AMAP2 – Characterising the potential for Wrecks (5653)

Final Report

Version 2.0

25/07/2011

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PROJECT NUMBER: 5653			DOCUMENT REF:		
Final report – version 2.0	OM				18/07/2011
Final report – draft 1.0	OM	VDM, JKD	EH		07/06/2011
	Originated	Checked	Reviewed	Authorised	Date
Purpose / Description					

SUMMARY

This report outlines the results of the *AMAP2 – Characterising the Potential for Wrecks* (AMAP2) project commissioned by English Heritage via the Historic Environment Enabling Programme (HEEP) in December 2009.

The AMAP2 project aims to improve the management of the marine environment through the enhancement of baseline data for marine spatial planning and by providing the basis for a more justified assessment of potential for unrecorded wrecks. This is being sought through improving our understanding of the relationships between the physical properties of wrecks and their surrounding environmental condition gained through an analysis of the distributions of wrecks of shared characteristics in English waters. The main objective of the project is the development of a characterisation of the variables affecting the potential for archaeological materials to exist and survive on the seabed.

The characterisation is being developed through the integration of the methodology applied during the *AMAP1 - Refining areas of Maritime Archaeological Potential for Shipwrecks* (AMAP1) with the modelling of marine environmental data based on techniques developed by University of Southampton (UoS), to produce a considered assessment of environmental character on a national scale.

The development of the methodology has been undertaken across a pilot area encompassing the Thames Estuary and Goodwin Sands based on the EU funded MACHU project areas. The aim of AMAP2 is to enhance the methodology for the characterisation of archaeological potential for shipwrecks. This has been done through:

Phase 1 - quality testing of previous results from AMAP1

Phase 2 - improved baseline information enabling more accurate data analysis

Phase 3 - added expertise of staff at SeaZone and the UoS.

The project report describes the stages taken in the development of an enhanced methodology for AMAP2 initially across the trial area and the results of work conducted during Phase 2 leading to the interpretation of the relationships between wrecks and their environment through statistical and spatial analysis and the development of an environmental characterisation of the variables affecting the archaeological potential of England's continental shelf.

The results of the project mostly reflected those of AMAP1 while raising some key research questions which were addressed during the main phase of analysis of the project. Similarities were identified in the age bias of wrecks and the relationships between the physical characteristics of wrecks and their environmental parameters.

Since the start of the project, SeaZone have been acquired by, and now operates as a trading group of HR Wallingford Ltd, allowing SeaZone to draw upon resources and expertise in HR Wallingford as part of its team. This has proven to be of benefit to the project in a range of areas through the provision of expert input into statistical analysis and the development of sediment transport modelling by UoS.

Abbreviations

ADS – Archaeological Data Service

AMAP – Areas of Maritime Archaeological Potential

AMIE - Archives and Monument Information England

ALSF – Aggregate Levy Sustainability Fund

AMAP – Area of Maritime Archaeological Potential

BGS – British geological Survey

CRS – Co-ordinate Reference System

Defra – Department for the Environment and Rural Affairs

DNF – Digital National Framework

EH – English Heritage

EIA – Environmental Impact Assessment

ESRI – Environmental Systems Research Institute

EU – European Union

GIS – Geographic Information Systems

HER – Historic Environment Record

HTML – Hyper Text Mark-up Language

HWTMA – Hampshire & Wight Trust for Maritime Archaeology

HSC – Historic Seascapes Characterisation

IACMST - Inter Agency Committee for Marine Science and Technology

INSPIRE – INfrastructure for SPatial InfoRmation in Europe

LAT – Lowest Astronomical Tide

MEDIN - Marine Environmental Data and Information Network

MEDAG - Marine Environmental Data Action Group

MDIP – Marine Data Information Partnership

MHW – Mean High Water

MLW – Mean Low Water

MoRPHE - Management of Research Projects in the Historic Environment

UOS – University of Southampton

NRHE – National Monuments Record

OS – Ordnance Survey

OSGB36 – Ordnance Survey Great Britain 1936, the geographic datum of British National Grid

UKHO – United Kingdom Hydrographic Office

UKLS – UK Location Strategy

SHAPE - Strategic Framework for Historic Environment Activities and Programmes in English Heritage

SMR – Sites and Monuments Record

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1. PROJECT BACKGROUND

1.1 Introduction

SeaZone Solutions Ltd has been commissioned to undertake a two phase project to develop a GIS characterisation of the environmental parameters which determine the potential for wrecks to exist and survive in seabed sediments. The project is being run in collaboration with the University of Southampton (UoS).

This report outlines the overall results of the project at the end of Phase 2. The *"AMAP2 – Characterising the Potential for Wrecks"* project, which sought in Phase 1 to restructure UKHO wreck data across all English Waters in order to facilitate spatial queries of wreck distributions. Further modelling of environmental data has also been undertaken by the UoS over a series of pilot areas (Goodwin Sands and Thames Estuary). The results of wreck queries applied to the UKHO and NRHE databases have been tested over these areas and compared with results from AMAP1.

Phase 2 applied the methodology developed in phase 1 to the rest of the UK continental shelf, where the coverage of environmental data was available, quality testing existing results, with an aim of building an environmental characterisation to support the assessment of the variables affecting archaeological potential during marine planning.

This report comprises one of the key deliverables for Phase 2 of the project, alongside the Phase 2 steering group meeting which was held on 7th April 2011 and the project GIS containing a spatial characterisation of the environmental variables collated for the assessment of wreck data. The report and GIS are to be delivered to the Maritime Archaeology Team at English Heritage upon completion of the project.

1.2 Background

Areas of Maritime Archaeological Potential (AMAP) are areas where it is considered that the navigational (i.e. reefs or sandbanks) or environmental conditions (i.e. tidal races or overfalls) present in the area are likely to have caused shipping losses in the past and where the seabed conditions are such that preservation of archaeological material is thought to be likely.

The *Navigational Hazards* project was an Aggregate Levy Sustainability Fund (ALSF)-funded project completed in January 2007 which identified Areas of Maritime Archaeological Potential (AMAPs) through the identification of areas where the potential for ships to be lost due to natural navigational hazards coincides with the potential for archaeological materials to survive, based on the bearing capacity of different sediment groups.

The project highlighted the need for further variables, such as seabed stability, sediment depth, the nature of localized contemporary maritime activities and their relationship with shipwreck data, which affect the potential for vessels to be lost and to survive on the seabed. The ALSF project *"Refining Areas of Maritime Archaeological Potential for Shipwrecks - AMAP 1"* (Merritt, 2008), funded through English Heritage in 2007/08, sought to enhance the results of the Hazards project by integrating the quantitative analysis of additional marine datasets with the environmental characterization produced for the *Navigational Hazards* project. The method was developed across a pilot area encompassing the Eastern English Channel. The results suggested significant relationships between the distribution of wrecks across the area and some environmental variables. The project design for AMAP 2 was commissioned to assess the presence of these relationships on a national scale taking account of improved data availability and draw on expertise from SeaZone and UoS to improve the methodology for characterising archaeological potential.

The project seeks to improve the interpretation of archaeological potential on the seabed in order to assist industry, regulators and curators in giving guidance on the marine historic environment

during marine planning. Refining the basis for the assessment of archaeological potential on the seabed will improve the regulation of dredging for sand and gravel by enabling a more justified and better informed statement of archaeological potential for impact assessments.

2. AIMS AND OBJECTIVES

2.1 Project Aims

The primary aim of the project is to improve the management of the marine environment through the enhancement of baseline data for marine spatial planning and by providing the basis for a more justified assessment of potential for unrecorded wrecks. This has been achieved through the assessment of potential trends in relationships between of the environmental variables affecting the potential for archaeological materials to exist and survive on the seabed and the condition of wrecks on the seabed through the analysis of the distributions of wrecks of shared physical characteristics in England's waters, leading to the development of a methodology for characterising those variables.

The characterisation has been developed through the integration of the methodology applied during AMAP1 with the modelling of enhanced marine environmental data, where available, to produce a considered assessment of environmental character on a National scale.

2.2 Project Objectives

The main aim of the project has been met through the following objectives:

(1) To extract information from UKHO and NRHE databases for the purpose of the project to optimise attribute queries.

(2) To develop a character map of the environmental variables which affect the potential for shipwrecks to survive in different seabed environments

(3) To improve our understanding and interpretation of archaeological potential for shipwrecks during both industry-led impact assessments and strategic marine planning for aggregate extraction

(4) To develop a working methodology for encouraging a more justified interpretation of potential which may in the future, be applied to other archaeological features

(5) To disseminate the results of the project across a broad range of disciplines including the geospatial, archaeological and marine communities via a series of research papers and a published project report.

Phase 1: AMAP METHOD ENHANCEMENT

1a. Setting Up and Familiarisation

Familiarisation of project staff with the data and methodology employed for AMAP1, with software packages and with improvements in available marine data

1b. Data Extraction

Extraction of information from UKHO and NRHE wreck data for all English waters, initially over a test area, to optimise the identification of trends in wrecks during spatial analysis.

1c. Environmental Characterisation

Application of the method for characterisation of AMAPs taking account of improved data and lessons learnt during MACHU

Development of an enhanced methodology for characterising AMAPs based on available data and expertise

1d. Trial Area Analysis

Analysis of test area wreck data in conjunction with environmental modelling over trial areas in the Goodwin Sands and the Thames Estuary to enable the relationships identified during AMAP1 to be tested and better understood.

The results of the analysis will provide a basis for the development of a methodology for the analysis and characterisation of the potential for wreck materials to survive in seabed sediments.

Phase 2: CHARACTERISATION OF ENGLISH WATERS

2a. Analysis and Characterisation of Full Area

Application of enhanced AMAP methodology to all English waters out to the territorial limit taking account of Phase 1 results

2b. Case studies

Testing of GIS characterisation over a range of case study areas reflecting different seabed environments, to demonstrate the application of the project results

2c. Reporting & Delivery

Produce project report

Deliver project GIS

Phase 3: DISSEMINATION

2d. Dissemination

Write and Publish of two academic papers and dissemination of project results online

3. METHODOLOGY

3.1 Stage 1a: Set-up and Familiarisation

Staff required for the project were already in post within SeaZone along with the necessary data hardware and software.

Initial set-up included the familiarisation of core staff with the AMAP1 methodology and research undertaken via the MACHU project. A meeting was held between SeaZone staff closely involved with the project to discuss the project's phasing and technical requirements including the upload of NRHE data to the AMAP schema in Oracle, mapping between databases and development of bespoke tools to facilitate the extraction process. The NRHE data was uploaded to Oracle to facilitate the use of bespoke Oracle tools to extract information from the NRHE fields, and to enable mapping between the UKHO and NRHE databases to take place.

The University of Southampton (UoS) identified an ideal candidate for the Masters of Research (MRes) studentship. The student worked to the project brief under the supervision of the course supervisor, Justin Dix (JKD) and project manager (OM).

3.2 Stage 1b: Data Extraction

3.2.1 Data Gathering

The datasets gathered for the project during Phase 1 was based on those used for AMAP 1 (Merritt 2008) and reflected a combination of shipwreck data and environmental datasets available in a range of digital and documentary formats.

SeaZone is familiar with a wide range of marine digital data and are involved in the improvement and enhancement of data and the standards used to collate them. With a combined expertise in GIS, Historic Seascape Characterisation method development, oceanography and marine archaeology, the team have a firm understanding of the relationships between human activity and the natural marine environment, and the inconsistencies which exist in available marine datasets.

The project sought to employ a combination of shipwreck data and environmental data in the development of the AMAP2 methodology as follows:

- Shipwreck Data:
    - UKHO wrecks and obstructions
    - NRHE wrecks and reported losses
- Environmental Data:
    - Bathymetry
    - Seabed sediments
    - Marine Bedrock deposits
    - Hydrographic Survey metadata
    - Sediment transport model
    - ALSF Navigational hazards

3.2.2 Shipwreck Data

As highlighted in the results of the AMAP1 project (Merritt, 2008), there is considerable scope for using physical information embedded in wreck databases as indicators of the nature of their surrounding environment. The isolation of the physical and circumstantial characteristics of wrecks can highlight relationships between the nature of wrecks and the environmental factors which determine their potential to survive. The project focussed on using data held by the National Record of the Historic Environment (NRHE) and the UK Hydrographic Office as they both provide a consistent comprehensive coverage of digital data across England's territorial waters. The NRHE

database is based within the 12nm limit while the UKHO database contains wrecks out to the limits of the UK continental shelf and beyond.

3.2.2.1 United Kingdom Hydrographic Office (UKHO) Shipwreck Data

The remit of the United Kingdom Hydrographic Office (UKHO) is primarily concerned with gathering and supplying data for navigational safety purposes. The UKHO holds a database of shipwrecks, which therefore contains accurate co-ordinates for each site, site name and date where known, and extensive information on the physical properties of each site, including survey history, information of wreck state and scatter. The data is distributed in digital format via SeaZone.

UKHO shipwreck an obstruction data delivered by SeaZone includes the Hydrospatial Wrecks and Obstructions layers and the wrecks and obstructions database upgrade. The wrecks and obstructions upgrade contains key descriptive attribute fields which contain additional information on the circumstances of loss, survey history and general comments on the state of each site the form it was originally delivered by the UKHO, and provided the basis for the extraction of information from UKHO records. The wrecks and obstruction database contains the UKHO identifiers (HOID), also recorded by the NRHE where known. This common reference enabled the UKHO and NRHE shipwreck records to be joined, to identify previously matched records.

The data was provided by SeaZone referenced to the WGS84 horizontal datum, which is an internationally globally applicable geodetic Co-ordinate Reference System (CRS) (http://www.epsg.org/; urn:ogc:def:crs:EPSG::4326).

3.2.2.2 National Record of the Historic Environment (NRHE) Shipwreck Data

The NRHE is responsible for administrating and maintaining records of known shipwrecks of historical interest and casualty records in English Waters, out to the 12 nautical mile limit, in line with English Heritage's remit of responsibility under the National Heritage Act 2002 (HM Government, 2002).

NRHE records of known shipwrecks are available either as individual paper records or in a digital format from the National Record of the Historic Environment (NRHE) office. Records of reported losses are also held. These records contain reports of ship losses for which a location is not yet recorded on the seabed. The NRHE delivered all known shipwreck records and reported losses from the NRHE database in a digital format for the purpose of the project.

The data was delivered as two shapefiles for each class of record, one for point data and the other for polygons, accompanied by five additional MS Excel spreadsheet containing additional fields.

The GIS data provided contains the core data required to plot each of the features recorded in the database. In order to view information such as the name of the wrecks (where known), the data held within the associated MS Excel files need to be joined to the shapefiles where possible using the unique identifiers for each record. These identifiers are labelled as either HOB_UID or UID.

Each of the files delivered by the NRHE for AMAP2 is described in the table below:

Table 1: Description of contents of AMIE records delivered for the AMAP2 project

File Name	Description	Fields
All SIT Records 11 Nov 2009_AMIEMonumentPoint.shp	Contains mapped records of known wreck sites for ships boats and aircrafts represented as point	HOB_UID, Name, Description, Mon_precis, Capture_sc, Easting, Northing
All SIT Records 11 Nov 2009_AMIEMonumentPolygon.shp	Contains mapped records of known wreck sites for ships boats and aircrafts represented as polygons	HOB_UID, Name, Description, Mon_precis, Capture_sc, Easting, Northing
Casualty Records_AMIEMonumentPoint.shp	Contains mapped records of reported losses of ships and boats, represented as point	HOB_UID, Name, Description, Mon_precis, Capture_sc, Easting, Northing

File Name	Description	Fields
Casualty Records _AMIEMonumentPolygon.shp	Contains mapped records of reported losses of ships and boats, represented as polygons	HOB_UID, Name, Description, Mon_precis, Capture_sc, Easting, Northing
AMAP Core Digital Data.xls	Contains the unique identifier (UID), name (where known) and eastings and northings, enabling the core point data to be plotted, along with the text description and location details	UID, NRHE number, summary, 100km, Easting, Northing, County, District, Parish, Primary Name
AMAP Phase_Class Data.xls	Contains details of each site's period where known along with feature type classifications.	HOB_UID, Period, Min_date, Max_date, Class scheme, Term
AMAP Condition Status Data.xls	Contains data on the nature of the evidence on which the record is based and whether it lies in the intertidal, marine or terrestrial zone	UID, Condition scheme, Status
AMAP Other Identifier Data.xls	Contains the identifiers for other records of the same site including the old UKHO identifiers	HOB_UID, Identity method, Value
wreck_numbers.xls	Table provided by the UKHO to the NRHE. Contains the old and current UKHO identifiers	No field names

3.2.3 Environmental Data

3.2.3.1 Bathymetry & Topography

Marine bathymetric data and coastal elevation data were supplied as part of the SeaZone Hydrospatial digital marine dataset. In addition to data provided as depth area polygons and contour polylines, bathymetric data was also provided by *SeaZone* in the form of gridded ASCII files.

High resolution bathymetry was also provided by UoS across localised areas of the Dorset coast and Thames estuary for use during the case studies.

3.2.3.2 Superficial Seabed Sediments & Offshore Bedrock Deposits

Seabed sediment data and offshore bedrock deposits were delivered by Seazone Solutions Ltd. as part of the SeaZone Hydrospatial package. The Natural and Physical feature dataset contains two themes from the British geological Survey (BGS) 1:250 000 scale offshore geological maps including bedrock geology (DigRock250) and sea-bed sediments (DigSBS250) (http://www.bgs.ac.uk/).

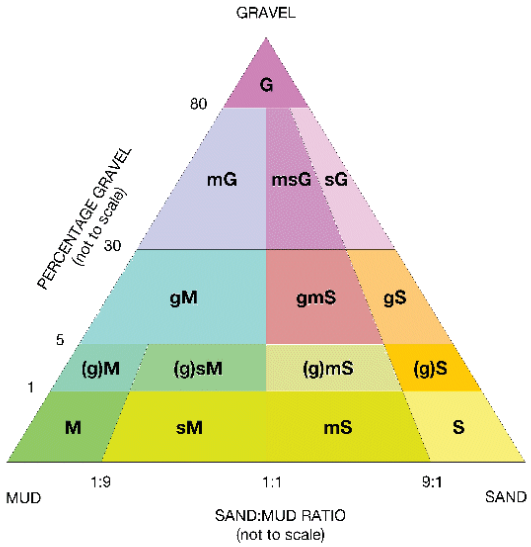
The DigSBS250 map is based on sea-bed grab samples of the top 0.1m, combined with cores and dredge samples as available. A standard Folk (1954) triangle classification has been used based on the gravel percentage and the sand to mud ratio (Figure 1).

The 1:250 000 scale resolution of the superficial sediments dataset provides an approximate representation of the characteristic sediment groups across offshore areas, but does not cover intertidal and inshore areas, producing a white ribbon along the coast of approximately 1 km.

The seabed sediment data was reclassified following the grouping used for UKSeaMap to produce a more generalised representation of sediment grain size while employing a simplified version of the Folk classification approach which is more focussed towards the EUNIS habitat classification

system and was developed for UKSeaMap as part of the MESH project (http://jncc62new.wisshost.net/pdf/UKSeaMap2010_Initial_report.pdf) (Figure 2).

The data was also reclassified following the parameters first developed for the ALSF Navigational Hazards project and used during AMAP1 to reflect preservation potential (Gregory 2007). This classification used sediment grain size and the percentage of gravel content to assess the bearing capacity of the seabed (Figure 3).



M	Mud
sM	Sandy mud
(g)M	Slightly gravelly mud
(g)sM	Slightly gravelly sandy mud
gM	Gravelly mud
S	Sand
mS	Muddy sand
(g)S	Slightly gravelly sand
(g)mS	Slightly gravelly muddy sand
gmS	Gravelly muddy sand
gS	Gravelly sand
G	Gravel
mG	Muddy gravel
msG	Muddy sandy gravel
sG	Sandy gravel

The above classification is based on that of R.L.Folk, 1954, *J. Geol., 62* pp344-359.

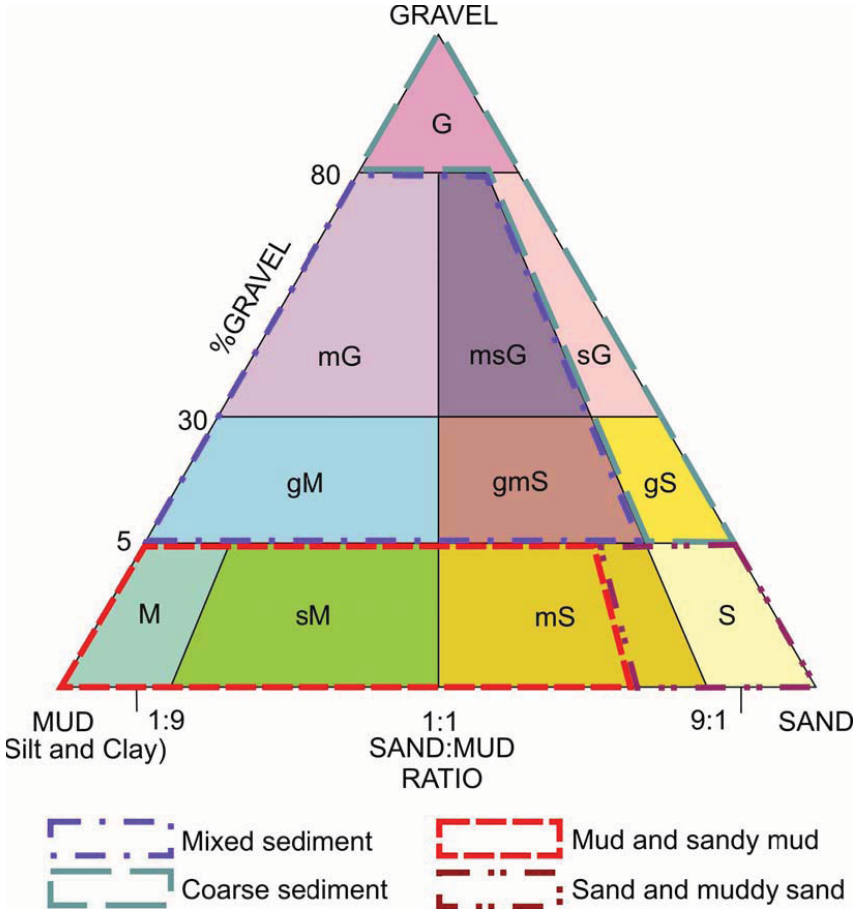


Figure 1: Diagram depicting the R.L. Folk classification (1954) for sediment types used by the BGS and the MESH reclassification

