Rogation processions evolved, following these early models, to become community processions through the fields of the parish held on the 25th of April and in the week before the feast of Ascension. This was an opportunity for parishioners to beseech God and the saints for protection throughout the year from all manner of calamities such as warfare, epidemics and natural disasters. It has been noted in relation to France that these rogation ceremonies almost always included areas that were likely to flood such as marshes (Sluhovsky 1998: 86; Guillerme 1983: 21-26) and fast rising rivers. To mitigate extreme events, as in the early examples, processions were held outside of this annual cycle as in Paris in 1206 when the saintly relics of Saint Genevieve were processed through the streets to lower the flood waters of the Seine (Luchaire 1912: 2-3). Similarly, a procession of the Holy Sacrament, a common practice especially in France and Germany (Mackay 2006: 420), was held in Cologne in 1374 to bring an end to flooding on the Rhine (Snoek 1995: 273). Floods were not the only calamity against which processions were marshalled, with one being held for protection from earthquakes in Girona, Spain, in the 15th century (Snoek 1995: 273). The inclusion of relics or the Holy Sacrament in a procession could increase its efficacy, for example the reliquary of Saint Werburga was paraded through the streets of Chester in 1180 to prevent the spread of a fire (Wall 1905: 61) as were the relics of St Thomas Cantilupe in Hereford in 1349 to mitigate the spread of the Black Death (Wall 1905: 143).

From the evidence discussed in previous chapters it is clear that processions formed a major element of medieval European responses to natural hazards. In Britain, the clearest evidence for this can be found in relation to flooding with documentary evidence suggesting this was a common practice (Powicke and Cheney 1964: 1086). This however does not necessarily mean that processions were not employed against the other hazards as it could be that this study has missed evidence, that the evidence does not survive or that protection against these hazards was usually combined into 'catch-all' processions such as those held on rogation days, as suggested by Hanska (2002: 68), which were routine and not normally documented. This was almost certainly the case with universal hazards such as storms and lightning but by comparison, wind-blown sand affected only a limited area so it is unsurprising that no record of a procession specifically intended to prevent sand inundation has yet been discovered.

Processions offered communal mitigation and protection but personal assistance for individuals came through direct supplication to the saints. To medieval Christians this would have been an obvious reaction in times of need because so many of the lives of the saints were connected to people receiving their help, often in connection to natural hazards. One such example can be found among the miracles of Thomas Becket in which a man who was struck by lightning which made him lose his mind was healed after drinking water in which the clothes of the saint had been dipped (Robertson 1875: 404-406). Finucane's (1995: 111) study of miracle accounts in England demonstrated that healing miracles were the most common type obtained through saintly intercession, but 10% of those recorded were 'non-healing' miracles which included assistance such as safety from a flood or protection in a storm. Local patron saints were also common providers of spiritual protection or intercession on the behalf of individuals or the community. This has been noted against aeolian sand at Y Ferwig, Ceredigon, where Saint Pedrog was called on for assistance against the sand but the protection offered by patron saints was not limited to particular hazards and would have encompassed natural hazards, human enemies, and epidemics along with other ailments (Wilson 1983: 24).

Particular saints were revered as especially efficacious against particular hazards. As discussed above, Saint Barbara was thought to offer special protection against lightning, Saint John of Nepomuk was locally revered as a protector against floods in Austria and Bohemia (Rohr 2005: 82) and Saint Blaise was invoked against storms by the villagers of Subiaco, Italy (Roth 1915: 7). Saint Christopher was particularly popular throughout the medieval period because it was believed that by beholding an image of him the viewer was protected from sudden death on that particular day (Pridgeon 2008: 94-95). Sudden death, along with many fates unconnected to natural hazards, would have included death from lightning, drowning or being killed by a falling tree or building debris in a storm. Paintings of St Christopher survive in English parish churches in greater numbers than any other subject (Kinch 2013: 167). These images were most often displayed on the north wall in a church, opposite the entrance, to ensure that anyone that entered would see his image and be protected (Coe 1981: 51), as in the stained glass at All Saints, North Street, York (Pedersen 2000: 38). The relationship between ship graffiti and shrines of St Nicholas (Champion 2013: 112-113) also indicates, at least in south-east England, that this saint was important in protecting mariners at sea but how far this practice spread geographically and whether this protection extended to more general protection from storms is unknown.

