



**Maritime
Archaeology
Sea Trust**

PROTECTING OUR FUTURE

Coronation

Geophysical Survey



**Geophysical Survey report of the *Coronation* site
Prepared for English Heritage
October 2012**

**Coronation Protected Wrecksite
Geophysical Survey Tender**

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Coronation Protected wrecksite geophysical survey tender

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1 INTRODUCTION

Assessment of project

- 1.1.1 This document has been prepared by the Maritime Archaeology Sea Trust (MAST) and Cornwall and Isles of Scilly Maritime Archaeology Society (CISMAS) for English Heritage (EH) on behalf of the Department for Culture, Media and Sport (DCMS). It constitutes an edited version of the full report of the geophysical survey of the *Coronation* wreck site. Both the Licensed team and English Heritage have a full copy of the report alongside a DVD containing geophysical images and data.
- 1.1.2 The *Coronation* was a 90-gun second rate ship built at Portsmouth dockyard in 1683 and wrecked off Penlee point, Plymouth on September 3, 1691 (Lavery, 1983).
- 1.1.3 The *Coronation* Protected wreck site consists of two designated areas. The area in between these two protected sites is known as the “Intermediate” site. It is not protected but was included in this project as per the English Heritage tender document (English Heritage 2012).
- 1.1.4 The Offshore site (Site 17 Designation Number 2 Order 1978/321 discovered in 1977), lies in 18-22 metres of water and is defined by a circle of radius 100 metres (see Figure 1) centred on point 50° 18.601 N 004° 12.050 W (WGS 84). It comprises rugged rock formations and sand-filled gullies. The area is subject to strong tidal currents, particularly during spring tides.
- 1.1.5 The Inshore site (Site 33 Designation Number 1 Order 1988/2138 discovered in 1967), lies in 2-12 metres of water and is defined by a circle of radius 150 metres (see Figure 1) centred on point 50° 18.981 N 004° 11.637 W (WGS 84).
- 1.1.6 The “Intermediate” site is the undesignated area between the two sites.

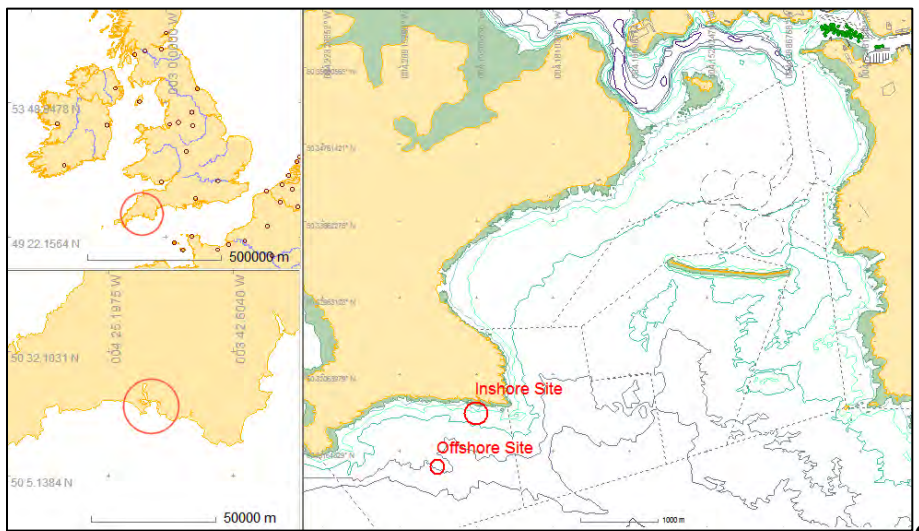


Figure 1. Location of the inshore and offshore designated areas

- 1.1.7 The main wreck site extends from the low water mark on the southern side of Penlee Point to a distance of more than 1300m in a south westerly direction and is at least

800m wide. The true extents of the site are not yet known as the ship was widely scattered at the time of loss.

- 1.1.8 Water depth on site ranges from zero at the northern end to 20m plus height of tide at the southern end. The tidal range from 2m at neap tides to 6m at extreme spring tides. The seabed is composed of low rock reef and gullies with pockets of sand to the north with areas of sand waves to the south.
- 1.1.9 The project was commissioned by EH, because, as it stated in its tender document “while the *Coronation* is not currently on the [At Risk] Register, the exposure of material caused by lowering bed level does mean that without the intervention proposed here, the wreck will be considered to be at Risk in future analysis and would be included in the 2012 Register” (English Heritage 2012).
- 1.1.10 The geophysical survey took place in three phases. The first survey data collected was the multibeam March 19-20, 2012, by Swathe Services. During the second phase of the survey the sidescan data was collected May 14-16, 2012. The magnetometer data was collected July 4-5 and on July 27, 2012.