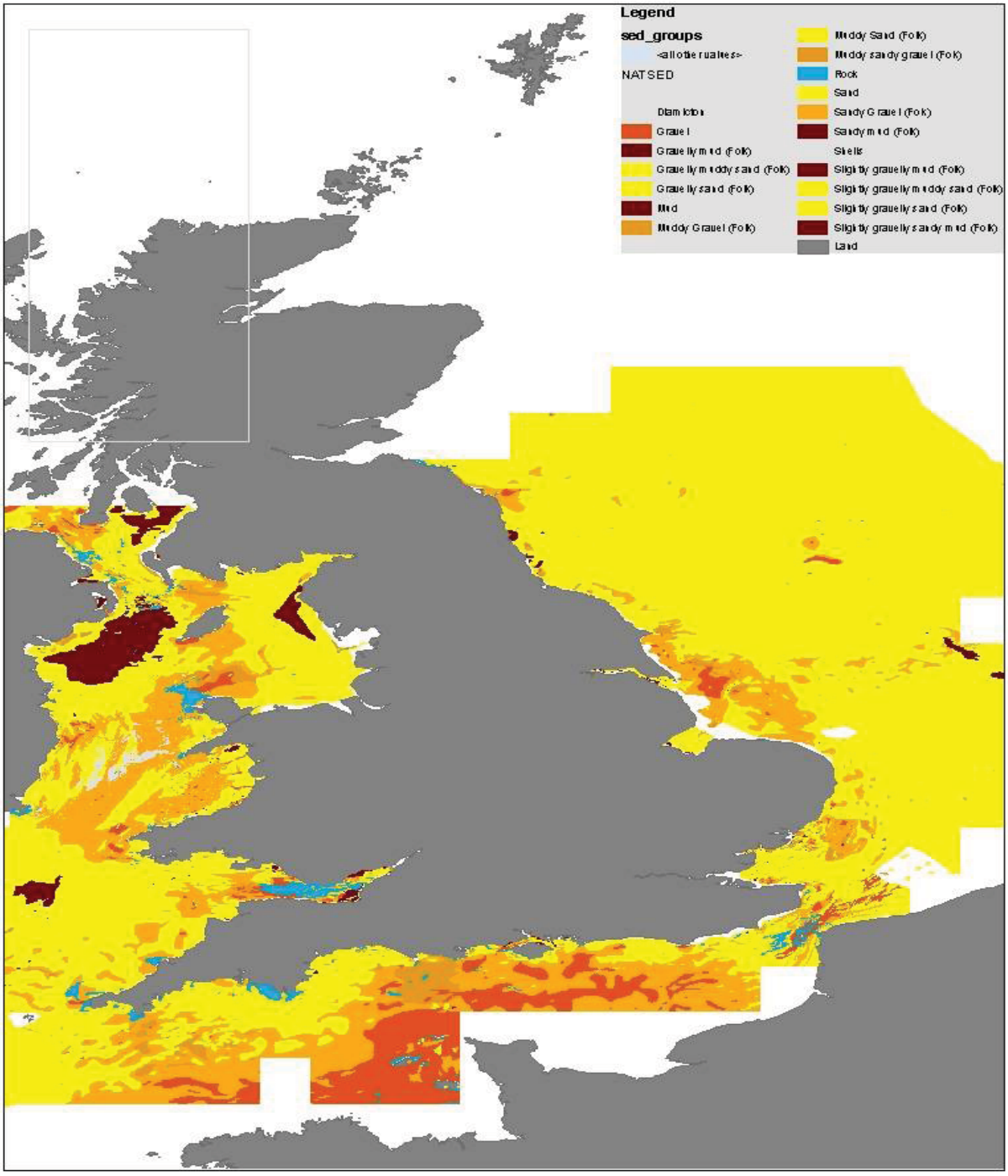


Figure 2: Reclassification of sediments using the MESH classification

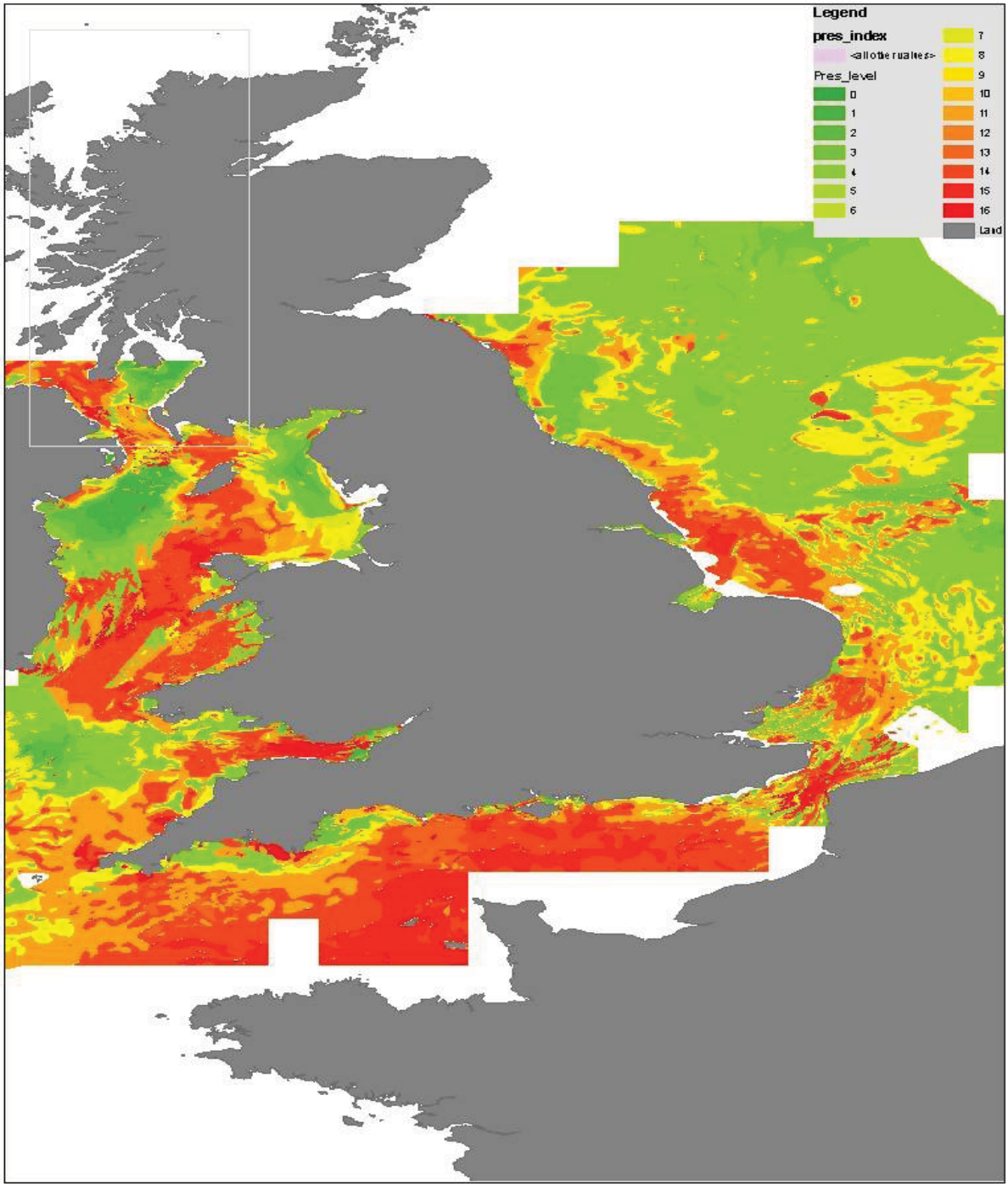


Figure 3: Reclassification of sediment types using the AMAP1 Preservation index

3.2.3.3 Seabed Sediment Isopachs

The need to identify areas where seabed sediments are shallow enough to reduce the potential for archaeological material to be buried was identified during the AMAP1 method development. The data was gathered in order to identify areas where sediment was shallow enough to restrict the potential for archaeological materials to be buried.

At the start of the AMAP2 project, the British Geological Survey (BGS) was contacted to discuss potential sources of data for mapping sediment thickness (producing isopach maps). The BGS are working on the development of an offshore sediment thickness map product. However the timeframe for the BGS product's development has been greater than originally anticipated and was not completed within the timescale of AMAP2. The BGS delivered a series of digital scans of Sediment Thickness inset maps which are published on the SBS & Quaternary map sheets. The map sheets were reviewed to identify those potentially containing information which could be used to produce a generalised map of sediment thickness.

All available tiles in covering English waters were digitised to produce a series of shapefiles containing discrete vector polygons for each tile which could be used alongside other environmental datasets in ArcGIS.

The maps provided by the BGS vary in their scale range between 1:1M and 1:500000 and were therefore difficult to pull together as a single dataset. A combination of maps showing thickness of superficial sediments, thickness of Holocene sediments and thickness of quaternary sediments were used to produce a broad-scale representation of sediment thickness. The data provided from the inset maps did however not provide completed coverage of the AMAP2 project area.

The primary objective of the classification is to differentiate between areas characterised by very shallow sediment and areas where sediment could be deep enough for considerable burial of large objects to occur. The scale ranges do vary considerably between tiles provided by the BGS (Figure 4). The sediment thickness tiles were therefore classified as far as possible to reflect the following categories:

- 0-1m (green)
- 1-5m (orange)
- 0ver 5m (dark orange and red)

3.2.3.4 Hydrographic Survey Metadata

In the initial project proposal for the AMAP1 project, it was anticipated that the assessment of known wrecks and obstructions in the context of hydrographic and geophysical survey metadata may help identify biases in the wreck data due to variations in the resolution and regularity of surveys undertaken across different seabed areas. Relationships between wreck scatters and the resolution of survey were thought to occur in the results of AMAP1.

SeaZone maintain a record of Digital Survey Bathymetry extent polygons, regularly updated as new surveys delivered by the UKHO are integrated as part of SeaZone products. SeaZone have been capturing survey extents from all survey sheets used during the in-house enhancement of digital bathymetry, producing a dataset which has greatly improved since the completion of AMAP1. This hydrographic survey metadata (Figure 5) provides valuable information on the biases in survey coverage and resolution which may affect the distribution of shipwrecks identified. Such data was used during AMAP1 and is proving to be useful in assessing patterns in wreck distributions for AMAP2.

3.2.3.5 Sedimentation-erosion model

The purpose of the numerical sedimentation-erosion model is to provide a regional scale backdrop of seabed conditions to cultural managers of archaeological sites, for use in conjunction with and as a context for guidelines developed for site scale management. The final outputs from the model are a description of the net sediment transport pathways and the nature of gross and/or sudden changes in seabed level (erosion or accumulation) as a response from either ambient tidal and wave conditions or extreme conditions (the passage of a storm through the area), as well as information of the direction and magnitude of sediment transport (e.g. Figure 6).

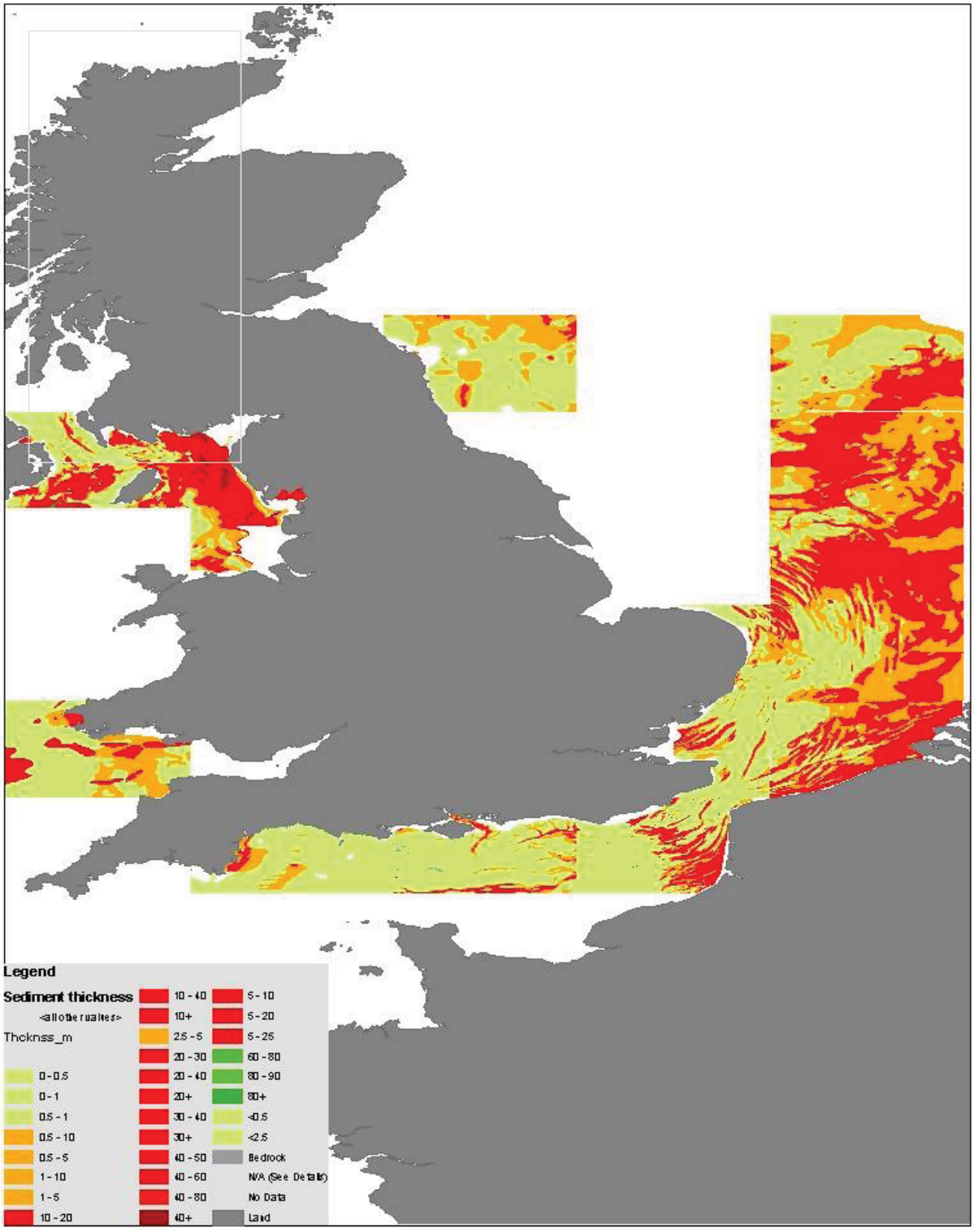


Figure 4: Seabed sediment thickness derived from BGS mapsheets.

Figure 5: map showing coverage of hydrographic survey extents across the pilot area

These outputs are derived from calibrated modelling of the direction and magnitude of tidal and wave induced currents and there interaction with different sediment fractions on the seabed. This project has used the Danish Hydraulic Institute's MIKE 21 2D hydrodynamic and sediment transport software, but the approach taken could be applied to a range of commercially available products. The MIKE 21 model produced decoupled hydrodynamic and sediment transport models (i.e. the output from the hydrodynamic model was exported and then used as input conditions to the sediment model. A coupled hydrodynamic-sediment approach is available (i.e. the two models run interactively) but the run times are considerably longer so were not used in this instance. Two versions of the hydrodynamic model were developed: a tidal current only version and a tide and wave current version (Figure 6).

The model requires a number of different inputs and starting parameters including: the land boundaries; bathymetry; open water tidal inputs; the seabed sediment distribution; the "roughness" of the seabed (a composite parameter of the small scale seabed morphology [e.g. ripples and sand waves] and surface grain size); the wind/wave regime; the mesh resolution to define the spatial output of the calculated hydrodynamic and sediment dynamic properties; and the time steps and time period over which the model should run.

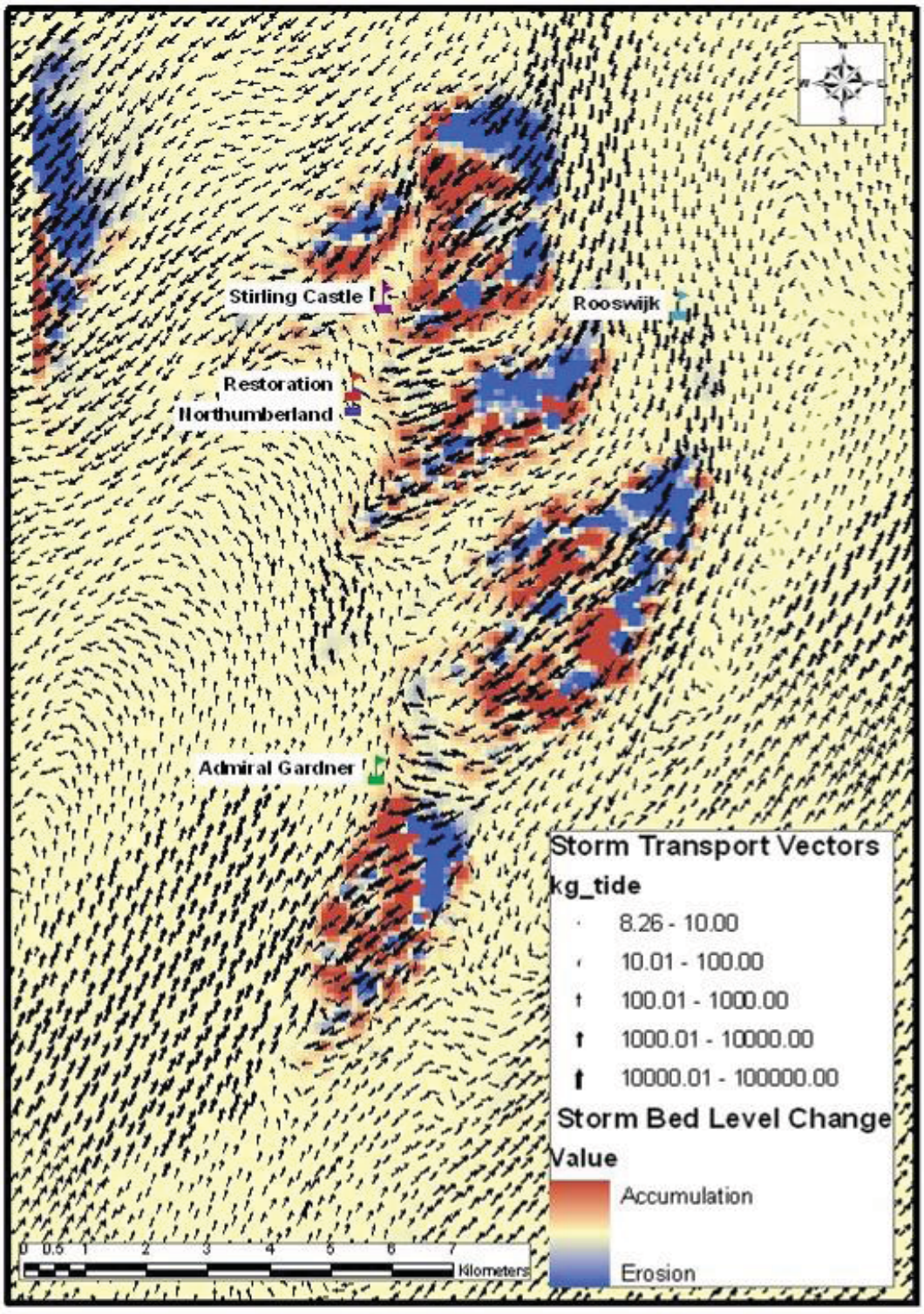


Figure 6: Bed Level Change and sediment transport magnitude and direction for the Goodwin Sands.

SeaZone provided UoS with enhanced bathymetric models for the Thames Estuary and Goodwin Sands, whilst swath bathymetric data for the Dorset coast was made available via the DORIS project. These data enabled the generation of enhanced models across the AMAP2 pilot areas. A coarser model of sediment transportation was also generated across the full project area. Once inputs have been defined the model required an iterative approach to model calibration and validation prior to producing the GIS compatible outputs. A report was produced by UoS outlining the approach taken in the development of the model (Carrizales, 2010).

3.2.3.6 ALSF Navigational Hazards and AMAP1

The experience gained from the development of the GIS characterisations developed for the Navigational Hazards project and AMAP1 have provided an important foundation for developing a characterisation which can be used to support planning decisions during the assessment of archaeological potential.

The Navigational Hazards characterisation, which contains a characterization of areas where a high level of risk to shipping coincides with a high potential for preservation was used during the project. The analysis of risk was based on the identification of shallow areas which exhibited trends in environmental navigational hazards, supported by historical evidence of hazards.

The preservation index developed by Dr David Gregory for AMAP1 was included as a core dataset for AMAP2. The assessment of potential for preservation was based on the percentage of gravel contained in different types of marine sediment, which affect the rate at which wrecks are likely to be buried. BGS sediment types were classified using a preservation index (Merritt, 2009).There is a great deal of scope for integrating this analysis with other environmental parameters which affect site formation.

3.2.4 Wreck Data Processing

3.2.4.1 Data preparation

To facilitate the extraction of wreck data, the information within each of the wreck databases was brought together in a project specific Oracle schema, enabling the source data to be mapped to a structure suitable for comparing information held within common fields and integrating the best available information from the two datasets into a single AMAP wrecks attributes table (Figure 7).

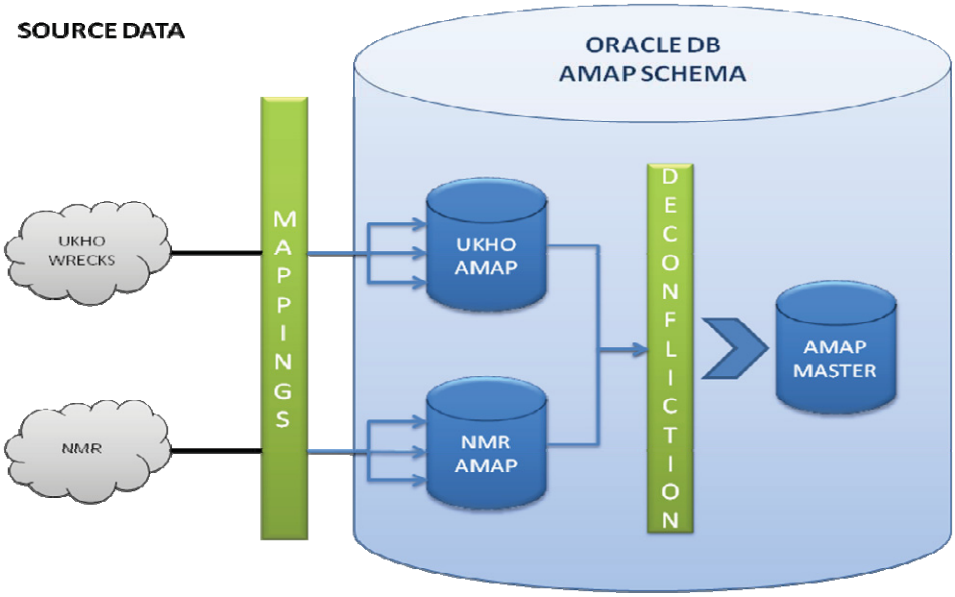


Figure 7: Diagram showing the processes required in the upload of UKHO and NRHE data to the AMAP schema

NRHE database was uploaded to the SeaZone Oracle database to enable the data to be viewed as a single flat file. The wreck data provided by the NRHE was delivered as a series of MS Excel spreadsheets which related back to unique site identifiers (HOB_UID). During the data upload, it

was noted that many of the tables reflected a one-to-many relationship with the HOB_UID. Of particular note was the presence of multiple features relating to a site. In most cases, these sites tended to be intertidal sites where a logboat find was accompanied by a findspot for instance. In these instance multiple dates, evidence, material and identification methods could be associated with a single HOB_UID.

The use of a site identifier rather than a feature identifier removes the presence of a unique identifier to which individual information is associated. To ensure no information was lost when joining the attributes to the AMIE points and polygons, the tabular information was divided into individual sites and given a unique identifier using changes in phase class (DAT_MAX, DAT_MIN) as an indicator of the potential for multiple sites. This approach however produced duplicate records where a record contained a value for one field but not the other.

NRHE data was uploaded to Oracle and associated to the geometries in the GIS layers provided by the NRHE, using the HOB_UID to produce the following structure:

```
ID              NUMBER(16),
NRHE_NAME       VARCHAR2(100),
NRHE_YEAR_OF_LOSS  NUMBER(10),
NRHE_PERIOD     VARCHAR2(100),
NRHE_MONUMENT   VARCHAR2(300),
NRHE_VESEL_TYPE  VARCHAR2(100),
NRHE_PROPULSION  VARCHAR2(100),
NRHE_CARGO      VARCHAR2(300),
NRHE_MATERIAL   VARCHAR2(300),
NRHE_CONSTRUCTION  VARCHAR2(100),
NRHE_LOSS_EVENTS  VARCHAR2(300),
NRHE_CONDITION  VARCHAR2(100),
NRHE_BURIAL     VARCHAR2(100),
NRHE_DETECTION  VARCHAR2(100),
NRHE_HOBUID     NUMBER(10),
NRHE_DESCRIPTION  VARCHAR2(4000),
SEED_ID         NUMBER(20),
UPDATED         DATE,
OBJL            NUMBER(10),
GEOMETRY        SDO_GEOMETRY,
HOID            NUMBER(10));
```

Once both databases were uploaded to the Oracle database, they were mapped to a project-specific schema following a data specification designed for the AMAP2 project. This involved identifying equivalent fields between UKHO and NRHE databases and the structure of data fields required for AMAP (Table 2). This highlighted fields of information shared by both databases and those which were unique to one or the other.

The wreck data review undertaken for AMAP1 (Merritt, 2007) highlighted the range and quality of information which could be drawn from the databases. Some fields are structured around controlled vocabularies (based on S-57 standards for the UKHO database and INSCRIPTION for the NRHE database) while others contain descriptive texts.