The historical record attests to a wide array of further practices and traditions which provided protection from meteorological hazards. For most it is impossible to know how accepted or widespread their practice was but they offer an insight into the diversity of practice throughout the medieval world. For example, protection from hailstorms was obtained in some places by erecting a cross in the fields or by depositing boughs of vegetation, blessed on Palm Sunday (Mackay 2006: 417). Additionally, in common with beliefs connected to St Christopher, John Myrc in 1450 writes in his *Instructions for Parish Priests*, that none shall suffer sudden death on any day in which they have also set eyes upon the sacred host (Peacock 1868: 10). A concern with ensuring protection from natural hazards may even have been a part of many people's daily routines, with an extract from William Aubrey's collection of old folklore describing how shepherds commonly ended their days by drawing a cross in the ashes of the fire and praying to the Lord and Saint Osythe to protect them from "fire, and from water and from all misadventure" (Britten 1881: 29). Comparably, the *Malleus Maleficarum* documents how it was believed that a hailstorm could be brought to an end by throwing the hailstones into a fire while at the same time invoking the Holy Trinity, after this "The Lord's Prayer is added two or three times along with the Hail Mary". If the storm had been caused by sorcery it would then suddenly end after the words "May this storm be put to flight by the words of the Gospel" (Mackay 2006: 419). One document details how it was thought that repeating Paternosters and Aves five times each could, among other benefits, protect one from sudden death, death without the sacraments of the Church and from wicked spirits, pestilence and all evil things (Linnell 1958-61: 125).

Archaeologically most of these rituals are invisible. An exception may be the application of burn marks to structures, usually houses or churches. These have been unambiguously demonstrated to be deliberate applications and interpretations have centred on apotropaic explanations, particularly protection from the devil in the guise of lightning, storms and fire (Lloyd *et al.* 2001: 66-67). Although these are usually found in post-medieval contexts, most frequently dating to the aftermath of the Dissolution (Lloyd *et al.* 2001: 68-69), a number of examples on earlier buildings suggest the practice may also have occurred in the late medieval period (Dean and Hill 2014: 10).

Historically documented beliefs can also be connected to artefacts which are routinely found on archaeological sites. Particular materials were thought to have magical properties and charms or amulets incorporating these materials could transfer them to the wearer. For example, emeralds were believed to prevent the wearer from being struck by lightning or from suffering harm in a storm (Evans and Serjeantson 1933: 40, 85). Where purse-strings could not stretch to real emeralds some may have settled for imitations in coloured glass, believing they could bestow at least some of the protective powers of the genuine material upon the wearer (Standley 2010: 146). Divine protection is also manifested in folded coins, a common archaeological find, which represented a contract between saints and supplicants (Duffy 1992: 184; Kelleher 2011: 1499) for assistance in the material world, such as safety in a storm. According to the French bishop William of Auvergne[20] the wax from Paschal candles, which were made into discs with the *Agnus Dei* imprinted upon them and blessed by the pope, had the power to protect against lightning (Thorndike 1923: 353). These *Agnus Dei* discs were made into jewellery or framed, as in the case of an early 15th century example from Germany (Lightbown 1992: 507), or imitated in other forms to enhance and emulate the protection they could offer. An example of this comes from a 15th century silver pendant found in Gleaston, Cumbria, which bore the *Agnus Dei* symbol on one side and the holy monogram IHS on the other and may have once contained a wax *Agnus Dei* disc or a saintly relic (Enticott 1996: 10; fig. 34). With a similar connection to the Pope, papal *bullae*, lead seals from papal documents, were also believed to hold apotropaic powers and the evidence suggests they were used as

[20] Bishop of Paris from 1228-1249.

amulets within the home (Gilchrist 130-131) which may have offered protection from hazards. They are common finds on medieval sites throughout Britain[21] but to the author's knowledge a detailed study of their find-spot distribution has not yet been undertaken.

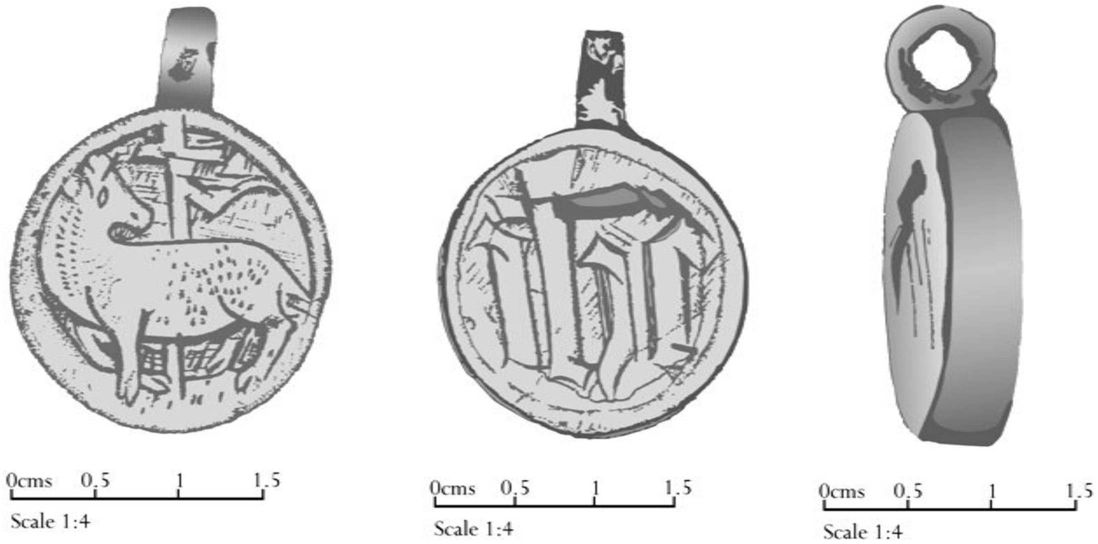

Figure 35 - A 15th Century Pendant bearing a depiction of the Agnus Dei on one side and the sacred monogram, IHS, on the reverse from Gleaston, Cumbria (Redrawn by the author after Enticott 1996: 10).