Table 2: Relationship table between key fields held within the UKHO, NRHE and AMAP wreck databases

UKHO	UKHO_AMAP	NMR	NMR_AMAP	AMAP_MASTER
NAME	UKHO_NAME	NAME	NMR_NAME	AMAP_NAME
DATE_SUNK	UKHO_YEAR_LOSS	MIN DATE (WHERE EMPTY, USE MAX DATE)	NMR_YEAR_LOSS	AMAP_YEAR_LOSS
		PERIOD	NMR_PERIOD	AMAP_PERIOD
SZ_FEATURE	UKHO_MONUMENT	MONUMENT TYPE	NMR_MONUMENT	AMAP_FEATURE_TYPE
TYPE_OF_OBSTRUCTION	UKHO_VESSEL_TYPE	MARITIME CRAFT TYPE	NMR_VESSEL_TYPE	AMAP_VESSEL_TYPE
TYPE_OF_OBSTRUCTION	UKHO_PROPULSION	PROPULSION	NMR_PROPULSION	AMAP_PROPULSION
CARGO, CIRCUMSTANCES OF LOSS	UKHO_CARGO	CARGO	NMR_CARGO	AMAP_CARGO
CIRCUMSTANCES_OF_LOSS	UKHO_MATERIALS	OBJECT MATERIAL	NMR_MATERIAL	AMAP_MATERIAL
		CONSTRUCTION	NMR_CONSTRUCTION	AMAP_CONSTRUCTION
CIRCUMSTANCES_OF_LOSS	UKHO_LOSS CAUSE			AMAP_LOSS1
CIRCUMSTANCES_OF_LOSS	UKHO_SECONDARY_ACTION	MANNER OF LOSS	NMR_LOSS2	AMAP_LOSS2
WATER_LEVEL_EFFECT	UKHO_EXPOSURE			AMAP_EXPOSURE
GENERAL_COMMENTS	UKHO_CONDITION	EVIDENCE	NMR_CONDITION*	AMAP_CONDITION
GENERAL_COMMENTS	UKHO_BURIAL	EVIDENCE	NMR_BURIAL*	AMAP_BURIAL
GENERAL_COMMENTS	UKHO_INCLINE			AMAP_ORIENTATION
GENERAL_COMMENTS	UKHO_SCOUR			AMAP_SCOUR
GENERAL_COMMENTS	UKHO_GEOMORPHOLOGY			AMAP_GEOMORPHOLOGY
TYPE_OF_OBSTRUCTION	UKHO_FUNCTION			AMAP_FUNCTION
ORIGINAL_SOURCE	UKHO_SOURCE	EVIDENCE	NMR_DETECTION*	AMAP_DETECTION
~~HOID~~	~~UKHO_HOID~~	~~HYDROGRAPH~~	~~NMR_HOID~~	~~AMAP_HOID~~
~~SZID~~	~~UKHO_SZID~~	.	.	~~AMAP_SZID~~
.	.	~~HOB UID~~	~~NMR_HOBUID~~	~~AMAP_HOBUID~~
GENERAL_COMMENTS	UKHO_GENERAL_COMMENTS			
CIRCUMSTANCES_OF_LOSS	UKHO_CIRCUMSTANCES_OF_LOSS			
		DESCRIPTION	NMR_DESCRIPTION	

The AMAP1 method was built upon through the generation of additional data fields, including one recording geomorphological characteristics where possible and through the addition of new terms. The schemas were developed using controlled vocabularies where possible and developing controlled values for newly created attributes and fields. These have been highlighted in the table below (Table 3).

Table 3: Table showing terms used to guide data extraction from fields within UKHO and NRHE attributes for the reclassification of data on the manner of loss and state of wrecks on the seabed

AMAP_ CONDITION	AMAP_ BURIAL	AMAP_ INCLINE	AMAP_ SCOUR	AMAP_ GEOMORPHOLOGY	AMAP_ MATERIALS	AMAP_ LOSS_TYPE	AMAP_ SECONDARY_ACTION
Intact	Exposed	Upright	Yes	Sandwaves	Wood	Military	Abandonment
Mainly intact	Partly buried	Inverted	No	Bedrock	Steel	Accidental	Capsize
Partly broken	Mostly buried	On side		Fine sediment	Iron	Other	Drifting
Well broken	Buried	Broken up		Coarse sediment	Metal		Salvage
Debris field		Listing		Mud	Aluminium		Capture
					Concrete		Dispersed
					Composite		Collision
					Plastic		Grounding
					Fibre glass		Explosive charge
					Ferro-concrete		Structural failure
					Wood-iron		Explosion
							Cargo shift
							Founder
							Fire
							Torpedo
							Gunfire
							Scuttling

3.2.4.2 Data Extraction

The classification of UKHO and NRHE wreck data was undertaken for all English waters to optimise the extraction of trends in wrecks during spatial analysis and ensure that the results are reflected on a national scale.

A great deal of useful information held within the UKHO database is embedded within descriptive string fields such as "GENERAL_COMMENTS" and "CIRCUMSTANCES_OF LOSS". An Oracle based tool was developed internally to facilitate the extraction of data from such fields (Figure 8).

The tool enabled the contents of fields to be checked for spelling. Key words can then be searched for via SQL queries or using a search box to identify all records containing specific terms or phrases within a chosen field. This process essentially formalises the approach taken for the AMAP1 project where SQL queries were applied directly to shapefiles via ArcGIS. The results were fed directly into the UKHO_AMAP table within the schema.

Once the optimum level of information had been extracted from both databases and structured according to the AMAP schema, the databases were linked via the UKHO identifier recorded within both datasets.

Attribute queries were applied to the data using ArGIS to filter out wrecks of shared characteristics, such as all records of vessels recorded as buried and partially buried or all records of vessels recorded as broken up and dispersed.

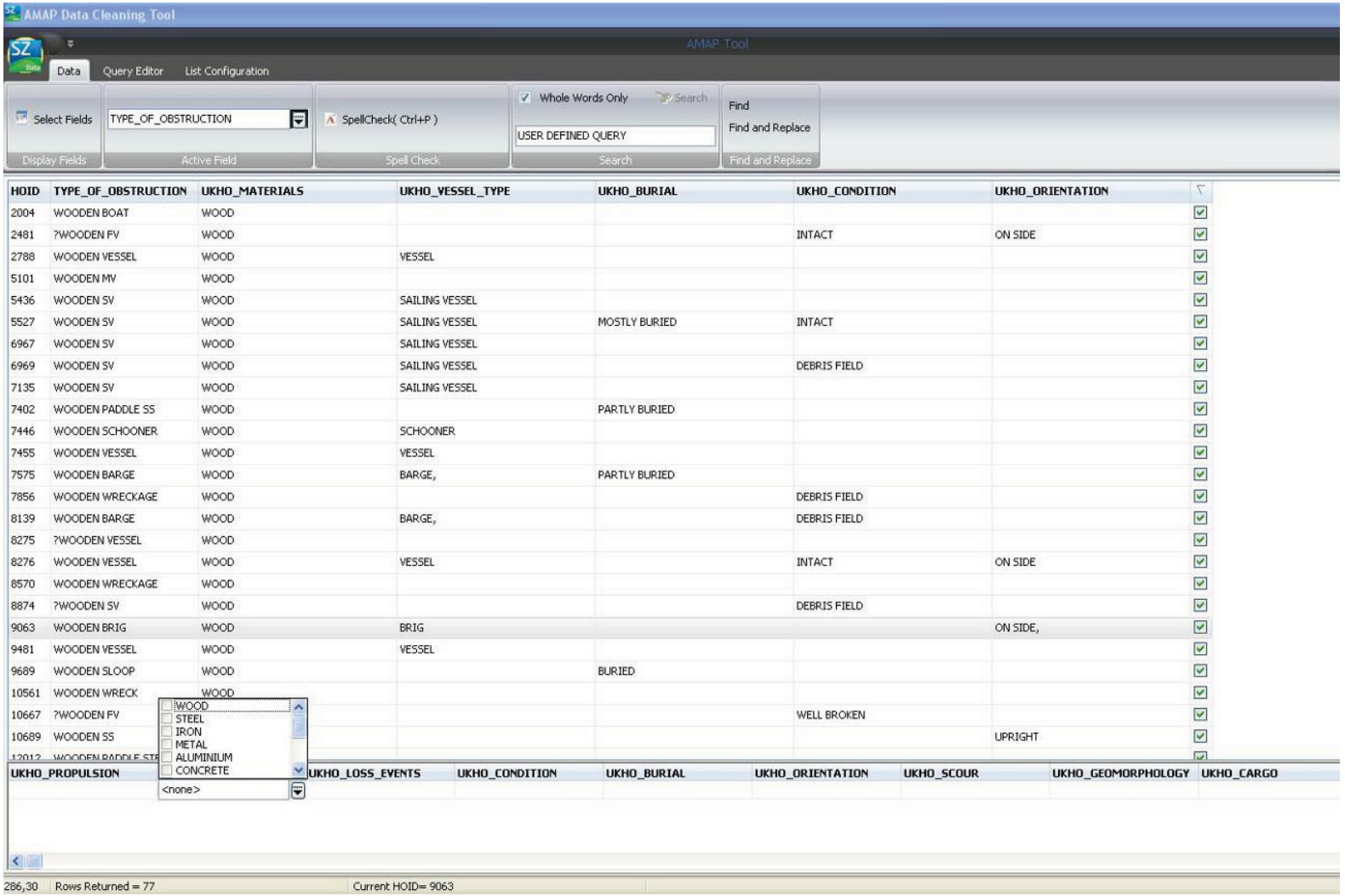


Figure 8: Data extraction tool used to spell-check, then filter valuable information out of the UKHO database and into the AMAP schema

Where information was held exclusively by only one data provider, queries were run on that dataset alone, as per the method used for AMAP1. Where information was drawn from both databases, the values had to be compared to ensure that the best available data was available before spatial analysis. This improved the method used during AMAP1 where queries were run on the largest datasets possible where comparable information existed, due to the complexities of deconflicting the data. Where conflicts cannot easily be resolved, these will be fed back to the *Enhancing the NRHE* project for resolution during its second phase.

3.3 Stages 1c: Environmental Modelling

The modelling of environmental marine data was undertaken by the UoS via an MRes student. This has enabled the project team to further develop the methodology employed for MACHU across the Goodwin Sands and Thames estuary, while providing opportunity for a suitable candidate to undertake original research under the close supervision of a range of experts.

The aim of this stage was to enhance the modelling of environmental data for AMAP, and compare the results with density analyses of wreck data during the analysis stage (1d.) The environmental characterisation during phase 1 was undertaken via the following stages:

1 – Review new environmental data available from BGS, SeaZone and MACHU project

2 – Train the researcher in the range of software packages required to undertake the work, including MIKE21, ArcGIS, Cadcorp SIS and BathySIS

3 – Identify research questions to guide the enhancement of environmental models, in communication with project staff

4 – Undertake modelling of environmental data in project pilot areas

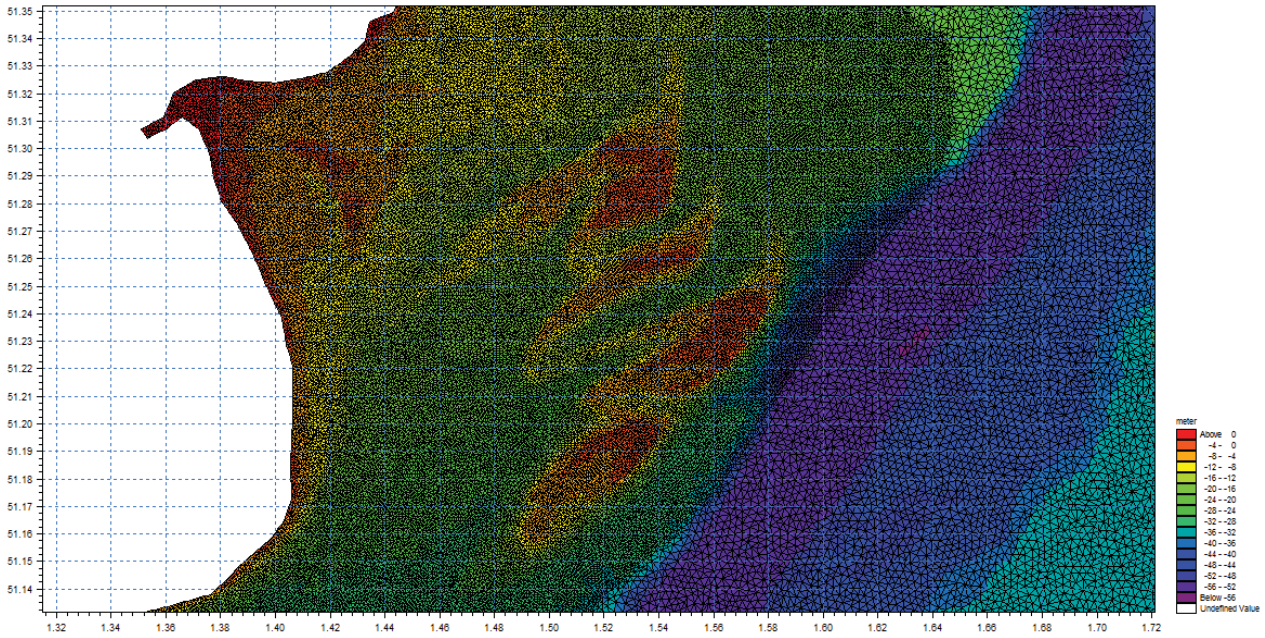


Figure 9: The mesh generated for the Thames area overlaid with bathymetry

SeaZone undertook a phase of modelling bathymetric data, combining best available survey data with charted bathymetry to produce a high resolution (20x30m) Digital Terrain Model (DTM) from its bathymetry holdings database. The model was supplied to UoS to generate a detailed quantitative prediction of sediment transport and bed-level change on a regional scale across the Thames Estuary and Goodwin Sands during the pilot phase of the project. The methodology employed in the development of the model is reported in detail in "*Development and refinement of regional sediment mobility models: Implications for coastal evolution, preservation of archaeological potential, and commercial development*" (Carrizales, 2010). The report will be delivered to English Heritage alongside the project report.

The model built via an MRes project, was produced by first developing a flexible mesh of linear triangular elements (Figure 9) using MIKE 21 over the entire UK continental shelf which increased in resolution (finest resolution 50 m) over the Thames and Goodwin Sands area, while maintaining a lower resolution (1-35 km) over the remainders of the domain (Carrizales, 2010).

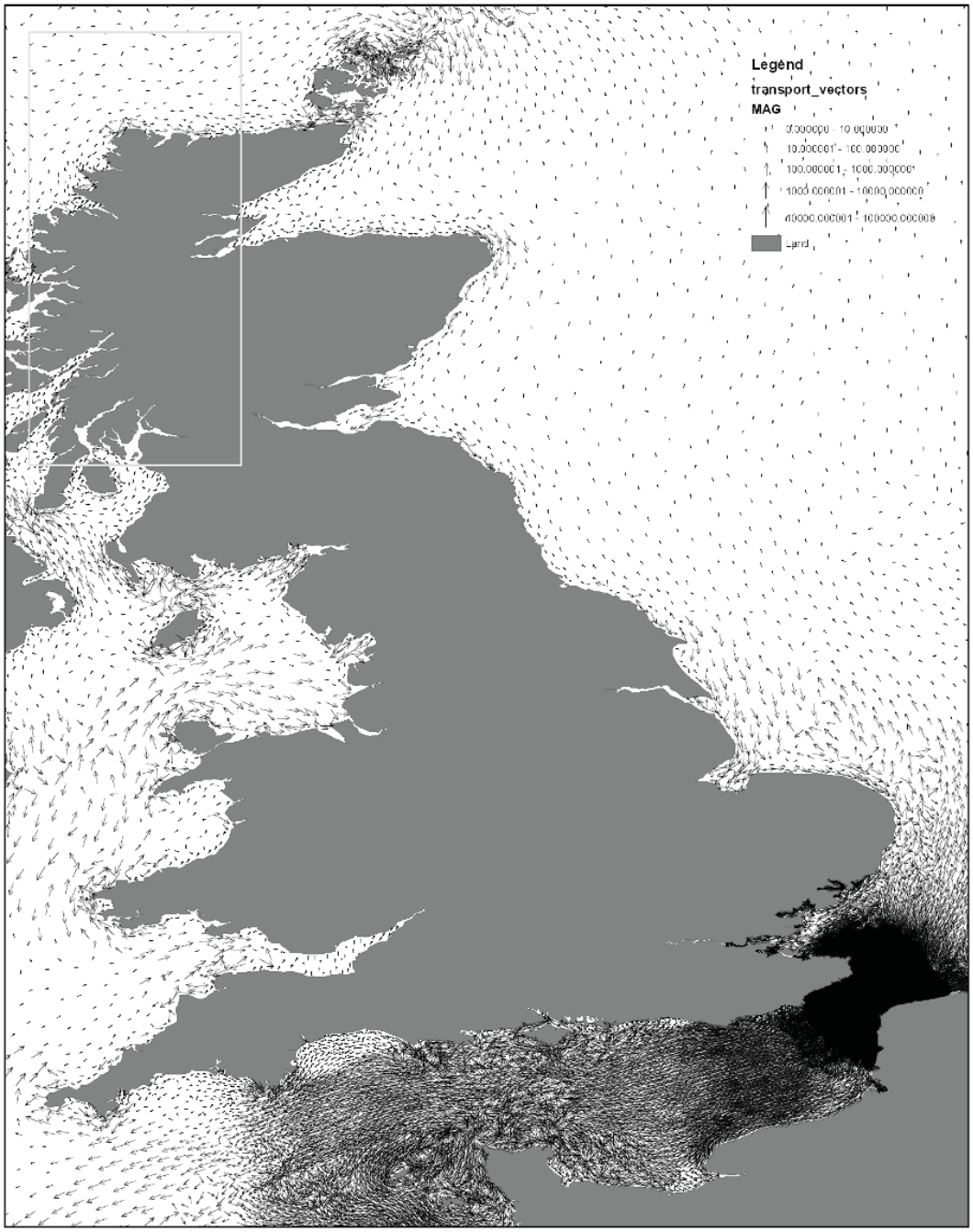


Figure 10: Extracted magnitude of sediment transport for AMAP to highlight dynamic areas

A hydrodynamic model was then produced using MIKE 21 taking account of bathymetry, drying areas over the Goodwin Sands and bed resistance.

A sediment transport model was built taking account of model type, differentiating between pure current or wave and current action, threshold current speed (the velocity at which sediment grains become mobile), and sediment properties.

The models produced underwent a process of calibration achieved through variation of the bed roughness coefficient (Manning number, M) (Carrizales, 2010)

A quality assurance process was also applied to the sediment transport model by comparing it to models produced by HR Wallingford across similar areas as part of the Southern North Sea Sediment Transport Model (HR Wallingford, 2002) as well as comparing against traditional approaches to inferring sediment transport pathways from sonar imagery.

The development of the model via the AMAP2 project brought together parallels in research conducted by SeaZone and UoS into the effects of environmental conditions on the physical properties of wrecks and significance in assessing archaeological potential. The work conducted by UoS also importantly enhanced the methodology for AMAP2 by providing an core dataset used in the analysis of the environmental processes affecting the physical condition of wrecks, both on a national scale and locally during the case studies.

The sediment transport model was used in the analysis of wreck data on a National scale through extraction of information and classification of the magnitude of sediment transport across large areas (Figure 10). On a local scale, the model was used in combination with other environmental datasets in the interpretation of the physical conditions on individual sites.

3.4 Stages 1d: Trial Area Analysis

Following the extraction of information from the wreck data during stage 1b, density maps reflecting different trends in shipwreck characteristics were produced. This analysis highlighted concentrations in the spatial distribution of wrecks which for instance, were timber built or whose physical remains are scattered.

The density analyses of wrecks and the distributions of individual wrecks of shared characteristics were compared with environmental data for the Goodwin Sands and Thames Estuary pilot areas. The results were also compared with those from AMAP1 to proof test the original relationships identified between trends in the condition and state of wrecks on the seabed and the environmental parameters which affect them.

The analysis of wreck data building on the AMAP1 methodology provides an assessment of spatial relationships on a broad scale, looking at distributions of shipwrecks on a national level and comparing them to often low resolution environmental datasets.

The sediment transport models generated by UoS enable a much higher resolution assessment of net sediment transport levels in the marine environment and allow the relationships between the sediment movement and the characteristics of shipwrecks to be compared on a much smaller scale.

The analysis of data across the pilot area focused on identifying and characterizing trends in shipwreck data and their relationships with circumstantial and environmental variables which determine the potential for ships to be lost and the potential for materials to be preserved.

The presence and state of wrecks on the seabed are determined by complex web of inter-relating variables (Figure 11). The methodology for characterising AMAPs has been further developed by looking at a more quantative approach to analysis using statistical analysis and spatial regression analysis to better demonstrate relationships between wrecks and their environments.

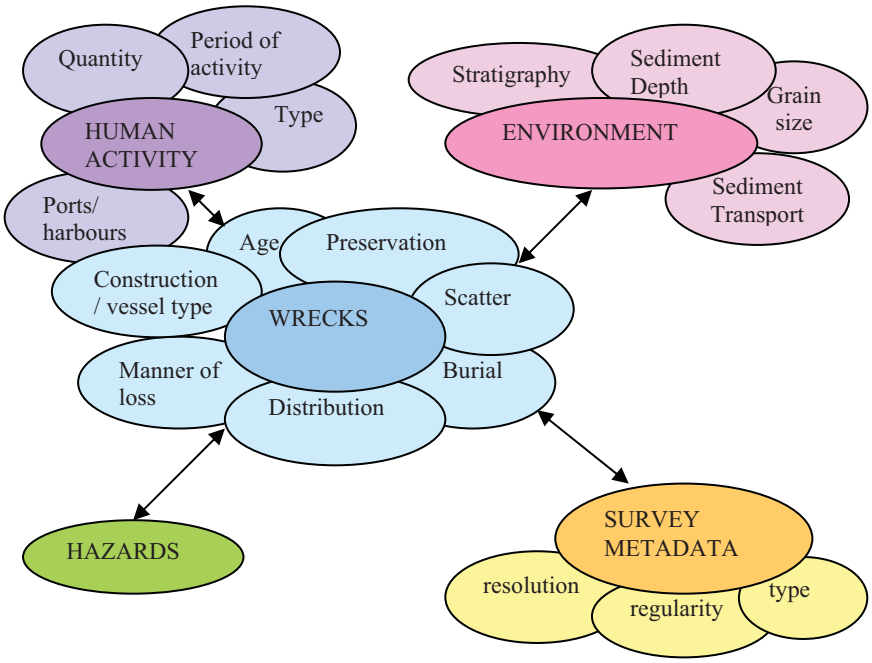


Figure 11: Diagram demonstrating the network of relationships between the available datasets and wreck data which affect the potential for wrecks to exist and survive on the seabed.

The methodology used for data analysis was based on the approach used during AMAP1. Therefore, following the integration of NRHE and UKHO wreck databases and separation of historical and environmental attributes into new field structures via the AMAP schema, a series of attribute queries were run to highlight wrecks with similar characteristics. The queries used across the pilot areas are as follows:

- iron or steel vessels
- wooden vessels
- vessels recorded as being intact
- vessels recorded as being broken up or dispersed
- vessels recorded as buried or partially buried
- vessels recorded as exposed or mostly exposed
- wrecks by period
- ships by manner of loss

The results of these queries were processed using the ESRI ArcGIS Spatial Analyst Density tool to generate raster density maps of wrecks shared characteristics.

The results were compared with the environmental data collated using a similar approach to that employed during. These datasets will be collated with the aim of reflecting the following environmental variables:

- Sediment type/grain size
- Sediment depth
- Sediment transport
- Water depth

3.5 Stage 2a. Analysis and Characterisation of Full Area

The process of analysis applied during Phase 1 was applies to all English waters out to the territorial limit taking account of Phase 1 results. The collation of environmental data was applied

across the entire continental shelf where full coverage of environmental data was available. These datasets included:

- sediment type,
- water depth,
- survey metadata and
- sediment transport

In the case of sediment depth, where the coverage for data was incomplete, the analysis was undertaken across areas where the data was available.

The results are of analysis of wreck data across the full project area is outlined in section 4.1. A comparison was made via three case studies between results interpreted from wreck data on a National scale with evidence drawn from high resolution bathymetric data on a small number of individual wreck sites. These are reported in section 4.2.

The development of an environmental characterisation was undertaken using available environmental data seen to affect the preservation potential of archaeological materials on the seabed.

3.6 Stage 2b. Case studies

The project design proposed that testing of GIS characterisation would be undertaken over a range of case studies areas focussed on aggregate license areas. It was however found that a review of available data within aggregate areas showed only limited availability of wreck sites within the license areas with recorded information on their physical condition and characteristics.

Two case study areas were chosen to compare the results of the full area analysis with trends seen on individual wrecksites. The areas were selected based on the availability of both suitable wreck data and environmental data within a limited area. UoS supplied high resolution bathymetry data from the DORIS project covering the Dorset area and data from the Thames Estuary. A series of sites across both case study areas were selected and compared with the national scale AMAP2 results.

The quality of bathymetry data enabled the condition of wreck sites to be assessed on a site by site basis and compared with the information recorded by the UKHO wrecks database and the assumptions made during the national scale comparison of wreck data with environmental variables.

The comparison of bathymetric images of wrecks with the attributes recorded by the UKHO and NRHE and with their environmental and archaeological parameters has highlighted the complexity of their relationships but provided support for the trend identified on a National scale. Further testing of these apparent relationships between large scale trends and individual sites would benefit from further investigation by looking at wrecks on a site-by-site basis across a larger area in order to confirm the validity of the results compared between two very different scales.

3.7 Stage 2c. Reporting & Delivery

A preliminary report outlining the results of phase 1 was delivered to English Heritage in November 2010.

This document provides a full report of the project's methodology and results. A report was produced by UoS to outline the methodology and results of the sediment transport modelling work undertaken for AMAP2. The report will be delivered to English Heritage as part of the project deliverables.

A project GIS will be delivered upon completion of the project. The GIS will consist of a vector grid-based characterisation of the environmental variables affecting the potential for wrecks to survive on the seabed, where coverage of data is available. The database of wreck information gathered from the UKHO and NRHE will also be delivered although constitutes a complex derived dataset which would need to be used under a license agreement with both the UKHO and NRHE.

4. RESULTS

The analysis of data focuses on identifying and characterizing trends in shipwreck data and their relationships with circumstantial and environmental variables which determine the potential for ships to be lost and the potential for materials to be preserved. The refinement of AMAPs has been undertaken through the quantitative analysis of groups of wrecks as outlined below in the context of environmental and circumstantial variables.

The distribution of wrecks was assessed by overlaying wreck point data and running attribute queries to gain an understanding of their distribution in relation to physical and environmental parameters. Spatial analysis was also used to produce density maps showing areas where similar wrecksites were concentrated. These maps were compared with environmental and historical parameters where relationships were anticipated.

4.1 Wreck Data Analysis

4.1.1 Introduction

The analysis of data focuses on identifying and characterizing trends in shipwreck data and their relationships with circumstantial and environmental variables which determine the potential for ships to be lost and the potential for materials to be preserved.

Two approaches have been used to assess relationships between wreck related parameters. Statistical analysis of the relationships between the physical characteristics of wrecks was undertaken using simple relationship tests such as Spearman Rank and regression analyses.

The spatial analysis was then applied between wreck properties and environmental parameters. The refinement of AMAPs has been undertaken through the quantitative analysis of the available datasets outlined bellow within the project study area in order to identify the relationships between them. The coverage of the two databases differs as the UKHO record wrecks lying in UK territorial waters and beyond, while the English Heritage remit include English waters out to the 12nm limit (Map 1a).

4.1.2 Wreck Data Assessment

During the initial joining of UKHO and NRHE wreck databases in the AMAP schema using the commonly recorded UKHO unique identifier (HOID), an assessment was undertaken of the quality of available matching records (map 1b). The results were used to inform the project regarding estimated best available results, to identify areas where data overlapped or conflicted and to feed the results back to the *Enhancing the NRHE* project run in parallel by Maritime Archaeology Ltd. The figures below provide insight into the number of errors on a national scale, providing context to the results of the work undertaken across a series of case study areas by Maritime Archaeology Ltd (see Dellino-Musgrave 2010).

The analysis was undertaken using the same methodology employed for the AMAP1 Shipwreck Data Review (Merritt, 2007) and the first phase of the *Enhancing the NRHE* project (Dellino-Musgrave 2010). The results are summarised as follows:

National scale data joins:		**Relationship counts (HOBUID : HOID):**	
UKHO wrecks	23025	1:1	4774
NRHE wrecks	5799	2:1	97
Total HOBUIDs linked	4788	1:2	14
Total HOIDs linked	4749		
No. NRHE Obstructions	138		
No. Linked with different name	3656		

The results showed that a large proportion of records held in AMIE in English waters have a recorded equivalent UKHO record (4991/5799) (Map 1b). The analysis did highlight cases of one-to-many relationships existing in both directions between the databases, making the numbers of matching records difficult to verify. The assessment suggested that a total of 4774 records could

be matched via a 1:1 relationship while the total number of UKHO records with a match is 4749 and the total number of NRHE records with equivalent UKHO UIDs was counted at 4788. A further 138 UKHO obstructions were recorded as having equivalent NRHE records.

An assessment of the number of matched records with exact matching names was comparatively low as also shown via the *Enhancing the NRHE* project and previously in AMAP1. This is primarily due to variations in the recording standards for site names and vessel types between the UKHO and NRHE. However, cases of errors in the association between two records have been identified, where vessels had an entirely different name and date of loss.

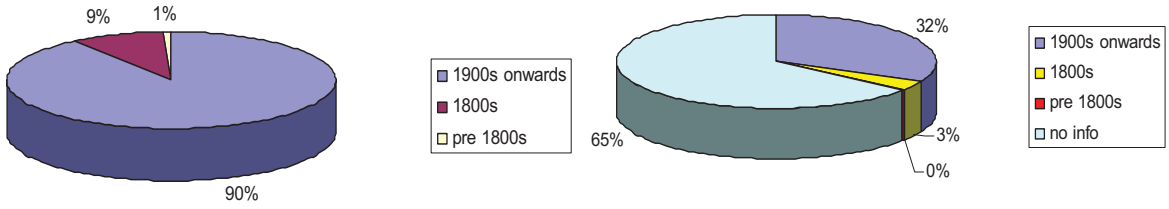
The results of the analysis undertaken during this project supported those of the *Enhancing the NRHE* project. The latter took place across a series of case studies, leading to the submission of a further round of project research to investigate and resolve where necessary potential inconsistencies between the UKHO and NRHE databases (see Dellino-Musgrave 2010).

4.1.3 Wrecks by Period

Wrecks were first queried to highlight their distribution with respect to their age. Wrecks were grouped using the following categories:

- 1900 onwards
- 1800 to 1899
- Pre-1800

The results of analysis across the full project area reflected those seen during AMAP1 and across the pilot areas for AMAP2, showing a strong correlation towards modern vessels (Figure 12) (90% of wrecks with a recorded date of loss and 32% of all wrecks), with a distinct drop in the number of records dated before 1900 (Figure 13). Only 1% of dated wreck sites were recorded as pre-1800 (Figure 14).



During the pilot study, the Thames Estuary showed a particularly low number of pre-1900 wrecks. A density map of pre-1900 wrecks across the full project area (showed a similar lack of wrecks in the Severn Estuary with contrasting high numbers of wrecks in Liverpool Bay and off the coast of the Humber Estuary.

The approaches to the Thames are characterised by large areas of fine grained seabed sediments with high sediment transport levels producing large areas of mobile sand waves and banks. The water depth is variable ranging from less that 1m to 50m. There are numerous modern DEAD wrecks recorded in the UKHO database within the area suggesting high numbers of sites suffering rapid degradation or burial due to the dynamic nature of the environment. This is likely to explain the lack of earlier wrecks recorded of an earlier date.

Wrecks recorded as LIFT tend to be focussed along the river rather than on the approaches. The area falls under the responsibility of the Port of London Authority (PLA), responsible for the maintenance of navigational channels up the Thames since 1908, which would have included the removal of wrecks and obstructions presenting a risk to navigation.

The Severn Estuary has one of the largest tidal ranges in the world and is characterised by large areas of exposed bedrock. The lack of LIVE or DEAD wrecks in the area suggests that wrecks were not being picked up by routine hydrographic survey or maintenance dredging in the first place. The approaches to the main ports on the Estuary around Bristol remain fairly direct routes with the channel only narrowing past Port of Bristol (including Bristol City, Avonmouth, Portishead and

Royal Portbury Docks) and Cardiff. The deep wide channel and lack of sandbanks provide relatively safe access to the larger ports despite the tidal range.

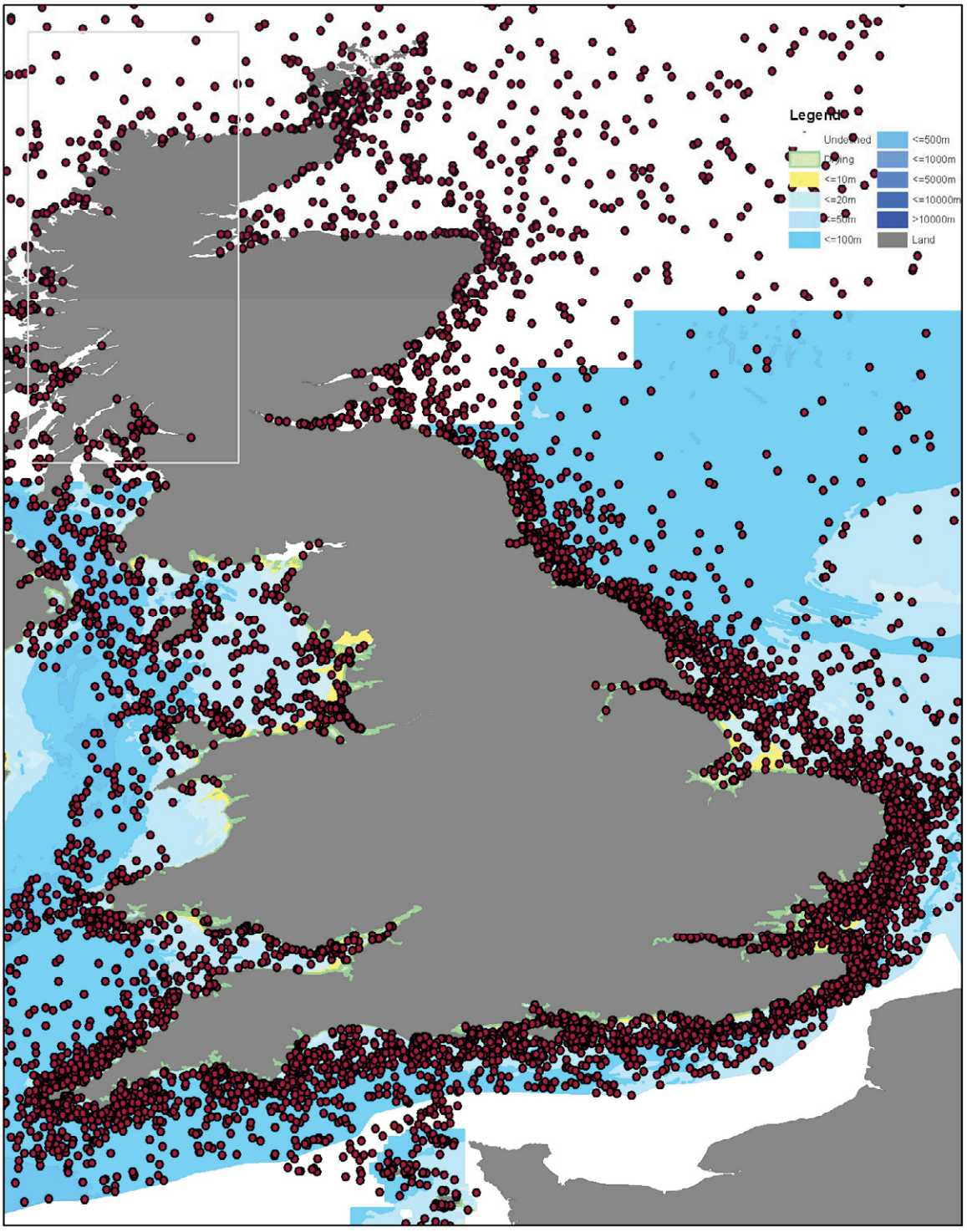


Figure 12: Distributions of wrecks by age showing post 1900 wrecks

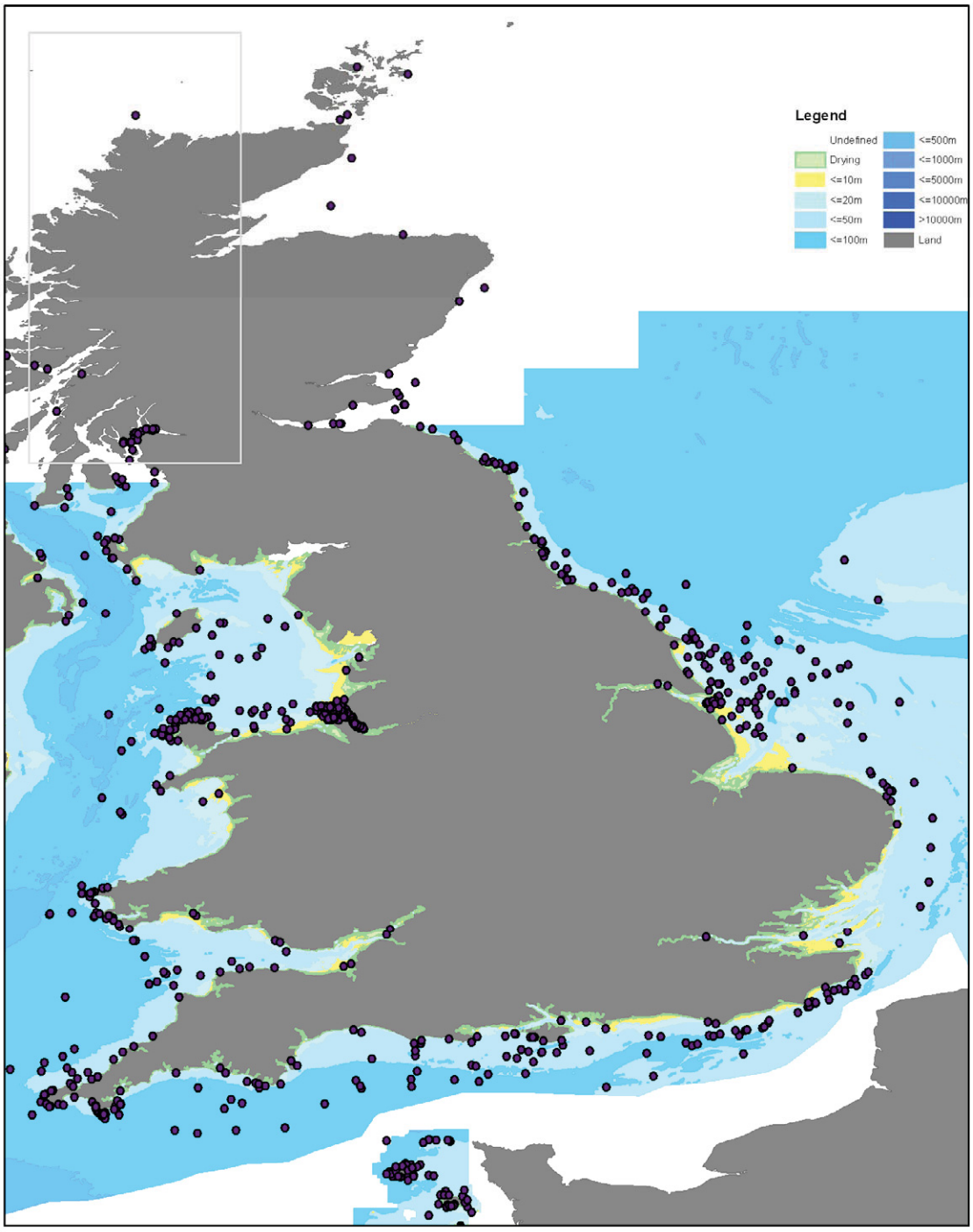


Figure 13: Distributions of wrecks by age showing wrecks lost between 1800 and 1900

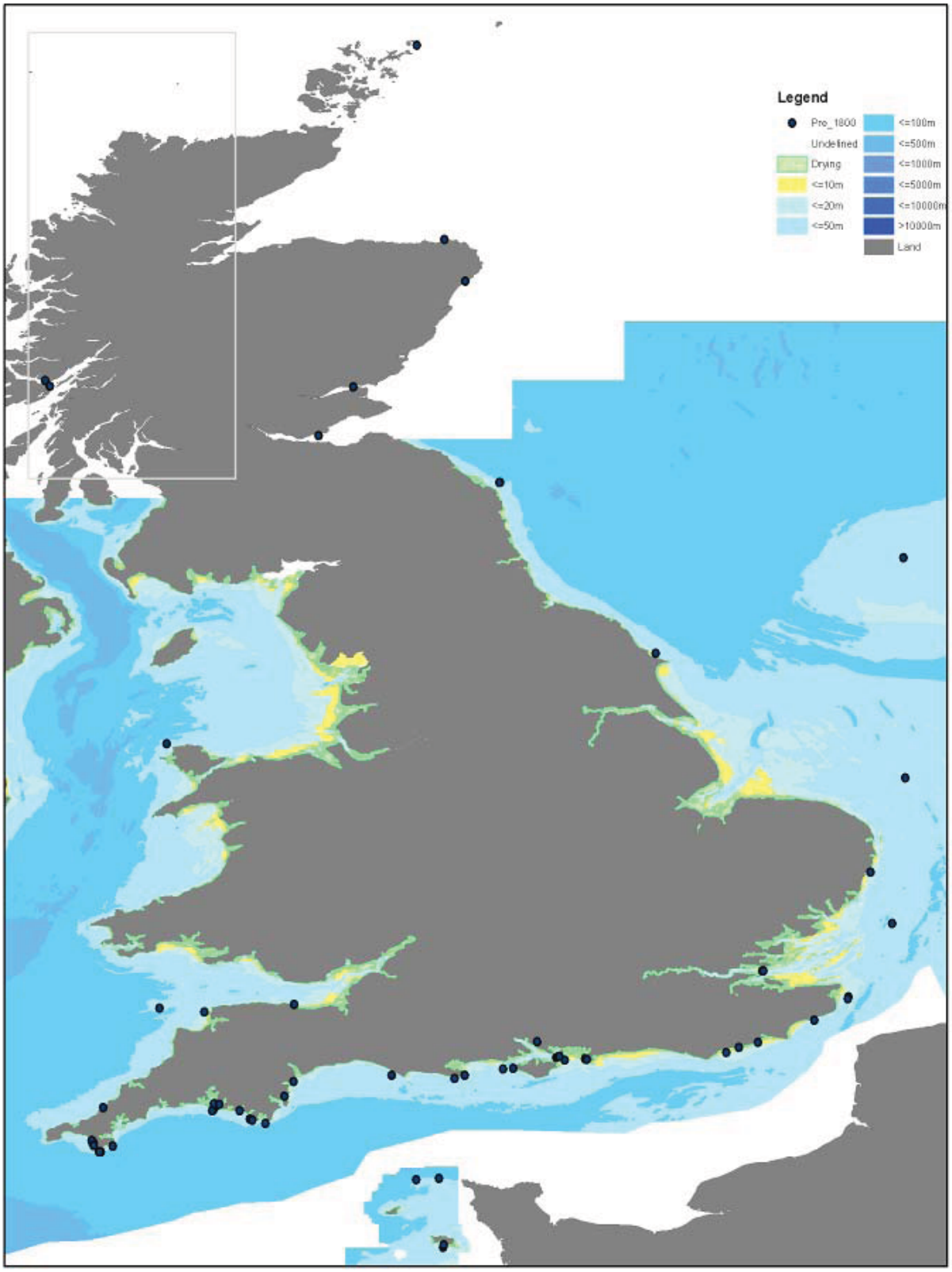


Figure 14: Distributions of wrecks by age showing pre1800 wrecks

The lack of sediment and dynamic environment also reduce the potential for wrecks to survive long-term through burial and preservation in situ. The correlations identified spatially were verified using statistical correlation tests which confirmed the bias and relationships between material construction and age.

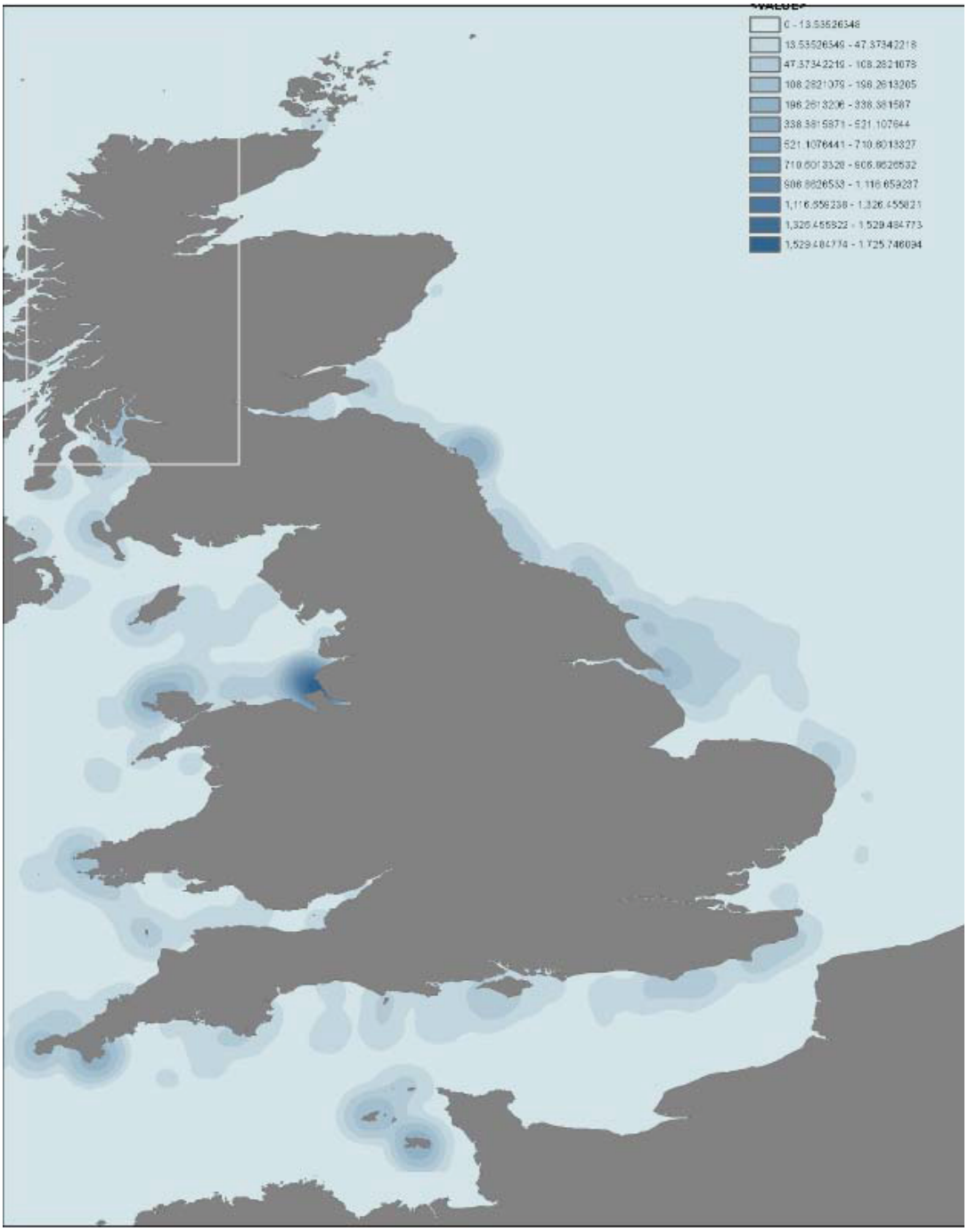


Figure 15: Density map of pre-1900 wrecks across the UK

Liverpool Bay has a similarly high tidal range but in contrast showed a high number of wrecks, particularly at the mouth of the Mersey River (Figure 15). The area is characterised by high levels of suspended sediment and re-deposition in the river and estuary suggesting a high potential for burial or archaeological materials. The Mersey is known for being a busy waterway, providing difficult access for shipping due to the narrow breadth of the channel, sandbanks on its approaches and high tidal range. A review of the sites at the mouth of the Mersey showed high

numbers of losses due to collisions. Most of the wrecks were recorded in the deeper parts of the channel and were recorded as broken up and dispersed, probably due to the high energy environment cause by the tides. Most wrecks in the area are recorded by the UKHO as LIFT or DEAD, suggesting that although many wrecks have been recorded there, few survive long-term. Regular maintenance dredging of channel would have ensured continuing new wreck discoveries in the dredged areas, as seen in the Eastern Solent (Merritt, 2008) despite their limited survival period.

The East Coast provides little shelter from storm events with its exposed coastline, but most areas apart from the Banks off the Humber are characterised by a steep increase in water depth from the coastline, providing few navigational hazards offshore, but difficult access to safe-havens within the harbours built along the exposed coastlines and up narrow river channels such as the Tyne and Humber. The concentration in wrecks along the North Eastern coast of England is focussed inshore along a busy coast characterised by several large industrial ports following the industrial revolution such as Hartlepool, Newcastle and Hull. The wrecks on the approaches to the Humber are focussed offshore around the Dogger Bank, where water depth can be less than 10m from Lowest Astronomical Tide (LAT), rather than in the Humber Estuary itself. The environmental conditions along the coast provided a high risk environment to shipping, particularly in bad weather, reflected in the high numbers of wrecks inshore between the Wash and Scottish Borders.