Ritual depositions were another method by which medieval populations sought to prevent natural hazards affecting them. Archaeological cases in which ritualised depositions may have been intended to avert catastrophe are not rare. Perhaps the foremost natural disaster to be studied by archaeologists, the Thera eruption which is controversially thought to have instigated the decline of the Minoan civilization (Marinatos 1939), bears this out with widespread evidence for ritual depositions of pumice in a variety of different settings as well as human sacrifice. This ritual activity has been interpreted as the practice of a 'crisis cult' which arose as a result of the volcanic eruption (Driessen 2001: 362-363). Comparably, deposition of human skulls surrounding settlements from Bronze Age central Europe have been viewed as communal acts intended to accrue divine protection from flooding (Menotti *et al.* 2014: 466) and Bronze Age hoard and weaponry depositions in England and continental Europe are similarly usually either found within or surrounding bodies of water (Yates and Bradley 2010a; Yates and Bradley 2010b). If these were offerings to a 'water deity' it is not a far stretch to suggest that they would have been believed to control floods and storms. If this was the case, these depositions could have been acts to appease a god or gods in the hope of favourable conditions in the future. Of course, without historical records this conjecture remains only theoretical.

Analogies with related documentary evidence for this type of activity can be found from the British Middle Ages. Metalwork and numismatic hoards may have been deposited in Scottish coastal areas with existing or antecedent Norse links. Due to the dynamic nature of the landscape in these locales, in common with Bronze Age hoards deposited in bodies of water, "it is hard to support the argument that their deposition was purely a 'practical' procedure" (Yates and Bradley 2010a: 66). This makes it

[21] At the time of writing there were 308 medieval *bullae* on the website of the Portable Antiquities Scheme, www.finds.org.

conceivable that their deposition was intended to protect against or mitigate the action of aeolian sand.

There are many other classes of artefact from the medieval period which can be similarly interpreted. On a less spectacular scale, Anderson (2010: 199-200) has shown that the locations of *ampullae* as reported by the Portable Antiquities Scheme, in rural cultivable land, suggest these were purposefully buried in fields rather than lost through carelessness. Documentary evidence exists for the application of holy water to fields (Thomas 1971: 30) and *ampullae*, often contained dust, oil or holy water connected to a saint which made them 'contact relics' (Anderson 2010: 182). Holy water, such as was contained inside *ampullae*, was certainly used against meteorological hazards as documentary evidence discussed in relation to lightning demonstrates (Gairdner and Brodie 1902: 300). The deposition of *ampullae* in fields therefore, possibly as part of rogation processions or as more personal acts, was most likely intended to protect the crops growing in the field not only from meteorological hazards, but disease, pests and marauding armies. Comparably, prehistoric lithics, widely believed to be petrified lightning bolts, were frequently included in homes, churches and fields and were thought to provide protection from storms and lightning (Gilchrist: 2012: 247).

A similar pattern can be seen in the curation of post-medieval shoes in buildings, usually houses or churches, beneath floorboards, in roof-spaces or chimneys (Houlbrook 2013). These too have been interpreted as methods of ritual protection by defending the building from evil forces, perhaps by warding them off through a metaphorical smell of burning leather or by trapping evil spirits or the devil within the shoe itself (ibid: 106-107). These practices are relevant to this discussion because they demonstrate that, certainly in Britain, popular practices including ritual deposition have taken place over the long-duree, from the Bronze Age to the post-medieval period, and these depositions have consistently been assigned a protective interpretation. The prevalence of this response as a means of gaining protection in other contexts and temporal settings adds weight to the less certain instances against wind-blown sand.

Responses orientated by religious beliefs were clearly one of the major methods by which medieval communities and individuals reacted to meteorological hazards. Practices were diverse both temporally and spatially but common practices such as processions and the veneration of particular saints, either local patrons or those universally believed to intervene in particular situations, were widespread. Throughout Britain, ritual practices including depositions involving various objects seem to have been a key method by which protection was achieved. The precise nature of many of these rituals and the motivations behind their application is a key area for future research to permit an improved understanding of how medieval populations protected themselves from natural hazards and the dangers of the world.