4.1.4 Wrecks by Period and Construction

When wrecks were displayed on a National scale by their primary construction materials, post-1900 wrecks showed a clear bias towards steel vessels with considerable numbers of iron and wooden wrecks, as both materials remained in common use throughout the 20th century. The majority of steel wrecks recorded were dated to the mid-to-late 1900s (Figure 16). All pre-1800 wrecks with construction were recorded as being of wooden construction, where information on construction was available.

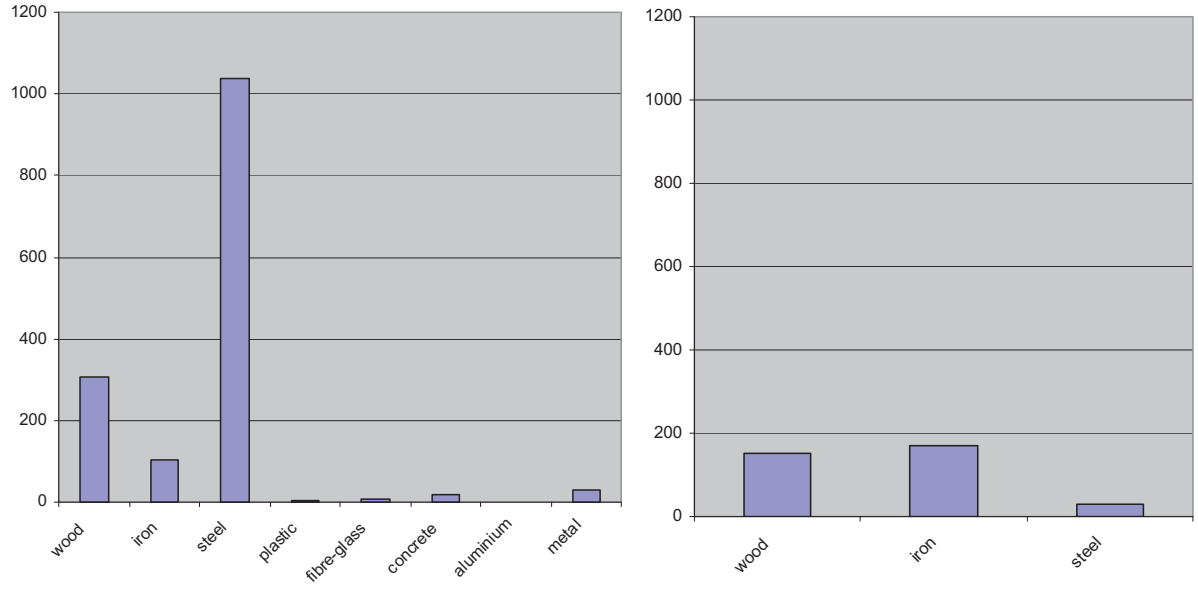


Figure 16: Histograms showing the numbers of wrecks of different material construction for a) post 1900 wrecks and b) 1801 to 1900 wrecks

Wrecks recorded as lost during the 1800s showed a distinct lack in the use of steel with high concentrations in iron and wooden wrecks. The spatial distributions of wrecks by period and material construction are shown in Figure 19, 15 and 16. Spatially, wooden wrecks showed a concentration of sites inshore, as suggested during AMAP1 (Figure 19). During AMAP1, it was assumed that they were likely to break up at a faster rate than iron or steel wrecks, and that there may be an increased potential for fragmentation followed eventually either by burial in some environments (fine grained sediments, stable) or dispersal and degradation in others (dynamic, coarse grained or exposed bedrock) (Merritt, 2007). This bias may therefore be explained by the condition of many older wooden wrecks making them less likely to be picked up through routine

hydrographic survey but more likely to be identified through recreational diving activities which tend to occur inshore.

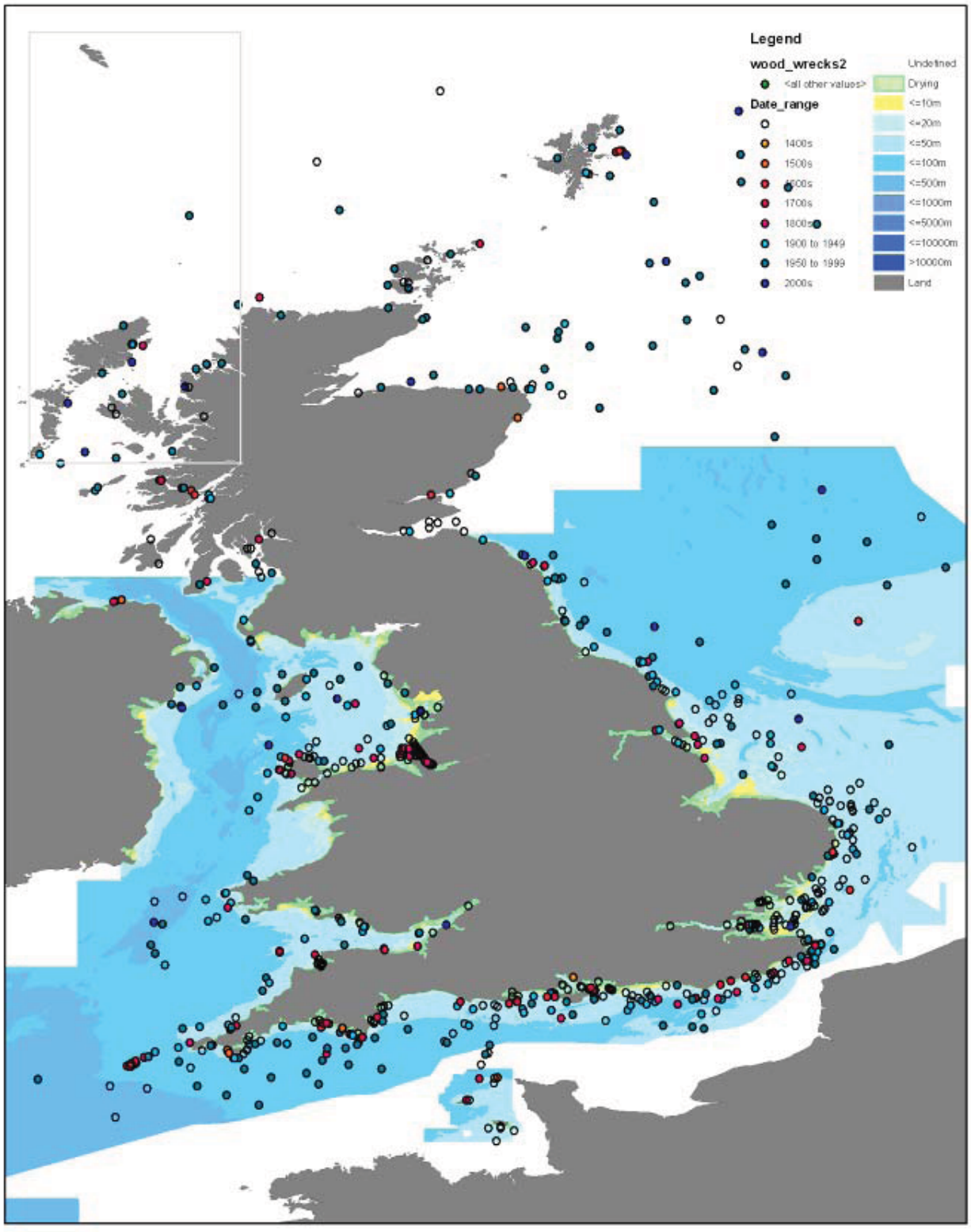


Figure 17: Wooden wrecks showing a fairly even mixture of periods ranging from pre 1800s onwards

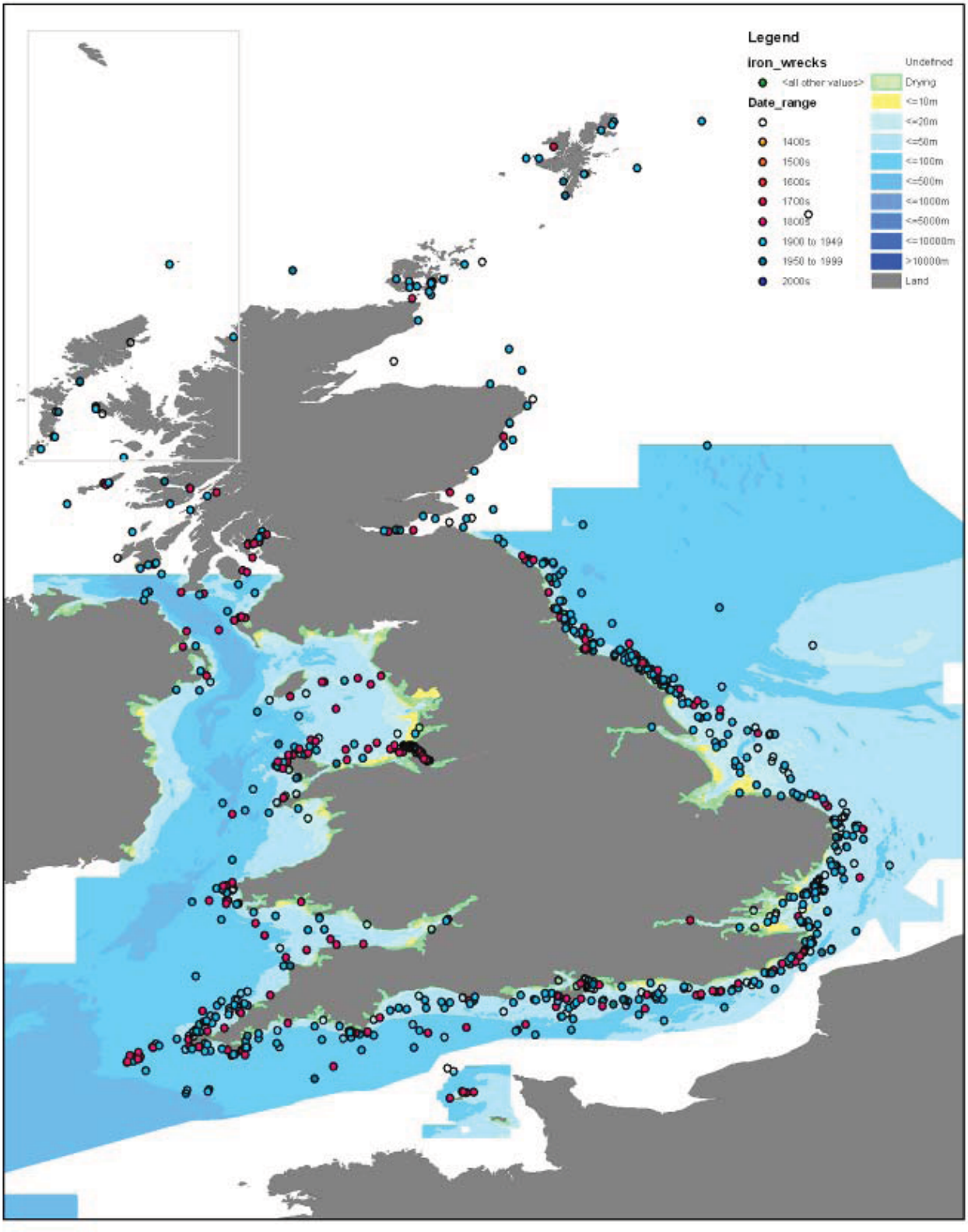


Figure 18: Iron wrecks showing a predominance of losses during the 1800s and 1900s

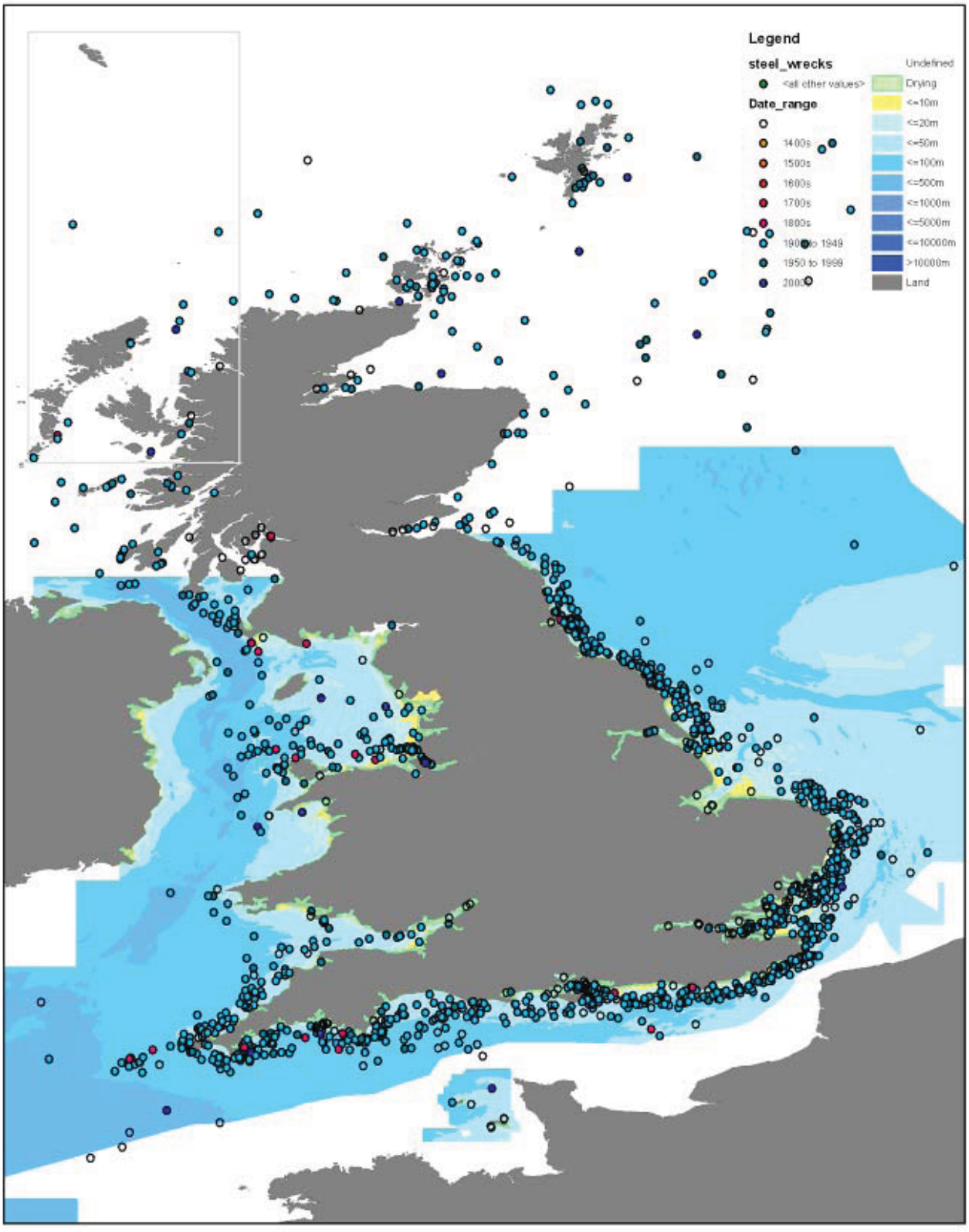


Figure 19: Steel wrecks symbolised by period, showing a majority of wrecks from 1900 onwards

A series of density maps of wrecks by material type, shown in figures 20, 21 and 22, suggest distinct show potential relationships between material type and industrial activities, particularly in the case of iron and steel wrecks. Steel wrecks, predominant used during the 20th century show some concentration in vicinity of busy industrial ports which played important roles during the 1st and 2nd World Wars such as Plymouth, Southampton and Dover on the South coast, the Thames estuary, Hull and Newcastle on the East Coast (Figure 20).

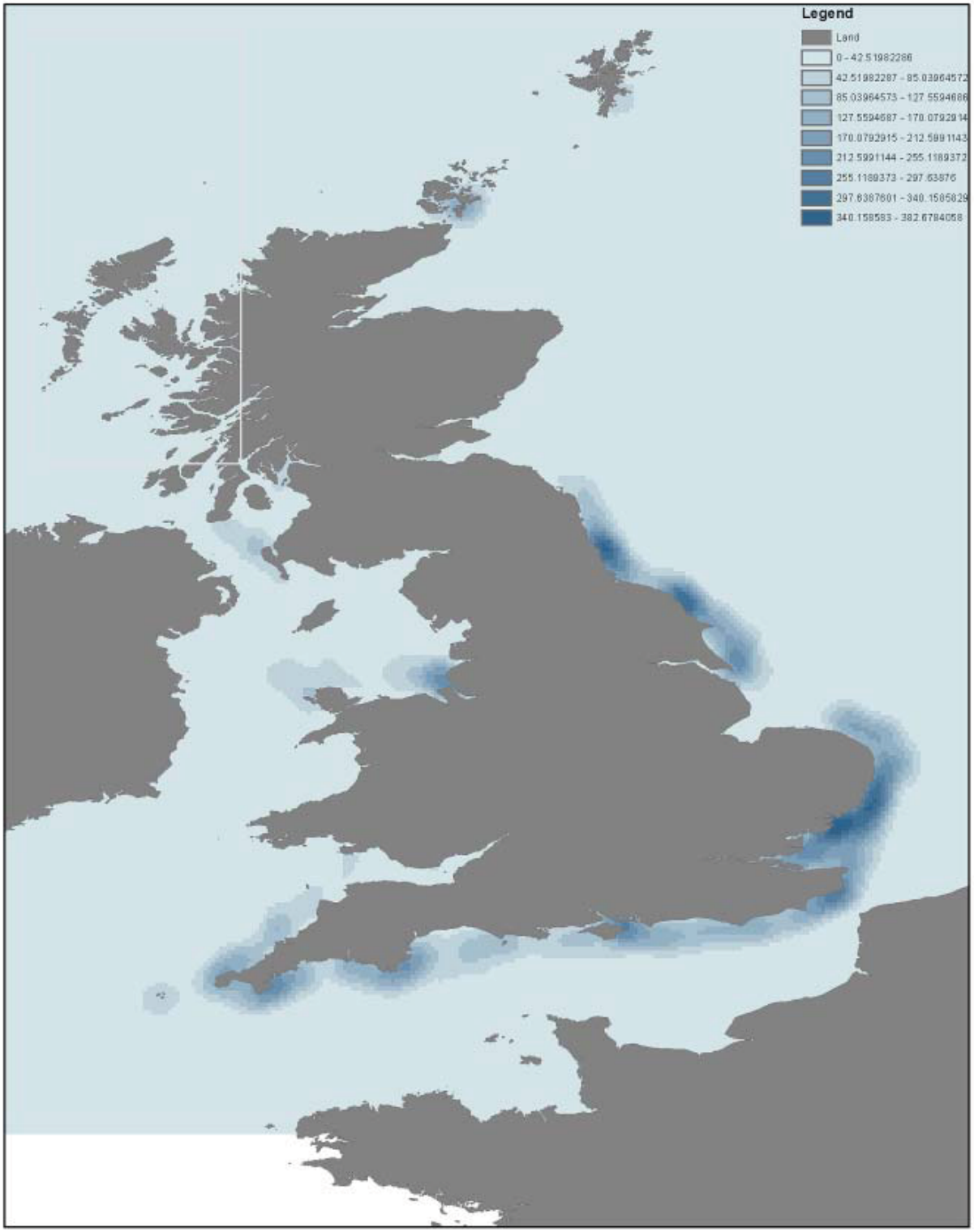


Figure 20: Density of steel wrecks

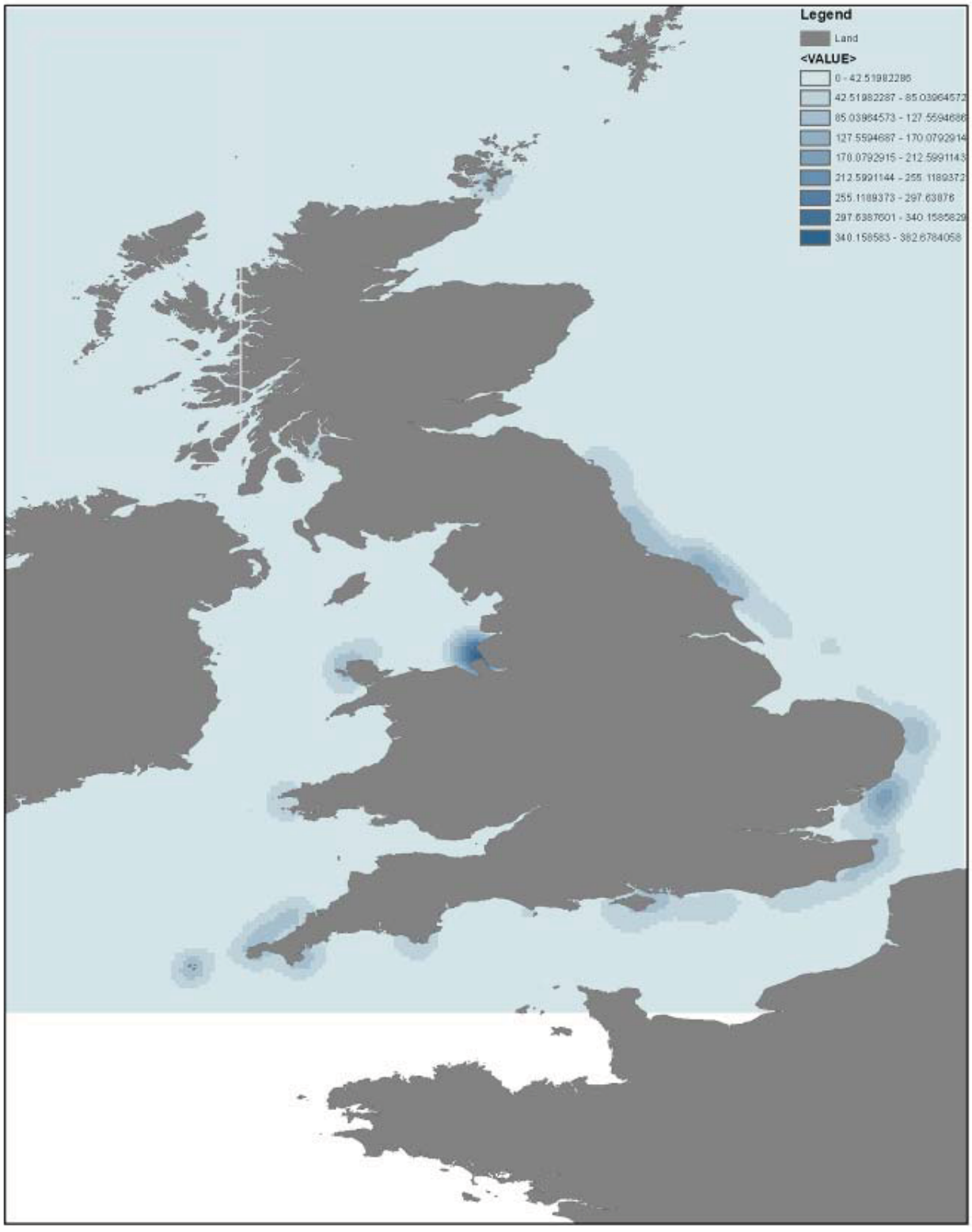


Figure 21: Density of iron wrecks

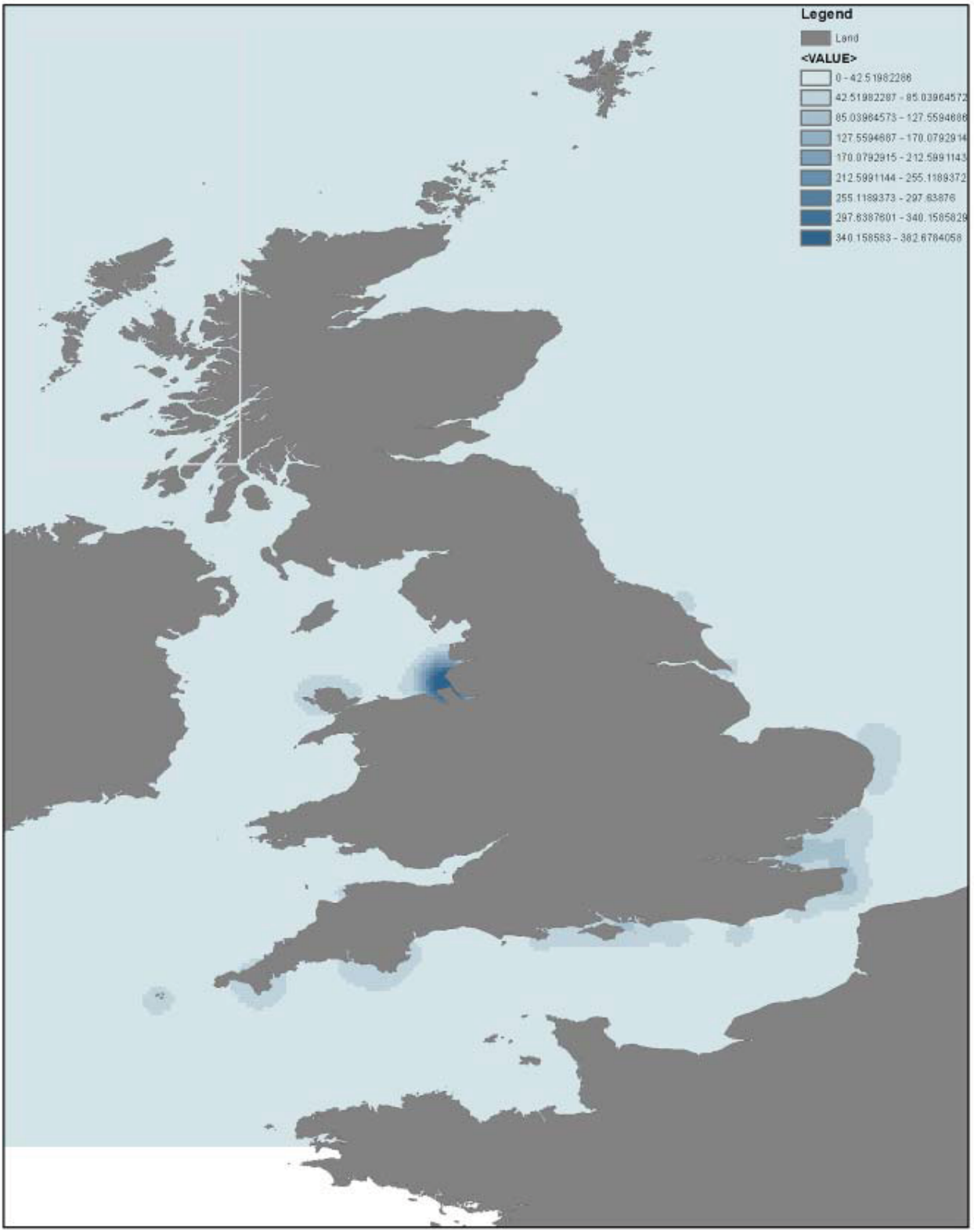


Figure 22: Density of wooden wrecks

4.1.5 Wrecks by Condition

The analysis of potential physical and environmental factors expected to have an impact on the deterioration in the structural condition of shipwrecks was assessed, initially across the pilot area in the Thames Estuary and Goodwin Sands.

The statistical analysis of relationships between the physical condition of a wreck and its material construction using the open source statistical package "R" suggested a demonstrable correlation between the two physical attributes. No correlations could however be demonstrated across the pilot area between the physical properties of wrecks and the environmental variables.

The Spatial analysis of wreck data conducted over the pilot area suggested a possible spatial relationship between condition, the depth of water and the dynamic nature of the environment and degree of sediment transport. The results showed a bias towards wrecks recorded as broken up and dispersed in areas of shallow dynamic environments (Figure 23).

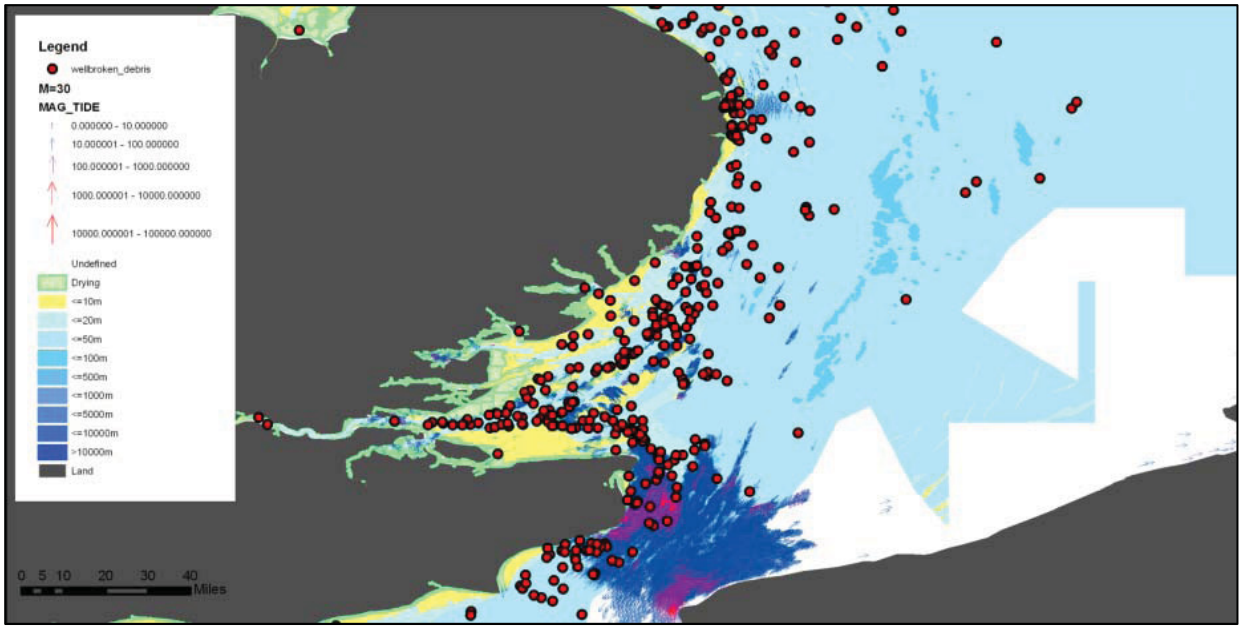


Figure 23: Distribution of wrecks recorded as highly fragmented or broken up, compared with water depth and sediment transport

On a national scale, a review of the spatial distributions of wrecks by their recorded condition on the seabed continued to suggest a bias in wrecks recorded as intact or mostly intact toward deeper water. Wrecks recorded as broken, mostly broken or debris fields tended to lie in areas characterised by medium or highly dynamic areas or shallow inshore areas (Figure 24).

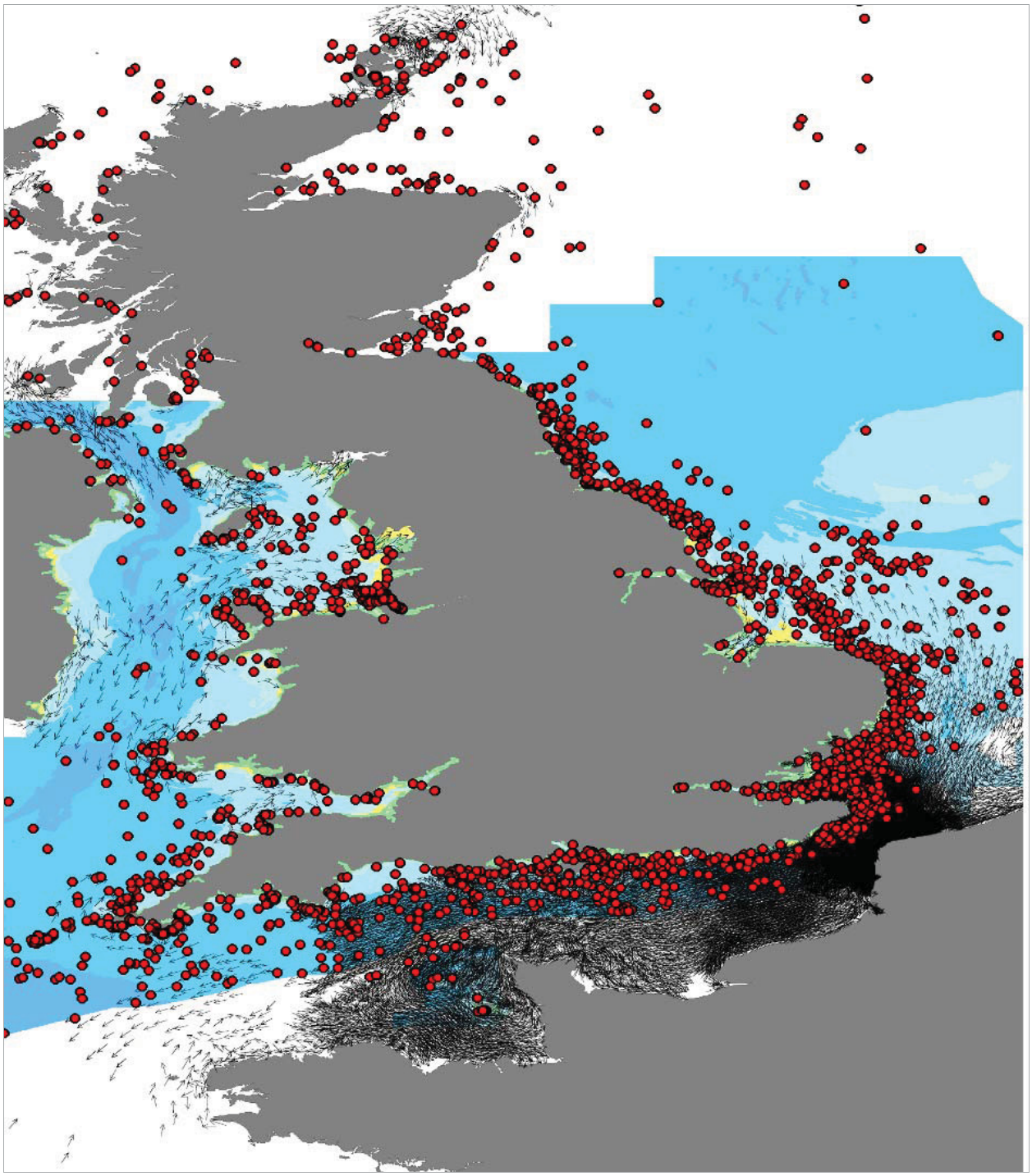


Figure 24: Broken wrecks shown overlaid with a medium to high sediment transport rate

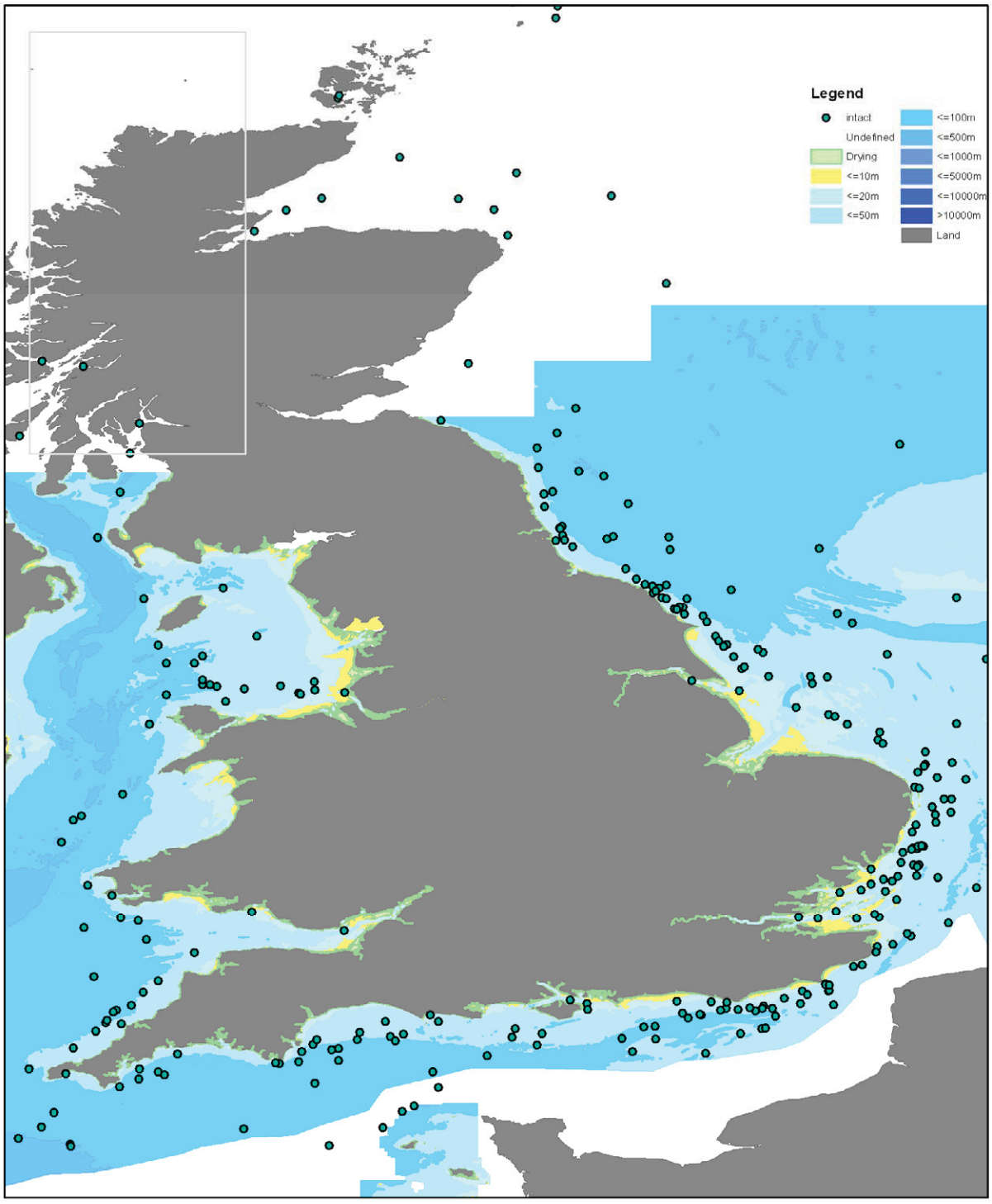


Figure 25: Distributions of wrecks recorded as intact showing bias towards deeper water and broken wrecks tending to correlate with dynamic areas

The distribution of wrecks recorded as intact shown in Figure 25 suggests greater concentrations in areas of deeper water, irrespective of the degree of sediment transport recorded. This may suggest that sediment transport has a greater impact of structural integrity of wrecks when combined with shallow depths.

AMAP1 showed little difference between the distributions of intact and scattered wrecks. Both groups contained records lying in areas characterised by shallow sediments and medium/high sediment transport, with less sites recorded in deeper sediments offshore (Merritt, 2007).

A review of the condition recorded for wrecks from different periods showed that those from the 1900s onwards had the highest numbers of sites recorded as intact with much lower numbers of sites recorded as very broken or debris fields. Wrecks from the 1800s showed a majority of wrecks recorded as very broken of debris fields when compared with intact sites (Figure 26). There were too few pre-1800 sites with a record of their condition (only 5) to show a meaningful histogram but it is likely from the low numbers of existing records and known condition of most protected wrecks from that period that the majority of pre-1800 wreck sites would be recorded as debris fields.

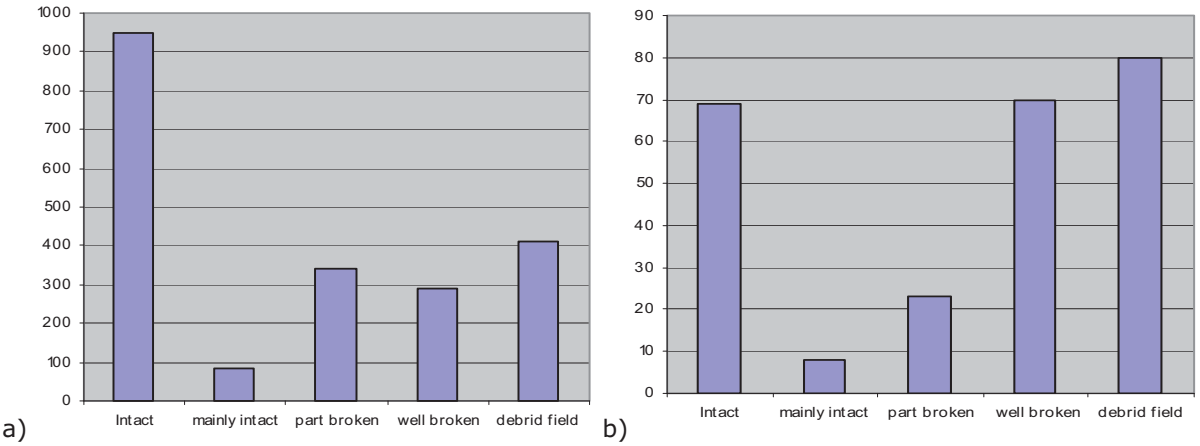


Figure 26: Histograms showing numbers and condition recorded a) post 1900 wrecks and b) 1801 to 1900- Majority v broken inshore in shallower waters, intact offshore in deeper water

The spatial distribution of well broken wrecks by their age group showed that the bias towards shallow dynamic areas of seabed bore no relation to age, but appeared to be reflected in modern as well as older wrecks (Figure 27).

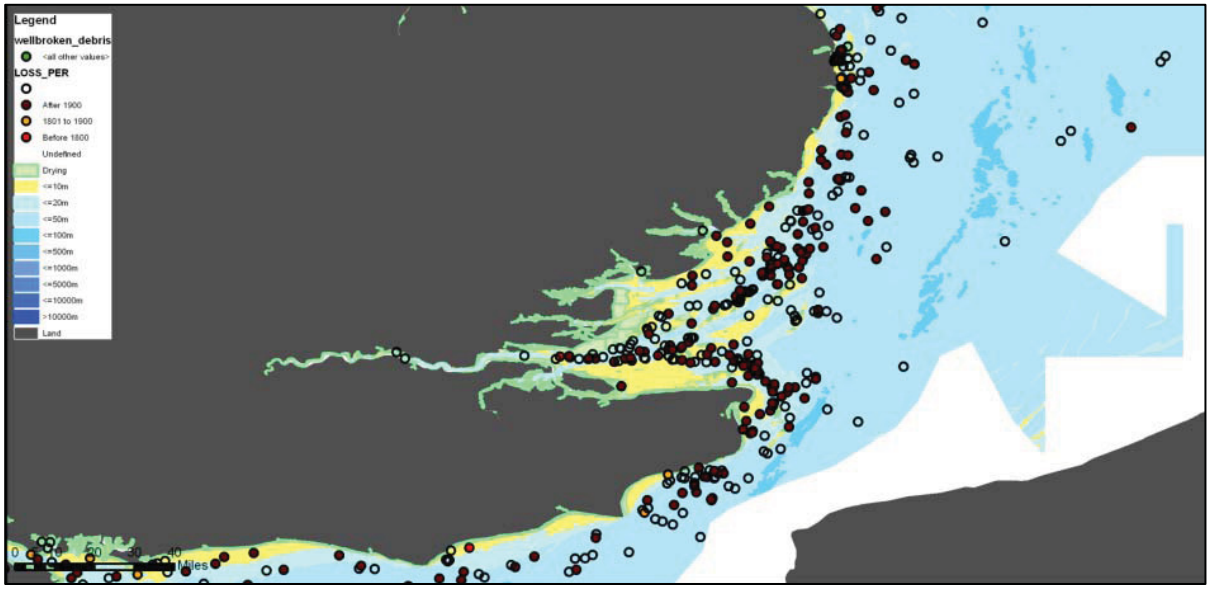


Figure 27: Map showing distribution of well broken wrecks symbolised by age group

4.1.6 Wrecks by their degree of Burial

Looking at the distributions of wrecks by their degree of burial on a National Scale, the patterns in the distribution of wrecks recorded as buried or mostly buried supported those observed across the pilot area.

The AMAP2 wrecks database was filtered to display wrecks by their degree of burial in seabed sediments where the information had been recorded. These were then compared with environmental variable anticipated to affect the burial of wreck sites.

A review of the distributions in wrecks recorded as buried or mostly buried across all English Waters showed that wrecks recorded as buried or partly buried occur in areas where sediment depth is estimated to be less than 1m deep (Figure 28), supporting the theory that wrecks can be recorded as buried in the UKHO wrecks database in areas of very shallow sediment.

Most deep sediment areas in the Thames Estuary, analysed during the pilot study are due to the presence of large sandbanks and sandwaves. In studying the pilot area, it was found that most wrecks recorded as experiencing a notable degree of burial were not necessarily recorded in areas characterised by deeper sediments. A similar trend was seen during AMAP1. Although a large number of sites exhibiting some degree of burial have been recorded in deeper sediments in the mouth of the Estuary, several concentrations of *partially buried* wrecks lie in areas where the sediment is less than 1m thick (Merritt, 2010).

The distributions seen in the Thames Estuary did however suggest that wrecks recorded as experiencing a high degree of burial, recorded in the database as *buried* or *mostly buried,* do however tend only to occur in areas of deep sediment or in close proximity to them, also characterised by a high level of sediment transport. An assessment of the condition recorded for the same wrecks showed no direct correlation with the state of wrecks on the seabed, i.e. wrecks could be recorded as intact/mostly intact and buried in shallow sediment areas.

AMAP1 assessed the age and construction of wrecks recorded as buried, finding that most buried wrecks to be of iron/steel construction with only as small proportion constructed from wood Merritt, 2007). The same analysis, applied to the AMAP2 pilot area showed few records of buried sites containing information on construction materials. The few identified were primarily of wooden construction.

Although the relationship between burial and sediment thickness was not immediately apparent, comparison of the degree of burial affecting sites with the sediment types characterising their local environments showed that wrecks recorded as experiencing some burial, ranging from those recorded as *partially buried* to *mostly buried* and *buried,* tended to lie in areas of fine grained sediment (Figure 29). Where wrecks were recorded in areas of coarser sediment, these tended to remain in close proximity to dynamic fine grained areas of seabed. A strong relationship also appears to be evident between burial and medium or high levels of sediment transport (Figure 30). These results were reflected in the initial observations made across the pilot areas (Merritt 2010).