6.3 Adaptation

From investigating the four hazards, long-term adaptation seems to be the area for which the least evidence exists. Especially in the case of lightning and windstorms, the unpredictability of the hazard and the fact that medieval populations did not fully understand the causes, meant there was little that could be done to reduce vulnerability. Architectural developments show a limited attempt to reduce damage in windstorms with conical spires and buttresses added to buildings that had previously received damage while damage from lightning was something that medieval populations had to accept and try to protect themselves from through spiritual means. With wind-blown sand, while it is possible to adapt to the hazard and reduce exposure by the promotion of stabilizing vegetation, such as marram grass and pine, by the time that sands had begun to move, it would often be too late to prevent large scale sand inundations from occuring. However, by the close of the later medieval period there does appear to have been an enhanced understanding of the need to protect vegetation in vulnerable locales, perhaps signalling that increased exposure to the hazard throughout the LIA had driven some social adaptation. Flooding is the hazard which seems to have triggered the most visible adaptation. The organization of the agricultural year avoided times when floods were most likely to occur, grazing animals would have been carefully managed and removed from fields threatened if an inundation was deemed likely and in areas where timber was in short supply, materials were reused and buildings were able to be easily rebuilt following an inundation. Areas known to flood on regular occasions were avoided for permanent settlement and active river management was undertaken to try to reduce the likelihood of floods affecting vulnerable urban settlements. Frequent flooding could be dealt with by switching to more flood resistant crops such as legumes or from cereals to pastoral agriculture. The monastic houses, especially the Cistercians, frequently moved their foundations from sites affected by continued floods to more habitable locations. Therefore, medieval communities did adapt when other options could be found but the limitations imposed by their level of scientific and technological understanding meant that, for some hazards more than others, there were a lack of viable alternatives.

6.4 Characterizing Medieval Responses

Medieval British populations were not helpless in the face of meteorological hazards. Although the action of the hazard itself often left them with no choice but to relocate and wait for a return to normal conditions, they had a limited range of physical reactions and a broad suite of religious responses with which they probably believed they were suitably protected. To what extent traditional responses, such as those from the medieval period, differ from present-day approaches has been the subject of research for some time. G. F. White (1974: 5) proposed that an inherent difference exists between the ways industrial and pre-industrial societies respond to natural disasters (fig. 35). This has recently been restated by Chester *et al.* (2012: 66) and (Reike 2014: 337). While some of the assertions made by this model fit the medieval evidence well, for example experience of the hazard had great time-depth, as many medieval beliefs were certainly shaped by earlier pagan ones and it is likely that responses had developed over the *longue duree* since prehistory. These traditional responses however, offered little assistance when hazards occurred in unexpected ways, more suddenly or of greater magnitude, than had occurred in folk memory. It is also true that medieval people appreciated that loss was an unavoidable part of life. It was an inevitability that these events occurred, as can be seen in the contingencies made for the marble cross at Froyle (Baigent 1882: 27-28), and this had to be accepted. On the other hand a number of categories are too simplistic. For example, the assertion that higher authorities only became involved following industrialization is incorrect. The involvement of royal officials can be seen in the case of wind-blown sand with various laws issued to protect exposed bodies of sand, while Royal Commissions *de walliis et fossatis* were frequently involved in the aftermath of floods and, from 1554, aeolian sand inundations. On a smaller scale, the restrictions placed on the prices tilers were able to charge by the Abbot of St Albans following the 1362 storm demonstrates the involvement of another type of authority in medieval response strategies (Riley 1869: 46-47). In reclaimed lands, capital investment in flood defences could also be viewed as ‘high’ (Gardiner 1988: 117) and represented a significant percentage of annual costs for many medieval landowners. Even though most people in the medieval period were involved in agriculture and were thus more ‘in harmony with nature’, this did not stop the proliferation of unsustainable land use practices which increased vulnerability to wind-blown sand events. In addition, while there was undoubtedly a high variability in responses, particularly between individuals, more communal Christian responses such as processions and the veneration of saints were remarkably similar across western Christendom. Therefore while the medieval evidence accords well with around half of the requirements of a ‘pre-industrial’ society in this model, equally the other half do not adequately describe medieval responses. Chester et al. (2012: 66), in applying the model to Italian volcanology, argues that the different categories came into effect in different places at different times, with evidence for limited involvement by authorities in the Roman period. According to the model then, while medieval responses to hazards were far from what we would consider ‘modern’, they had certainly achieved many of White’s pre-requisites for ‘industrial’ society long before the industrial revolution.

	Pre Industrial	Industrial
Adjustment Range	Wide	Restricted
Actors	Individuals, households, small groups, communities	Authorities, authority co-ordinated groups
Relation to nature	Harmonisation with	Technological control over
Capital investment	Low	High
Spatial variability in responses	High	Low
Response flexibility	High	Low
Loss perception	Perceived as inevitable	Losses should be reduced by government, science and technology
Time-depth	Deep – Responses evolved over a long period	Shallow – Emerged in the 19th century and often replaces and suppresses traditional methods

Figure 36 – The differences in the ways pre-industrial and industrial societies respond to natural hazards according to Chester et al. (2012: 66). Redrawn after Reike (2014: 337).

7. Conclusions

The medieval experience of extreme weather events attests to the myriad impacts and consequences of meteorological hazards on a pre-industrial society. Many extreme events over the period had far-reaching ramifications, from entire coastal settlements engulfed by aeolian sand to enormous cathedrals and abbeys razed by lightning. At a regional level, these hazards frequently shaped the development of settlements and individual buildings but on rare occasions, such as the windstorm of 1362, the impact was felt far and wide across Britain. A lack of definitive population data for the medieval period makes detailed demographic analysis difficult but it appears that the relatively dense clustering of people in south east and central England were especially at risk from lightning and windstorms while flooding was more universal and wind-blown sand was limited to specific locales. The LIA was a time when hazards may have occurred with greater intensity than before and this, in unison with the sharp decline imposed on British medieval society by the calamities of the 14th century, which negatively affected medieval environmental management, strongly affected exposure and vulnerability from meteorological hazards.

Before and during the LIA however, these hazards were met with a wide variety of different responses. From a material perspective, in the moment of disaster medieval populations were at their most vulnerable, in the case of lightning induced fires an attempt could be made to fight the blaze but for other hazards, as there were no practical solutions available to lower floodwaters or drive away strong winds, the best option was often to escape to safety from the affected area. This would usually have been undesirable however as it meant leaving personal property, livestock and possibly even family and friends behind and in danger. To the medieval mind, the situation may have seemed less hopeless as the Church offered a wide range of methods, augmented by other less orthodox practices, including prayer to particular saints or processions. Holy water could be sprinkled on fields or the roofs of houses to provide protection in a storm or a coin could be folded and a pledge made to a local patron saint or one known to provide protection from a particular hazard. These methods were believed to mitigate the effects of hazards on individuals, groups and belongings. In the interim period between extreme events, populations had more options open to them. Dykes could be constructed against inundations, floor levels could be raised above the height of the last flood and in less common circumstances, rivers could even be diverted to prevent the encroachment of sand onto areas of anthropogenic activity. These methods too were enhanced by spiritual practices, such as routine rogation processions, vegetation blessed as part of Church festivals and personal artefacts such as *bullae*, prehistoric stone tools and amulets inscribed with the *Agnus Dei*, which were believed to offer protection from future events. Mounting evidence exists indicating that ritual depositions were motivated by a belief that they could prevent or protect from the future occurrence of hazards, for example, *ampullae* were almost certainly buried to provide protection from storms while hoards may have been involved in accruing protection from aeolian sand. For protective measures to be instigated however, society needed to both maintain communal memory of previous extreme events and perceive risk from future occurrences.

Medieval communities adapted to a limited extent to the pressure of extreme weather events, for example by attempting to protect vegetation in areas vulnerable to wind-blown sand and making architectural adjustments in cathedrals and churches to protect them from high winds. The hazard which, arguably, medieval communities best understood and were able to protect against the most, flooding, saw extensive adaptation with many different social and technological practices which enabled populations to survive and recover from routine, but not extreme, floods relatively successfully. Against extreme events however, due to the level of technological advancement, there were few options available. Perhaps as a result and because there was a strong belief that natural hazards were caused by divine influence, this encouraged medieval populations to turn instead to spiritual methods of protection. Despite the importance of religious responses, while British medieval society was undoubtedly 'pre-industrial' the way in which it responded to meteorological hazards had certainly achieved a considerable number of the characteristics of 'industrial' societies according to White (1974: 5) and this is reflected in the way medieval communities approached many of the occurrences of hazards enumerated in this study. In sum, while medieval society was poorly equipped to deal with extreme meteorological hazards by modern standards, they were neither helpless nor, by their standards, ill-equipped as diverse rituals and artefacts allowed them to channel spiritual help against almost any hazard.