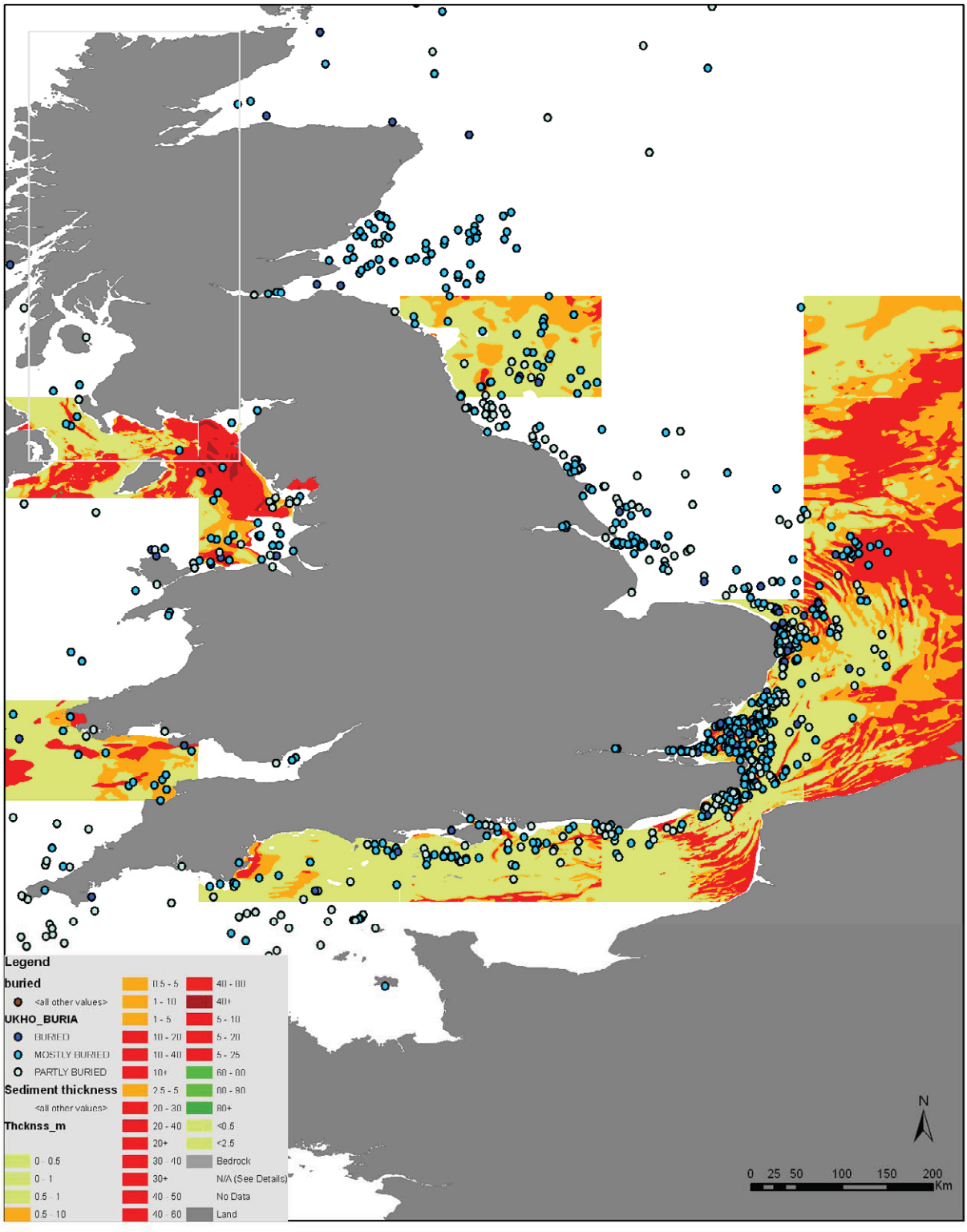


Figure 28: Wrecks recorded as buried or mostly buried shown overlaid with a sediment thickness map

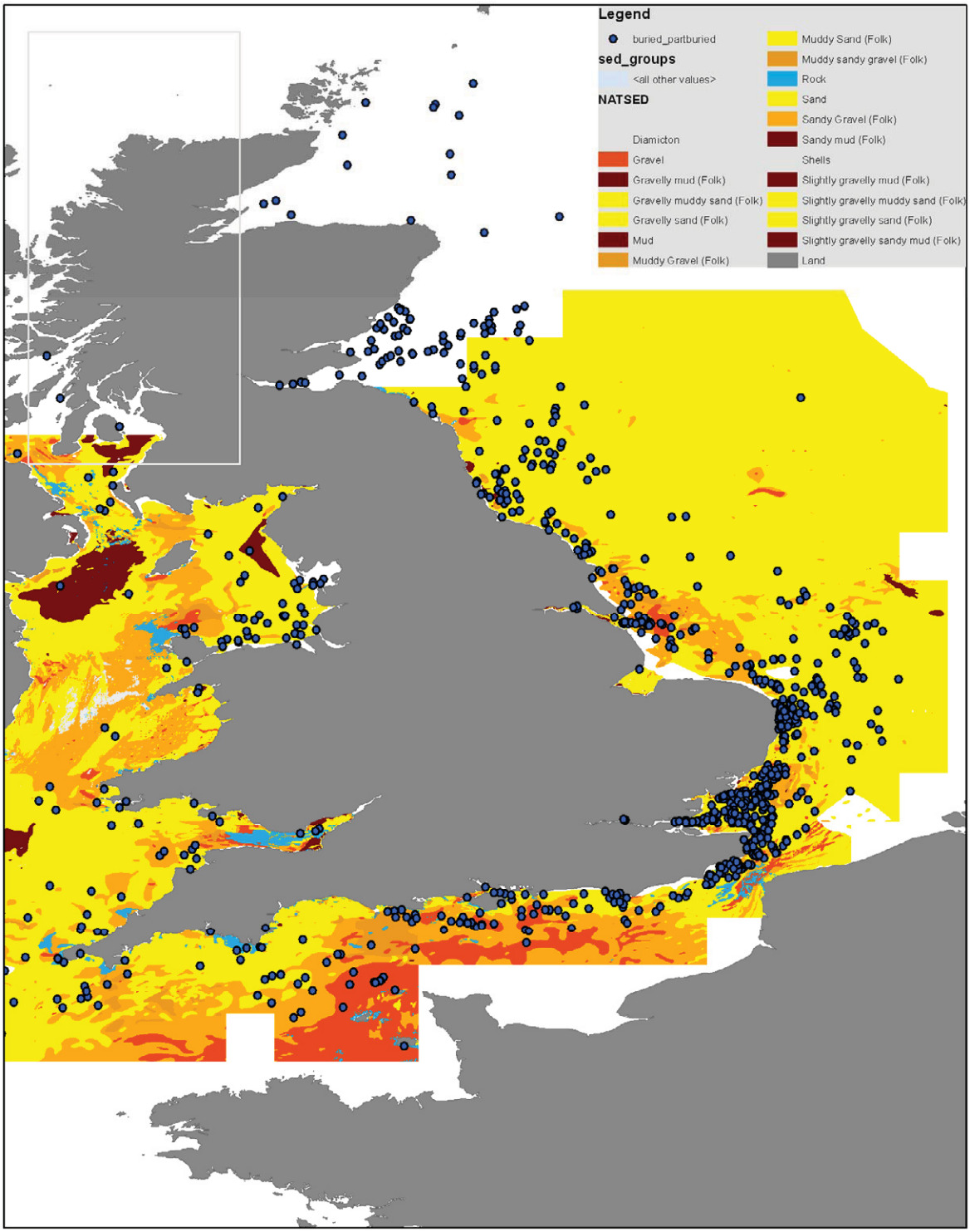


Figure 29: Map showing wrecks recorded as buried or partly buried lying in areas of predominantly fine grained sediment

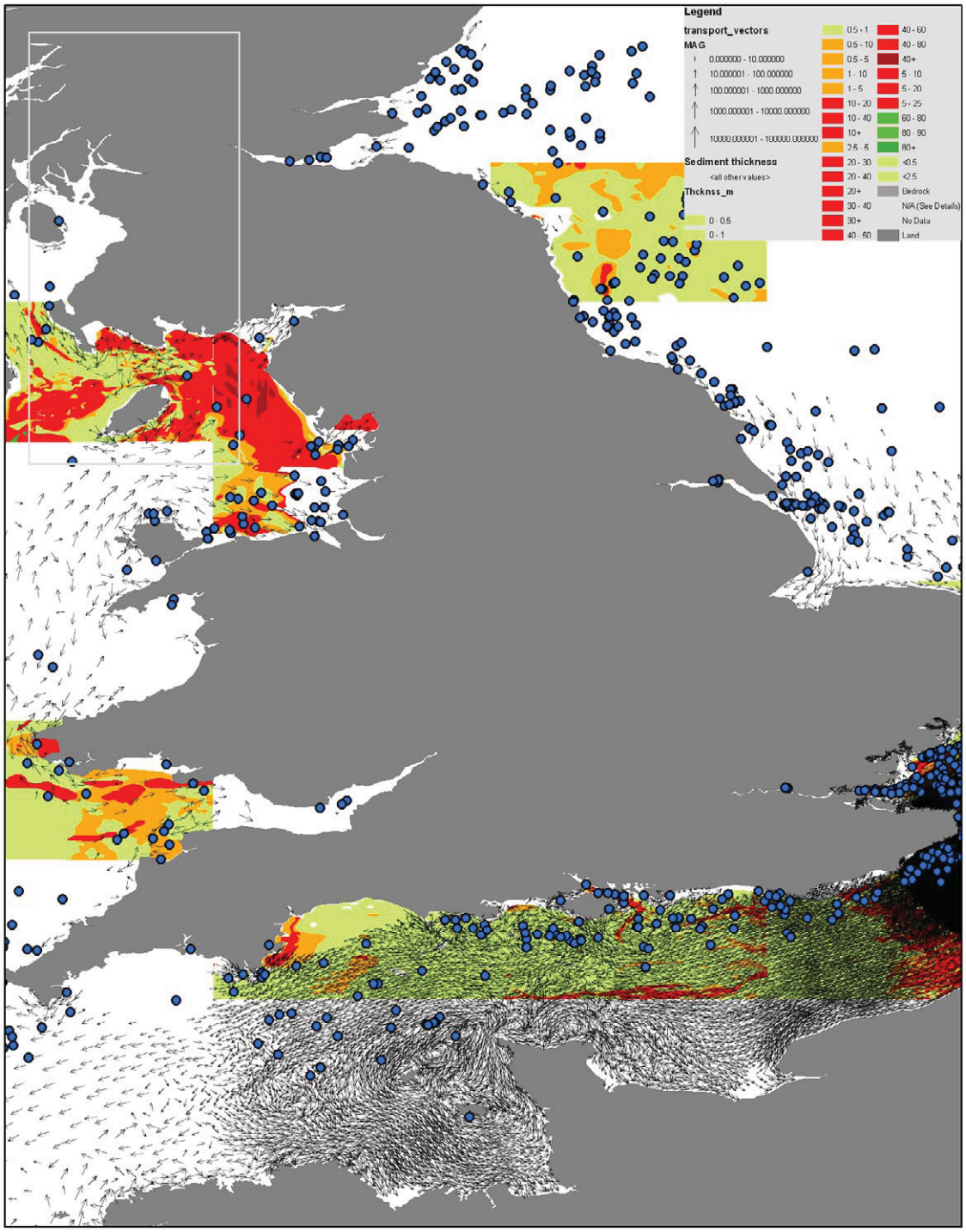


Figure 30: Maps showing wrecks recorded as buried or partly buried lying in areas characterised by medium to high sediment transport rates

An observation of wrecks recorded as exposed or experiencing marginal levels of burial, recorded in the database as *Exposed* or *Mostly exposed,* tended to lie in areas of shallow coarse grained sediment (Figure 31, Figure 32) when assessed across both the pilot area and full project area. They are also often recorded in areas of dynamic seabed, suggesting very limited transport of coarse grained sediments even in high energy environments.

A review of the year of loss of wrecks recorded as exposed showed the majority to be post 1900.

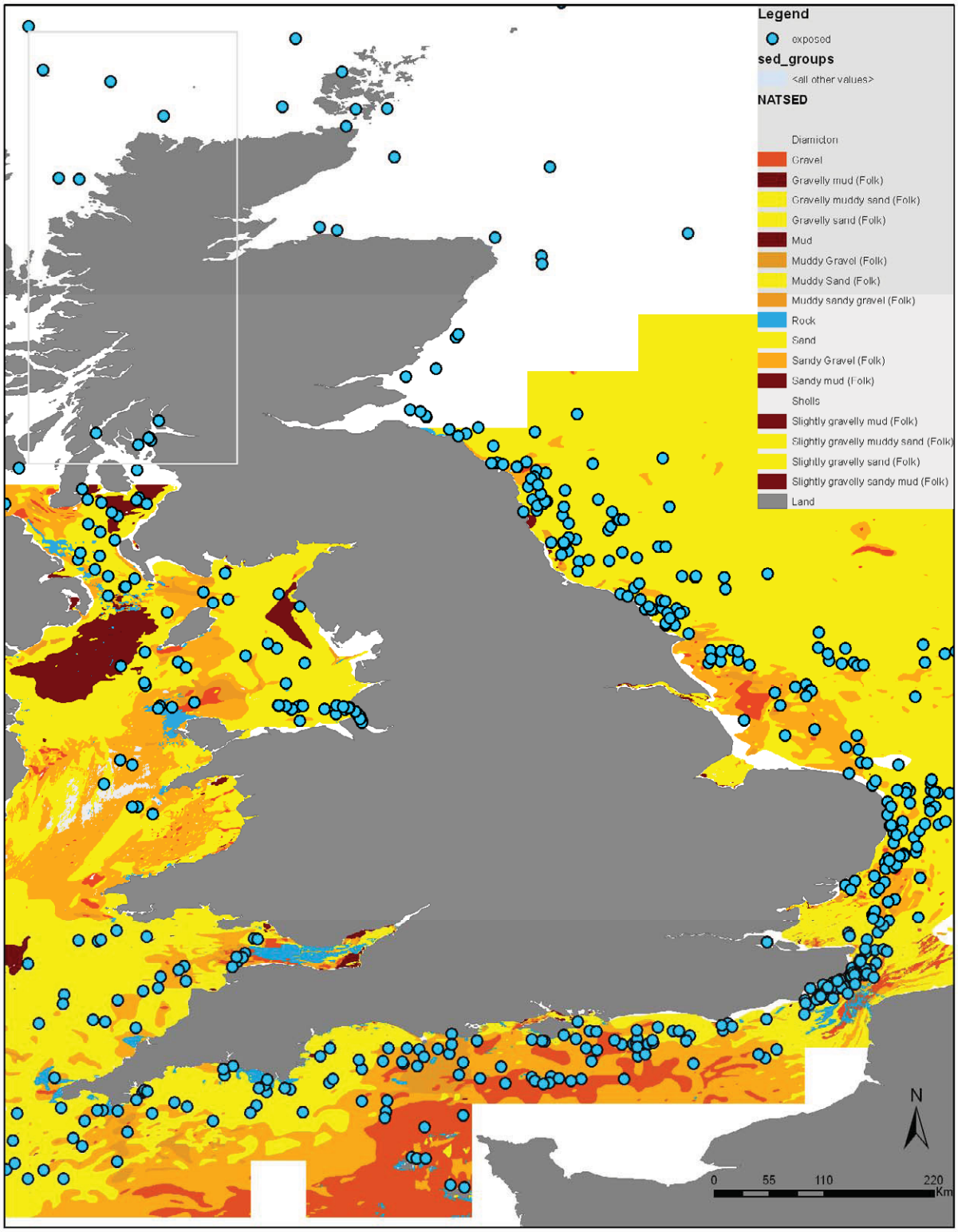


Figure 31: Maps showing wrecks recorded as exposed or mostly exposed correlating with areas of shallow sediments

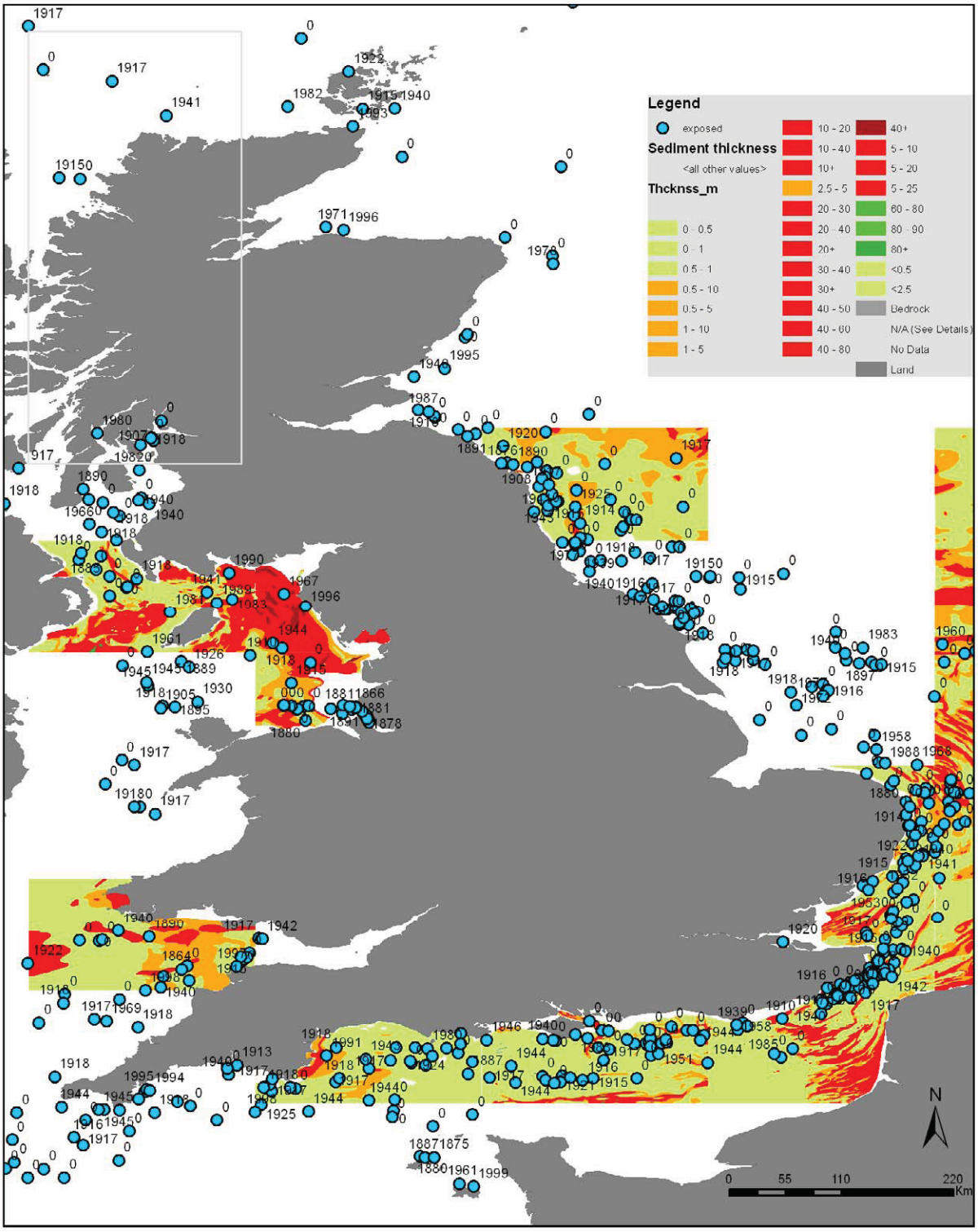


Figure 32: Maps showing wrecks recorded as exposed or mostly exposed correlating with areas of coarse sediment types

4.1.7 Wrecks by Manner of Loss

The results of the assessment of wrecks grouped by their manner of loss produced similar results to those of AMAP1. The same categories of loss were employed to group the sites. The dominant

causes of losses recorded in the database were due to torpedo attacks, groundings or collisions (Figure 33).

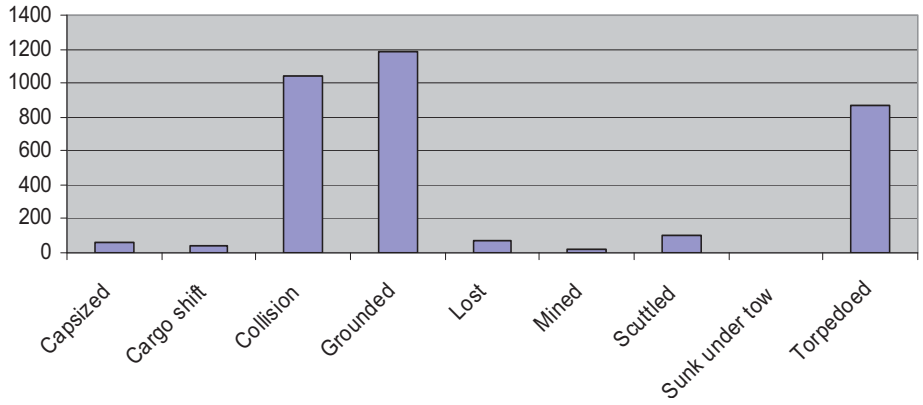


Figure 33: Graph showing dominance of wrecks recorded by the NRHE and UKHO as lost due to torpedo attacks, grounding or collisions

The distribution of wrecks lost due to grounding however showed a predictable correlation with shallow water depth (Figure 34), and tended to be recorded as scattered similarly to those assessed for AMAP1. Only a very small number of wrecks lost due to grounding were recorded as intact. The majority of wrecks lost due to collision were dated from the late 19th century onwards and the majority were steam powered.

Similarly to AMAP1, vessels lost through military action showed that by far the largest number of vessels lost in the pilot area were due to mines, with a concentration clearly visible off the south Kent Coast outside Dover. The next highest number of wrecks was due to torpedo attacks.

4.2 Case studies

Two areas were chosen to compare the results of the full area analysis with trends seen on individual wrecksites. The areas were selected based on the availability of both suitable wreck data and environmental data within a limited area. UoS supplied high resolution bathymetry data from the DORIS project and for the Thames Estuary. A series of sites across both areas were selected and classified by their physical and environmental parameters to form three case studies for comparing individual sites with the National scale AMAP2 results.

The quality of bathymetry data enabled the condition of wreck sites to be assessed on a site by site basis and compared with the information recorded in the UKHO wrecks database and with the assumptions made during the national scale comparison of wreck data with environmental variables. The comparison of bathymetric images of wrecks with the attributes recorded for each site has highlighted the complexity of the relationships between environmental and physical parameters while providing support for the trend identified on a national scale.

Previous research undertaken by UoS into site formation processes around shipwrecks has demonstrated the importance of understanding the relationships between wrecks and their surrounding environment (Dix et al., 2007, Dix et al., 2008a, b and c). Many of the projects conducted have focuses on modelling localised environmental processes, taking account of the direction of flow and associated patterns of erosion and accumulation around a wreck structure. A combined assessment of the environmental conditions and associated scour patterns can provide valuable insight into the potential for and extent of the distribution of artefacts around a site. These results support and explain many of the conclusions drawn by the AMAP2 project from National scale observations of wreck distributions.

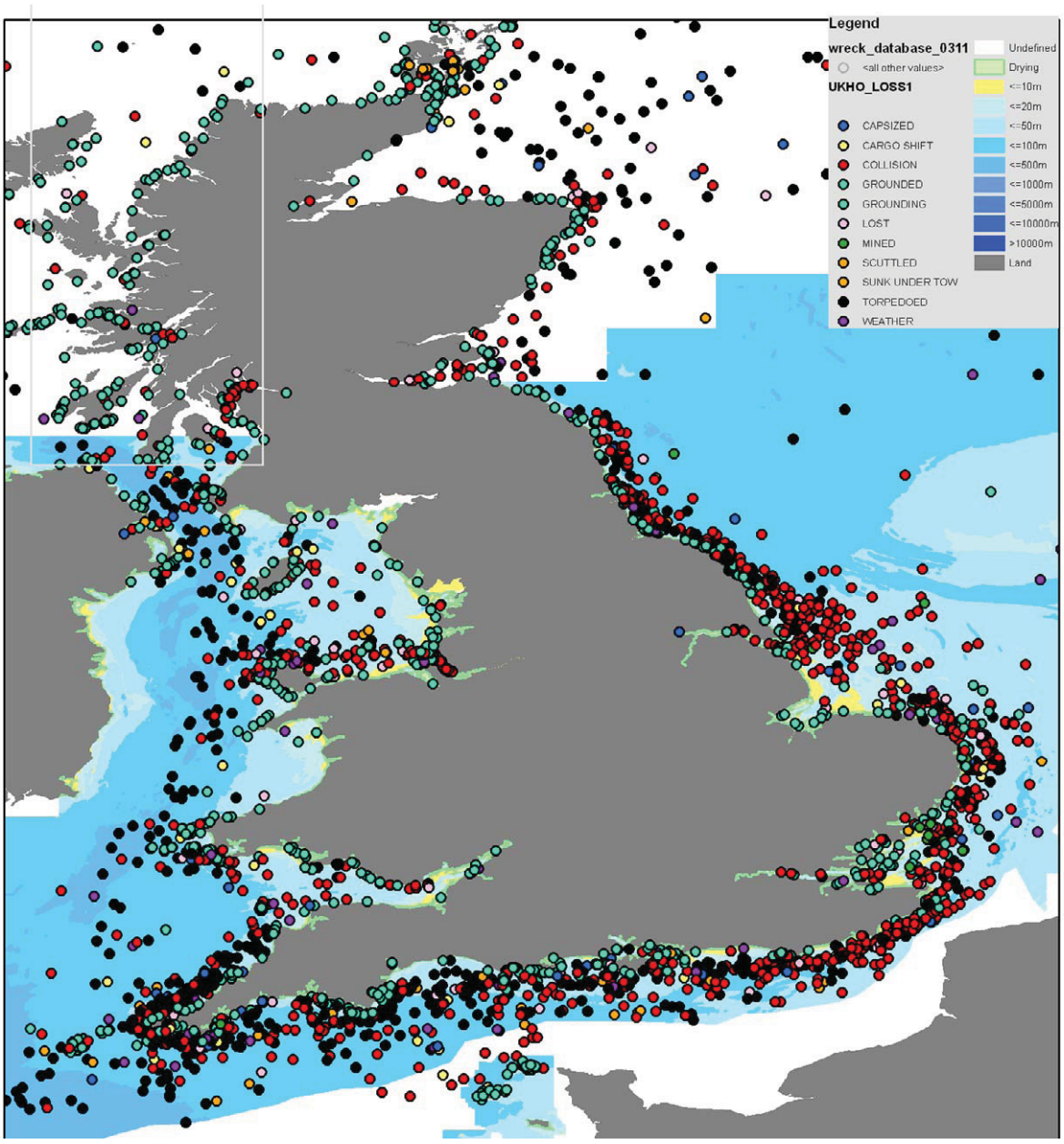


Figure 34: Map showing distributions of wrecks displayed by their manner of loss

The case studies selected for the project sought to investigate whether the trends seen on a national scale were mirrored when looking at individual wreck sites. The following parameters were reviewed where information was available:

- Age
- Material
- Condition
- Burial
- Year of loss
- Date of last UKHO update
- Sediment transport
- Sediment type

- Sediment thickness
- Preservation index

The case studies reported on below reflect the analysis of three pairs of wrecks exhibiting comparable physical characteristics and lying in similar types of marine environment. The high resolution bathymetric data provided by UoS has enabled ground truthing of the sites' features such as condition, burial, sediment thickness, relative sediment transport direction and scour. The environmental data gathered for the project and collated wreck data was compared with the features visible from the bathymetry.