Appendix 1 – List of Medieval Sites affected by Wind-Blown Sand

Site Name	County	Grid Reference	Date Range (years AD)	Description	Reference
Bay of Skaill	Orkney	HY238196	1100-1400	Norse longhouse	Griffiths and Harrison 2011
Berrow	Somerset	ST294525	1400-1600	Church and medieval settlement	Rippon 2000; Rippon pers. comm.
Eldbotle	East Lothian	NT499847	1370-1430	Medieval settlement	Hindmarch and Oram 2012
Evertaft	Orkney	HY455512	830-1050	Viking Age farming settlement	Barrett *et al.* 2000
Flixborough	Licolnshire	SE 876143	1400-1600	Medieval settlement	Loveluck 2007
Forvie	Aberdeenshire	NK021266	1400-1450	Medieval settlement	Milek 2012; Lamb 1982
Glenluce	Dumfries and Galloway	NX149554	1400-1495	Hoard deposited in sand layer covering ruins of structure	Jope and Jope 1959
Great Yarmouth	Norfolk	TG523081	800-1200	Medieval settlement	Rogerson 1976
Kenfig	Glamorgan	SS801827	1400-1600	Medieval settlement	Wessex Archaeology 2012
Llys Rhosyr	Anglesey	SH419654	1320-1340	Welsh Royal Residence	Johnstone 1999
Newborough	Anglesey	SH422658	1550	Medieval settlement	Ellis 1838
Mawgan Porth	Cornwall	SW847675	1000-1066	Medieval settlement	Bruce-Mitford 1997
Meols	Merseyside	SJ227903	1475-1525	Medieval settlement	Griffiths *et al.* 2007
Merthyr Mawr	Glamorgan	SS884775	1500-1600	Medieval settlement	Randall and Rees 1932
Mound of Snusgar	Orkney	HY236196	800-1100	Norse 'Castle'	Griffiths 2011; Griffiths 2013
Perranzabuloe	Cornwall	SW772565	1000-1200	Church site, shrine of St Piran	Ravenhill 1955
Penmaen	Swansea	SS533880	1300-1340	Possible medieval settlement	RCAHMW 1982
Pennard	Swansea	SS546883	1316-1528	Medieval settlement	Lees and Sell 1983
Pierowall	Orkney	HY440489	1340-1430	Agricultural land	Sommerville 2003
Rhossili	Swansea	SS416883	1540-1600	Medieval settlement abandoned before sand inundation	Davidson *et al.* 1987
Sandhill	Orkney	HY558332	1340-1430	Agricultural land	Sommerville 2003
Stackpole	Pembrokeshire	SR981944	1300-1600	Rabbit warren	Benson *et al.* 1990
St Ninian's Isle	Shetland	HU369209	1000-1200	Hoard deposited beneath church in layer of sand	Barrowman 2011
Y Ferwig	Ceredigon	SN185496	1400-1500	Medieval settlement	Roberts and Williams 1923

Appendix 2 – List of Medieval Lightning Induced Fires

Site Name	County	Grid Reference	Year	Description	Reference
Abingdon	Oxfordshire	SU501972	1265	Tower struck and set on fire but extinguished	Ditchfield, P. H. and Page, W. (eds.) (1907), *A History of the County of Berkshire, Volume II*, Archibald Constable and Co: London. p. 54.
Andover	Hampshire	SU365458	1175	Priest killed by lightning	Bond, E. A. (ed.) (1866) *Chronica Monasterii de Melsa, Volume I*, Rolls Service: London. p. 210.
Arbroath Abbey	Angus	NO643413	1272	Abbey set on fire by lightning	Taylor, S., Watt, D. (eds.) (1990), *Scotichronicon by Walter Bower, Volume V*, Aberdeen University Press: Aberdeen. p. 385.
Arbroath Abbey	Angus	NO643413	1380	Abbey set on fire by lightning	Lindsey, E. R. and Cameron, A. I. (eds.) (1934), *Calendar of Scottish Supplications to Rome 1418-1422*, Scottish History Society: Edinburgh. p. 92.
Baldock	Hertfordshire	TL244339	1444	Struck in same storm as St Paul's and Kingston upon Thames	Riley, H. T. (ed.) (1854) *Ingulph's Chronicle of the Abbey of Croyland*, London. p. 402.
Balmerino Abbey	Fife	NO358247	1419	Abbey set on fire by lightning	Twemlow, J. A. (ed.) (1906), *Calendar of Papal Registers Relating to Great Britain and Ireland, Volume 7*: 1417-1431, HM Stationery Office: London. pp. 141-147.
Barnwell Priory	Cambridgeshire	TL463589	1287	Tower struck, fire started, church nearly destroyed - lady chapel used for services for a whole year	Luard 1866: 340; Luard 1869: 314.
Cambuskenneth Abbey	Stirling	NS809939	1364	Bell tower struck by lightning	Bliss, W. H. (ed.) (1896), *Petitions to the Pope: 1342-1419*, HM Stationery Office: London. p. 475.
Coleshill, Church of St Peter and St Paul	Warwickshire	SP201890	1550	Spire destroyed by lightning	Salzman 1947: 54
Danbury	Essex	TL779051	1402	Spire struck by lightning	Riley, H. T. (ed.), (1864), *ThomaeWalsingham, Quondam Monachi S. Albani, Historia Anglicana, Volume II, A.D. 1381-1422*, HM Stationery Office: London. p. 250.
Deganwy	Conwy	SH781794	809	Deganwy burnt by lightning	Williams 1860: 11
Dureford Abbey	Sussex	TQ051671	1417	Church tower struck by lightning and destroyed along with 8 bells	Page, W. (ed.) (1973), *A History of the County of Sussex: Volume 2*, Oxford University Press: London. pp. 89-92.
Durham	County Durham	NZ273421	1429	Cathedral tower damaged by lightning	Cambridge 1992: 96
Durham	County Durham	NZ273421	1459	Cathedral tower damaged by lightning - forcing major rebuilding	Cambridge 1992: 116
Elston	Nottinghamshire	SK762483	1187	Gabriel d' Elyston killed by lightning in the porch of Elston church	Thornton 1797: 339
Ely Cathedral	Cambridgeshire	TL541803	1110	Tower over Porta struck	Wharton, H. (1691), *Anglia Sacra, Volume I*, London. p. 617
Glasgow Cathedral	Glasgow	NS603656	1378	Cathedral spire hit by lightning, fire spread throughout chancel, vestry and chapter house	Durkan 1975
Gloucester Abbey	Gloucestershire	SO831188	1122	Not specifically named as lightning but description could be	Giles 1914: 187

				describing lightning	
Gloucester Abbey	Gloucestershire	SO831188	1214	Lightning caused damage to Abbey	Storer, J. (1816), *History and Antiquities of the Cathedral Churches of Great Britain, Volume 2*, London. Gloucester (e)
Gloucester Abbey	Gloucestershire	SO831188	1223	Lightning caused damage to Abbey	Storer, J. (1816), *History and Antiquities of the Cathedral Churches of Great Britain, Volume 2*, London. Gloucester (e)
Grantham, St Wulfran's Church	Lincolnshire	SK915361	1222	Burnt by lightning	Giles 1849: 441.
Great Eversden	Cambridgeshire	TL367533	1466	Damage from lightning necessitated the reconstruction of the nave, chancel and tower	Cotton 1997: 101.
Grey Friars, London	London	TQ319814	1341	lightning destroyed "very fine work" of the Greyfriars	Riley, H. T. (ed.) (1863) *The French Chronicle of London, AD 1259 - AD 1343*, Victoria Press: London. p. 286.
Keyingham	East Yorkshire	TA245255	1396	Church struck by lightning and almost completely burnt down	Bond, E. A. (ed.) (1868) *Chronica Monasterii de Melsa, Volume III*, Rolls Service: London. pp. 193-195.
King's Lynn	Norfolk	TF620194	1363	Lightning burned Carmelite Friary and Tolbooth	Gransden 1957: 276.
Kingston upon Thames	London	TQ179692	1444	Church struck by lightning	Anderson 1818: 73.
Lacock Abbey	Wiltshire	ST919684	1447	Abbey buildings heavily damaged by lightning	Maxwell Lyte 1909: 86.
Lichfield Cathedral	Staffordshire	SK116098	1550	Cathedral spire struck by lightning	Greenslade and Pugh 1970: 168
Litlington	Cambridgeshire	TL316429	1315	Windmill destroyed by lightning - rebuilt in 1318 but exact location unknown	Maxwell Lyte, H. C. (ed.) (1893), *Calendar of Close Rolls, Edward II 1313–18*, HM Stationery Office: London. pp. 545–546.
Meaux Abbey	East Yorkshire	TA092394	1372	Abbey Struck by lightning but fire extinguished	Bond, E. A. (ed.) (1868) *Chronica Monasterii de Melsa, Volume III*, Rolls Service: London. p. 166
Milton Abbey	Dorset	ST798023	1309	Abbey almost entirely destroyed by lightning fire	Pentin 1933: 5
Norwich Cathedral	Norwich	TG234088	1271	Spire struck by lightning and damaged	Britton 1816: 20
Norwich Cathedral	Norwich	TG234088	1463	Spire struck by lightning, fire throughout cathedral requiring repair	Gilchrist 2005: 76
Salisbury Cathedral	Wiltshire	SU137328	1092	Struck by lightning and partially destroyed	Pugh and Crittall (1956): 156-157.
Salisbury Cathedral	Wiltshire	SU143295	1559	Spire struck by lightning - fracture down spire	Pugh and Crittall (1956): 189-190.
St Albans Abbey	Hertfordshire	TL145070	1251	Lightning struck but little damage	Giles 1853: 465.
St Albans Abbey	Hertfordshire	TL145070	1254	Lightning alluded to - date uncertain	Riley, H. T. (ed.) (1867), *Gesta Abbatum Monasterii Sancti Albani, Volume II, A.D. 1290-1349*, HM Stationery Office: London. p. 313.
St Albans Abbey	Hertfordshire	TL145070	1334	Fire caused by lightning set fire to Abbot's Chamber and Cloister Roof	Riley, H. T. (ed.) (1867), *Gesta Abbatum Monasterii Sancti Albani, Volume II, A.D. 1290-1349*, HM Stationery Office: London. p. 293.
St Albans, St Peter's Church	Hertfordshire	TL150076	1254	Struck by lightning, repairs may have focussed on the doorway	Page 1908: 419
St Andrews Cathedral	Fife	NO514167	1378	Cathedral struck by lightning?, extensive	Batho and Husbands 1941: 340; Bellenden 1821: 455