4.2.1 Case study 1

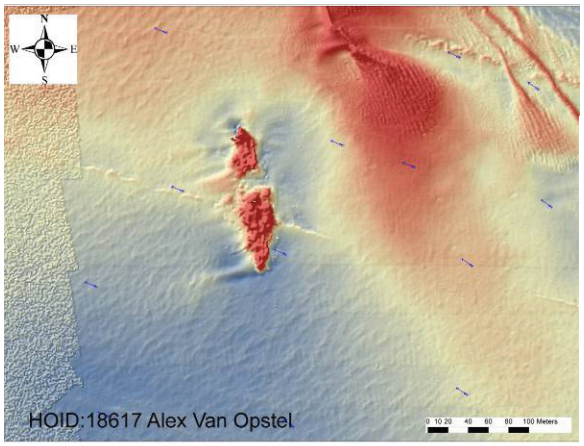
The first two wrecks reviewed shared similar environmental conditions. Both were located in areas of:

-very shallow sediment (0-0.5m)

- A moderate to high level of sediment transport

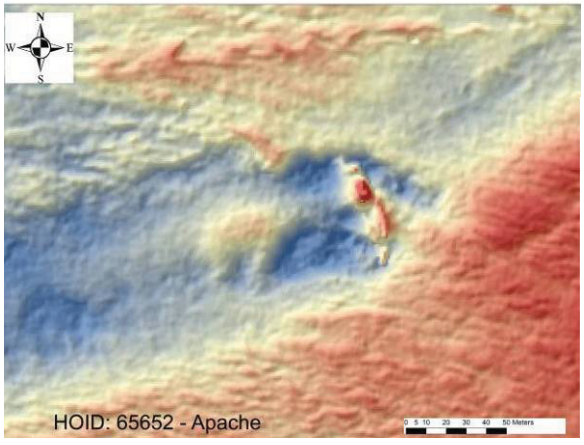
- Predominantly gravel seabed environment

- Medium water depth of 30-50m



NAME	Alex Van Opstal
YEAR LOSS	1939
TYPE	PASSENGER VESSEL
MATERIAL	STEEL
CONDITION	WELL BROKEN
BURIAL	-
MANNER OF LOSS	MINED
SCOUR	-
LAST UPDATE	10/07/2009

SED THICKNESS	0-0.5m
SED TRANSPORT	100-1000 (887)
SED TYPE	SANDY GRAVEL
WATER DEPTH	30-50m
PRES INDEX	14



NAME	APACHE
YEAR LOSS	1917
TYPE	S AUXILARY BARGE
MATERIAL	STEEL
CONDITION	INTACT
BURIAL	-
MANNER OF LOSS	
SCOUR	-
LAST UPDATE	04/01/2010

SED THICKNESS	0-0.5m
SED TRANSPORT	1000-10000 (8076)
SED TYPE	MUDDY SANDY GRAVEL
WATER DEPTH	30-50m
PRES INDEX	13

The work undertaken by UoS during the MACHU project suggested that sediment groups where larger grain sizes are predominant, such as gravels or sandy gravels, which have much lower relative rates of transport (are less likely to move) than finer grained sediment groups such as gravelly sands and sand (Soulsby, 1997).

The results of AMAP2 data analysis of wreck distributions also suggest a limited potential for burial in gravel environments, with a higher rate of burial observed in and in proximity to dynamic fine grained environments.

The wrecks observed for case study 1, lying in areas of very shallow mix of coarse and very fine grained sediment, show little evidence of burial across both sites, although the Alex Van Opstal exhibits some accumulation to the west side of the wreck.

Around the site of the Alex Van Opstal, the sediment transport of the sand fraction is low (50-60 kg/m/day) represented by only localised scour and sediment accumulation downstream of the net sediment transport direction. These sediment accumulations suggests E-W movement whereas the model gives values of ESE-WNW this slight deviation may be a product of the large bank to the west which would dominate the model output. A study of the DORIS data available in proximity to the wreck of the Alex Van Opstal showed the seabed environment to be marginally finer than that suggested by the BGS SBS250 data.

The Apache, lost in 1917, over 20 years earlier than the Alex Van Opstal does displays a greater level of decay (despite being recorded by the UKHO as intact), possibly due to the greater age of the wreck, direction and increased energy level across the site. It also appears that the wreck is lying in an area either stripped of sediment or exhibiting a very thin veneer of very coarse grained material that even this under tidal conditions is not moving. What look like an accumulation of sediment in the channel to the west of the site does therefore not correlate with the modelled sediment flow direction coming from the north west, supporting the likely lack of sediment in the area.

4.2.2 Case study 2

The two wrecks reviewed as case study 2 shared a different set of environmental conditions from case study 1. Both were located in areas of:

-very shallow sediment (0-0.5m)

- A low level of sediment transport

- Predominantly sandy seabed environments

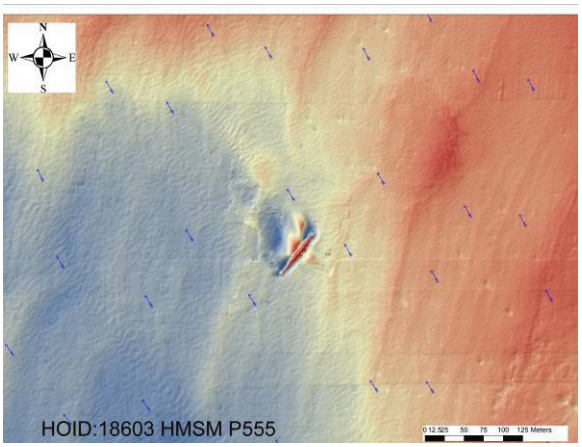
- Shallow to Medium water depth

Although the both sites are characterised by very low relative sediment transport rates and very shallow sediments, the predominance of fine sediments rather than gravels has produced greater levels of scour compared with the sites in case study 1.

The HMSM P555 exhibits distinct but not extensive scour probably because sediment not very thick. The sediment transport model predicts a sediment transport direction (SE-NW) reflected in the scour seen in the bathymetry. The site exhibits levels of accumulation both along the south eastern side of the site and within the scour pit of the HMSM P555, suggesting a direction of flow across the site from the south west. The accretion areas around the site have been shown in previous UoS studies to have a particularly high potential for containing re-deposited artefacts relating to the wreck.

The actual residual sediment transport is slightly higher than for the Alex Van Opstal (c. 100 kg/m/day) which dates from a similar period, but is still not very high by comparison to those in the Thames seen in case study 3.

The backscatter data provided by the DORIS project suggests slightly coarser data than recorded by BGS, although the bathymetry suggests there is still a notable degree of sediment transport across the site.



NAME	HMSM P555
YEAR LOSS	1947
TYPE	SUBMARIE
MATERIAL	STEEL
CONDITION	INTACT
BURIAL	-
MANNER OF LOSS	SCUTTLED
SCOUR	-YES
LAST UPDATE	29/12/2009

SED THICKNESS	0-0.5m
SED TRANSPORT	100-1000 (186)
SED TYPE	SLIGHTLY GRAVELLY SAND
WATER DEPTH	30-50m
PRES INDEX	8

NAME	-
YEAR LOSS	-
TYPE	STEAM SHIP
MATERIAL	-
CONDITION	INTACT
BURIAL	PART BURIED
MANNER OF LOSS	-
SCOUR	SAND PLUME
LAST UPDATE	15/01/2003

SED THICKNESS	0-1m
SED TRANSPORT	100-1000 (203)
SED TYPE	GRAVELLY SAND
WATER DEPTH	15-20m
PRES INDEX	11

These results suggest that only low levels of energy are required to produce instability across sites in areas of predominant fine grained sediments, even where sediment depth is very low.

Although the date of the second site is unknown, the site demonstrates a considerable length of scour, which may be caused by a combination of the length of time of the wreck on the seabed and direction of sediment transport along the site rather than across it. The wreck exhibits an unusually long pattern of scour running out from the bow and stern of the wreck with considerable burial along the western side of the wreck.

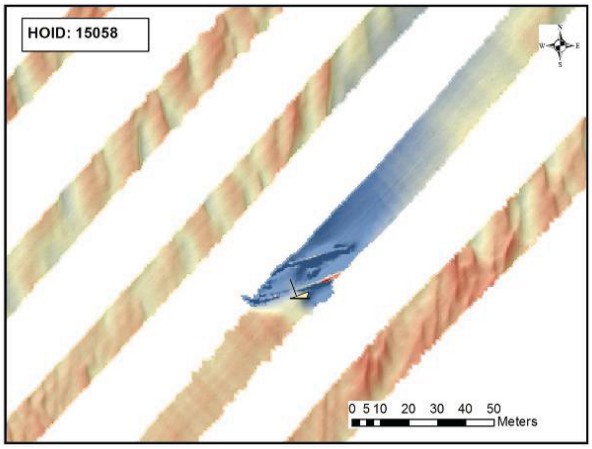
4.2.3 Case study 3

The two wrecks reviewed as case study 3 shared a different set of environmental conditions from case studies 1 and 2. Both were located in areas of:

- Deep sediment (10-20m)

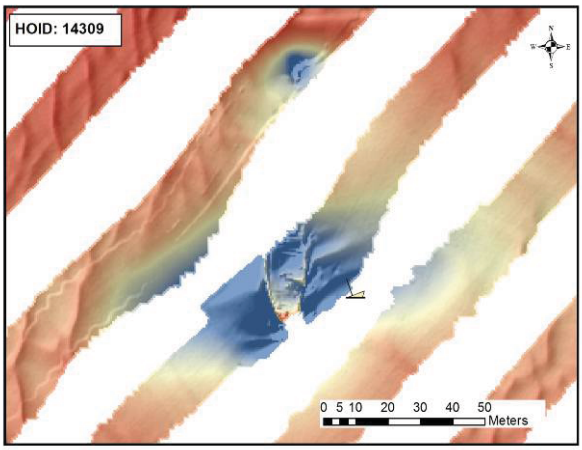
- Medium and high levels of sediment transport

- Very shallow water depth



NAME	-
YEAR LOSS	1917
TYPE	S AUXILARY BARGE
MATERIAL	STEEL
CONDITION	INTACT
BURIAL	-BURIED (not proud of seabed)
MANNER OF LOSS	-
SCOUR	-YES
LAST UPDATE	16/01/2003

SED THICKNESS	10-20m
SED TRANSPORT	100-10000 (631)
SED TYPE	SAND
WATER DEPTH	2-5m
PRES INDEX	4



NAME	-
YEAR LOSS	-
TYPE	STEAM TRAWLER
MATERIAL	STEEL
CONDITION	WELL BROKEN
BURIAL	MOSTLY BURIED
MANNER OF LOSS	-
SCOUR	-YES
LAST UPDATE	16/01/2003

SED THICKNESS	10-20m
SED TRANSPORT	1000-10000 (1137)
SED TYPE	SAND
WATER DEPTH	0-2m
PRES INDEX	4

Both sites therefore lie in very shallow water in an area characterised by dynamic fine grained sediment. Both wrecks lie on the top of sandwaves in the Thames Estuary, exhibit considerable levels of burial and are heavily damaged compared with those seen in case studies 1 and 2.

The first site, though lying in a fine grained environment which is more dynamic similar to both the sites in case study 2, appears to display a less distinct scour pattern around the wreck. This is due to the shallow depth of water it lies in increasing the turbulence around the site due to wave action. The spread of artefacts around the site is likely to reflect a similar pattern of re-deposition to those of the areas of heavy sediment accretion surrounding the site in all directions, particularly in the area of scour extending out to the north east of the site.

The second site is characterised by large amounts of sediment accretion around both sides of the wreck but particularly to the east and west at the southern end of the wrecksite. The direction of transport on the site, which lies in less than 2m of water, is not clear at all despite a high level sediment transport recorded across the area. This is due to the effects of wave action resulting from the presence of the site in very shallow water on top of a sandbank.

4.3 Environmental Characterisation

A GIS characterisation of the environmental parameters affecting the preservation potential of archaeological materials on the seabed has been constructed using available environmental data to meet the core deliverables of the AMAP2 project (Figure 35). The characterisation is designed to provide a coarse grained overview to guide the user in reaching an overall understanding of the environmental conditions across a marine area. The GIS layer combines information on sediment thickness, sediment type, sediment transport and water depth into a vector grid. The grid structure is based on that used for the MESH project (http://searchmesh.net/). The tool is designed to provide an overview of environmental conditions during the early stages of project

planning and provides a basis for making an early assessment of archaeological potential in advance of receipt of detailed site information. The tool does not replace the need for using environmental source data during marine planning and is designed to provide a snapshot of the core characteristics of the marine environment relevant to the assessment of archaeological potential.

The characterisation was constructed by running attribute queries on each of the environmental datasets to re-classify them to reflect the categories shown in Figure 35.

Once each category had been defined, the cells of the vector grid were selected where they intersected with each of the data categories, enabling the attributes of the cells to be populated to reflect the underlying environmental data. Where cells intersected more than one category, priority was given to the attributes most likely adversely affect preservation potential on archaeological assets.

The lessons learnt from the project suggest that planners may benefit more from combining the use of a purely environmental characterisation with a flow diagram to guide users through the thought processes required to assessing archaeological potential and environmental and physical risks to existing archaeological assets. There are concerns that without accompanying guidance, an interpretative map product could be misused during planning to short-cut important stages in the archaeological assessment process.

The characterisation therefore does not provide a summary of the trends in wrecks within each vector cell due to the biases known to exist within the wreck, such as the subjectivity seen in the definitions of classes of burial or condition seen in the UKHO records. Although the quality of data is enough to demonstrate the relationships between wrecks and their environment, these relationships cannot be used to quantify the level of risk without the use of other resources. Similarly, the integration of an interpretation of archaeological potential within the characterisation is thought to be premature without first going through a period of ground truthing.

Recommendations for further developing the outputs of the AMAP projects have been summarised in section 7.

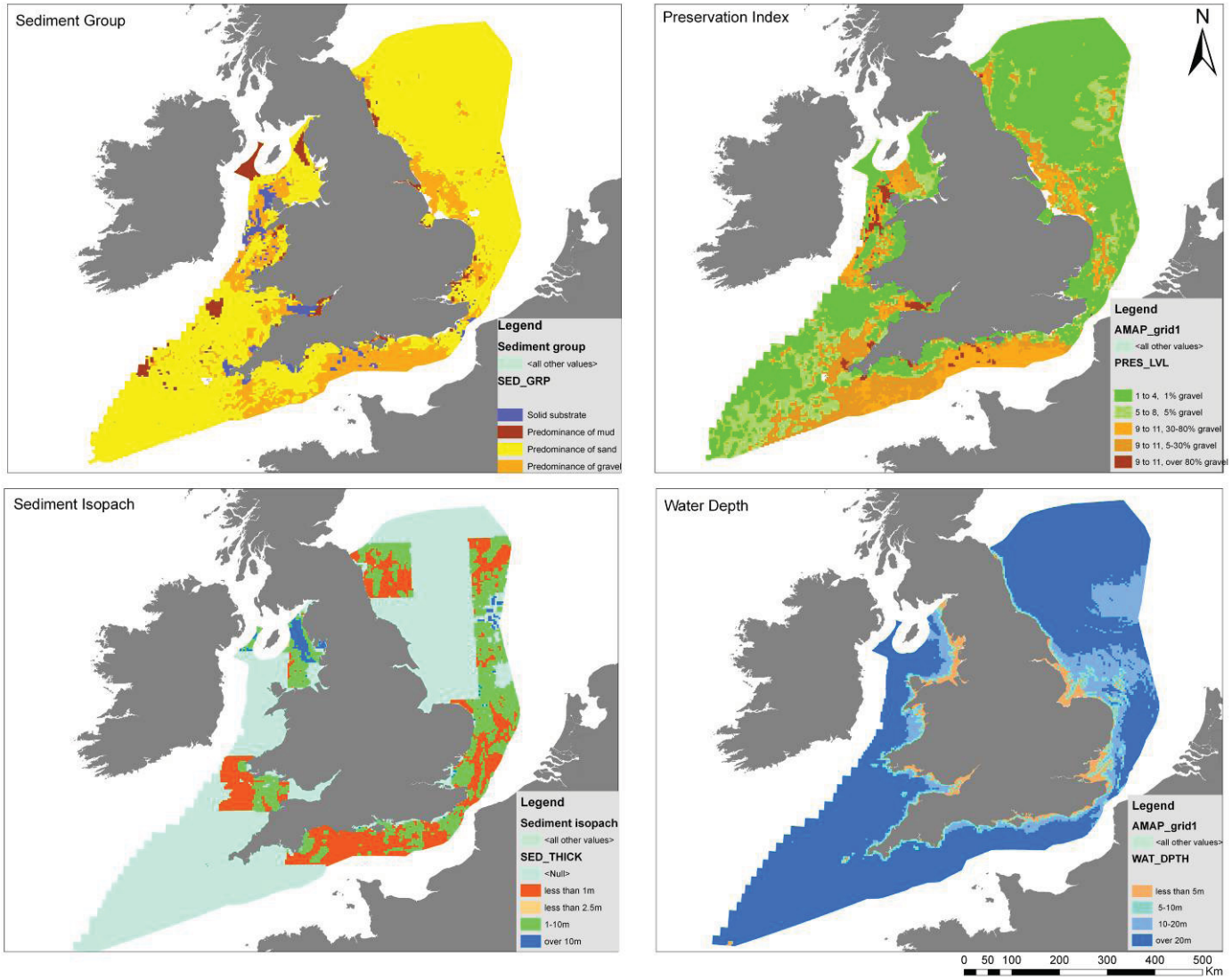


Figure 35: AMAP2 environmental characterisation vector grid, symbolised by sediment group, preservation index, sediment isopach and water depth.

5. DISSEMINATION

5.1 Project Steering Group Meeting

A project steering group meeting was held to gather feedback on the methodology developed and results produced for the pilot area. The meeting was held to ensure the project met the requirements of project stakeholders. The meeting was attended as a joint event between SeaZone and MA Ltd, to disseminate the Phase 2 results of the Enhancing the NRHE project and the pilot area results for AMAP2. The meeting was attended by English Heritage staff to ensure both projects met the requirements of English Heritage and the NRHE and to discuss further work. The meeting resulted in the production of a third Phase to the Enhancing the NRHE project and an agreement by SeaZone to seek out opportunities for contributions to wreck data enhancement work via MEDIN.

5.2 Project Dissemination

The start of the project was announced via the SeaZone website (http://www.seazone.com/uploads/news-SZPR%20AMAP2%20090310.pdf) .

A project flier has been produced by SeaZone for dissemination of the project at GIS corporate events http://www.seazone.com/uploads/news-SZPR%20AMAP2%20090310.pdf .

A project summary, based on the flier, was disseminated to a range of industry websites and attracted considerable interest. The summary was published on several GIS industry websites including GISCafe, The Hydrographic Society, Geo: International, GeoInformatics, Ocean News & technology, Hydro International and by MEDIN in Marine Data News (http://www.oceannet.org/marine_data_newsletter/documents/mdn_dec_09.pdf).

An article was also published in Geoconnexion International, raising awareness of the project on a global scale.

The dissemination phase of the project will seek to publish two articles discussing and promoting the research results of the project. SeaZone will seek to publish an update article in GeoConnexion International following the original article published on 10th March 2010 (http://www.geoconnexion.com/geo_online_article/SeaZone-on-Archaeological-Potential-for-Shipwrecks/362). SeaZone will also seek to submit a paper to the Journal for Marine Archaeology (JMA) or a similar academic publication outlining the results of first two phases of AMAP work.

UoS will seek to publish a paper outlining developments in sediment transport modelling for cultural heritage management integrating the work done through ALSF, MACHU and the AMAP projects.

6. CONCLUSION

The aim of the AMAP2 project is to the test the results of AMAP1 across a substantial area of seabed and further develop the methodology with an aim of characterising the relationships between shipwrecks and the archaeological and environmental variables which affect their presence and state on the seabed in order to produce a GIS product, based on the data collated, which encourages a more justified interpretation of the potential for wrecks to exist and survive on the seabed.

The analysis of the AMAP2 pilot areas, using a similar approach to that employed for AMAP1 strengthened many of the correlations apparent in the Eastern English Channel. A summary of the results of the analysis of relationships between the physical properties of shipwrecks and the variables in their marine environment are as follows:

Wrecks queried by period show a strong bias towards 20-21st and a very low number of known sites from the 19th century or earlier centuries in both the AMAP1 project area and the AMAP2 pilot area. The analysis in the Thames Estuary for AMAP2 showed a particularly notable lack of pre-1900 records which could not be explained by removal of wrecks through channel maintenance. This localised trend could therefore either be due to complete burial, rapid degradation and dispersal, or a combination of factors.

The majority of sites were modern and constructed of iron or steel, many of which were recorded as structurally complete. The small number of sites dating to 1800 or earlier tended to be constructed of wood. This trend was reflected in both project results. The number of earlier sites in the Thames estuary was particularly low in comparison to the distributions seen in the Eastern English Channel. The reason for this will be further investigated during the following phase of the project.

For AMAP1 both intact and scattered vessels tend to exist in areas of shallow seabed sediments and medium/high sediment transport. This may be explained partly through the more limited potential for wrecks to be buried, but in AMAP1 was also reflected through biases in survey metadata.

These biases were not so apparent in AMAP2. There appeared to be a greater number of wrecks recorded as scattered in shallow, dynamic marine environments while wrecks recorded as intact tend to be distributed in deeper waters although not necessary in low energy environments. However, for AMAP1, buried vessels tended to be found in dynamic areas of fine grained and coarser sediments. Many of these sites lay in areas where sediment thickness remained very low.

In the Thames Estuary, most heavily buried wrecks lay in or very near moderate to high energy areas characterised by deeper fine grained sediment. Wrecks recorded in areas of coarser grained sediment tended to be recorded as experiencing a low degree of burial. Exposed wreck tend to lie in shallow coarser sediment.

In both cases, the majority of buried wrecks are modern and of iron/steel construction while very few older wrecks recorded as buried.

A characterisation of the environmental parameters affecting the physical properties of wrecks has been developed to facilitate decision making and provision of archaeological advice by EH during the early stages of marine planning.

The structure of the tool has moved away from providing an interpretative characterisation of potential due to uncertainties still relating to biases in the wreck data as this may present a risk of encouraging presumptions to be made in advance of the receipt of accurate environmental data. The results of AMAP2 do however provide the basis for a greater understanding of the complex relationships between wrecks and their environment and demonstrate the untapped value of information embedded within the UKHO and NRHE's wreck databases, which has proved valuable in extrapolating information between wrecks and their environments beyond lessons learnt from the observation of individual wreck sites. The AMAP2 project has demonstrated the correlations existing between observations made from modelling on a local scale with patterns in the distributions of wrecks of shared characteristics on a national scale.

The results have provided a greater understanding of the relationships between wrecks and their environment. Further development of an approach to assessing potential will provide valuable insight into the identification and prioritisation of sites at risk.

AMAP2 has helped identify areas of new research and requirements for data accessibility, while investigating the scope for applying the results of AMAP in context of English Heritage's responsibilities towards the long term management of the marine historic environment through providing an improved understanding of the potential impacts of marine environmental variables to specific groups of wrecks.

The results of the project have pointed to a way forward in the development of planning tools to guide the interpretation of archaeological potential during planning as outlined below in section 7.

7. FURTHER WORK

The English Heritage National Protection Plan (NHPP) was recently published (English Heritage 2011). In terms of broad higher level objectives the NHPP states (English Heritage 2011: 3) that by the end of the first plan period in 2015 the outcomes will include:

- A better understanding of those parts of the historic environment that are most threatened;
- Actions well underway to reduce that threat;

The cohesion in results between the AMAP2 analysis of shipwreck distributions on a national scale with observations made on individual sites for the case studies highlights the validity of the AMAP2 in reaching a better understanding of the level of threat to heritage assets in different marine environments. It also provides the basis for undertaking an initial assessment of those risks during the early stages of planning marine works before baseline data has been collated.

A proposal for further work will be made to develop guidance for English Heritage staff in the use of AMAP2 outputs to support the assessment of risks to archaeological assets using the resources generated during the AMAP2 project. The proposal will seek to meet English Heritage's priorities in meeting the requirements of the National Protection Plan (English Heritage 2011), the MMO and the Marine and Coastal Access Act (HM Government, 2009).

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