				fire damage	
St Bartholomew's Church, London	London	TQ320817	1264	Belfry struck by lightning	Riley, H. T. (ed.) (1863), *Chronicles of the Mayors and Sheriffs of London*: 1188-1274. Trübner and Co: London. p. 234
St Martin's Church, Ludgate	London	TQ318812	1561	Church struck by lightning	Thornbury 1878: 241-243
St Mary's Abbey	York	SE599522	1377	Spire and crossing damaged by lightning fire	Galbraith 1970: 95
St Paul's Cathedral	London	TQ320811	1230	Lightning shocked worshipers inside	Kingsford 1908: 131.
St Paul's Cathedral	London	TQ320811	1341	Lightning damaged spire, cross replaced with weather vane.	Saunders 2001: 16
St Paul's Cathedral	London	TQ320811	1444	Lightning damaged spire.	Noorthouck 1773: 93
St Paul's Cathedral	London	TQ320811	1561	Fire burned spire.	Keene *et al.* 2004: 171-172
Staveley	Derbyshire	SK433749	1291	Lightning struck church, priest killed.	Maxwell, H. (ed.) (1913), *The Chronicle of Lanercost, 1272-1346*, pp. 82-83.
Strata Florida Abbey	Ceredigon	SN746657	1286	Fire caused by lightning, burning of lead roof.	Christie 1887: 115-117.
Taverham, St Edmund's Church	Norfolk	TG160138	1459	Burnt by lightning.	Sims 2000.
Walden Abbey	Essex	TL525382	1444	Struck in same storm as St Paul's and Kingston upon Thames.	Riley, H. T. (ed.) (1854) *Ingulph's Chronicle of the Abbey of Croyland*, London. p. 402.
Waltham Abbey	Essex	TL380007	1444	Struck in same storm as St Paul's and Kingston upon Thames.	Riley, H. T. (ed.) (1854) *Ingulph's Chronicle of the Abbey of Croyland*, London. p. 402.
Winchcombe Abbey	Gloucestershire	SP024283	1091	Struck by lightning (No standing remains).	Page 1907: 66.
Winchelsea, St Giles Church	Sussex	TQ903172	1413	Burnt by lightning.	Haydon, F. S. (ed.) (1863), *Eulogium: Historia sive Temporis, Volume III*, HM Stationery Office: London. p. 421.
Windsor Castle	Berkshire	SU971770	1251	Queen's apartments hit by lightning.	Giles 1853: 465.
Woburn Abbey	Bedfordshire	SP965325	1315	Abbey buildings damaged by lightning fire.	Stubbs 1882: 278.

Appendix 3 – List of Medieval Windstorm Events

Site Name	County	Grid Reference	Year	Description	Reference
Bury St Edmunds	Suffolk	TL 857641	1210	Tower brought down by storm?	Luard 1866: 32
Evesham	Worcestershire	SP038436	1210	Tower brought down by storm?	Luard 1866: 32
Chichester	East Sussex	SU860048	1210	Two towers toppled in storm.	Luard 1866: 32
Pilarton Hersey	Warwickshire	SP299489	1222	House collapsed killing 9.	Giles 1849: 442
Dunstable	Bedfordshire	TL021219	1222	Two towers brought down, into the church and the Prior's Hall.	Page 1912: 364-365
Worcester Cathedral	Worcestershire	SO850545	1222	Two towers collapsed, possibly adjoining the apse.	Luard 1869: 415
Arbroath Abbey	Angus	NO643413	1272	Houses and high buildings damaged in storm.	Watt 1990a: 385
St Andrews Cathedral	Fife	NO514167	1272	West front blown down in storm.	McRoberts 1976: 23
Mudford	Somerset	ST574199	1311	Bell tower brought down by storm.	Riley 1863: 126
Yeovilton	Somerset	ST547230	1311	Bell tower brought down by storm.	Riley 1863: 126
Norwich Cathedral	Norfolk	TG234088	1362	Spire blown down falling into the presbytery.	Woodman 1996: 179
King's Lynn	Norfolk	TF620194	1362	Recorded in the annals of the Franciscans at King's Lynn.	Gransden 1957: 275
St Mary's Church, Ashwell	Hertfordshire	TL267398	1362	Graffito memorializing storm.	fig. 27
Bury St Edmunds	Suffolk	TL857641	1362	Damage felt but unclear exactly what was damaged.	Rouse 2004
Austin Friars, London	London	TQ329813	1362	Steeple of the Austin Friars at Broad Street brought down by storm.	Hugo 1864: 9, 17-18
St Albans Abbey	Hertfordshire	TL144071	1362	Abbey gatehouse heavily damaged in storm.	Niblett and Thompson 2005: 254
Colchester	Essex	TL998246	1362	Documentary evidence records damage from storm winds.	Bliss 1896: 444
Salisbury Cathedral	Wiltshire	SU143295	1362	Belfry and spire damaged.	Miles et al. 2004: 21
St Andrews Cathedral	Fife	NO514167	1409	South transept collapsed in storm.	Watt 1990b: 75
Cawston	Norfolk	TG134238	1412	Bell tower brought down by storm.	Cozens-Hardy 1952: 339

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