Metadata

- 1.1.11 All geographical position coordinates in this report are given on the WGS84 datum. All grid coordinates are given on the Universal Transverse Mercator projection Zone 30N. Horizontal positioning for the sidescan sonar survey was provided by a C&C C-Nav DGNSS receiver with a precision of $\pm 0.05\text{m}$. Horizontal positioning for the magnetometer survey was provided by a Garmin 76CSx WAAS DGPS receiver with a precision of $\pm 2\text{m}$. Depths are reduced to Lowest Astronomical Tide (LAT).
- 1.1.12 Sidescan sonar positions were computed using C-Max MaxView software V4.9.1.2011 using internal layback algorithms. Magnetometer positions were computed using 3H Consulting Site Searcher software V5.0.2.3 using internal layback algorithms. The multibeam was a new ultra-high resolution 700 kHz Sonic 2024 multibeam sonar from R2Sonic interfaced with an iXBlue HYDRINS Inertial Navigation System and Trimble RTK GPS receiver using a base station set up on Rame Head.
- 1.1.13 Multibeam and sidescan survey operations were conducted from the *Seeker*, a Lochin 38 work boat coded by the MCA at category 2 (60 miles from a safe haven) with a maximum of 14 aboard (12 passengers and 2 crew). The magnetometer survey was conducted from *Maid Maggie II*, a Cygnus Cyfish work boat coded to the same specifications. (For details see <http://www.wrightys-charters.co.uk/> and <http://www.maidmaggie.com>) (see Figures 2 and 3).



Figures 2 and 3. The Seeker and Maid Maggie II survey vessels

- 1.1.14 The geophysical survey was undertaken in three phases. Phase 1 (March 19-20) comprised the acquisition of multibeam data conducted by Swathe Services.
- 1.1.15 Phase 2 (May 14-16) comprised the acquisition of the sidescan data. The line spacing for this phase was 40m for the offshore and intermediate sites and 30m for the inshore site. The length of the lines was 1000m. The length of layback was noted every time there was a change.
- 1.1.16 Phase 3 (July 4-5) and July 27 comprised the acquisition of the magnetometer data. The line spacing for this phase was 15m. The length of the lines was 1000m. The length of layback was noted every time there was a change.
- 1.1.17 The sea state throughout most of the survey period was an average of a Force 3 to 4 south westerly on the Beaufort scale with intermittent rain squalls.

2 AIMS AND OBJECTIVES

- 2.1.1 The project aim was to provide EH with geophysical data of the project area and archaeological interpretations including a list of potential archaeological “hits”, to allow further, decision-orientated investigation of the project area.
- 2.1.2 In particular this project provides sidescan sonar, magnetometer data and multibeam data.
- 2.1.3 The overall aim for the site is for recording to Level 1 as defined in the tender document (English Heritage 2012).
- a) Survey and identify the extent of the debris trail between the two designated areas;
 - b) Survey additional exposed material within the designated areas; and
 - c) Produce a structured record of field observations;
 - d) Presentation of data, primarily in illustrative form, though including data tables where appropriate.
 - e) Production of client report for EH in hard copy and .pdf form.
 - f) Submission to OASIS

Previous geophysical investigations of the project area

- 2.1.4 The Offshore site was first located by magnetometer in 1976-77 although the Inshore site had first been located by divers in 1967 (Fuller 1983).
- 2.1.5 A review of all known previous geophysical surveys conducted on the *Coronation* since 1972 is in Appendix Two. This contains the file details, if known, positioning methods, the area of the site covered, the datum used, the quality of the data and who owns it. Much of the metadata for the historic surveys is not known. What is known is stated in the Appendix.

Methodology

Sidescan

- 2.1.6 For the sidescan survey we used a C-Max CM2 EDF towfish and transceiver unit. The sonar fish was towed from the stern A frame with the cable fed through a snatch block. It was towed with a layback which varied between 24m to 30m. The unit was towed at 4.4 knots. During the inshore survey, where depths range from 2-12m the sidescan was attached to a float (see Figure 4).

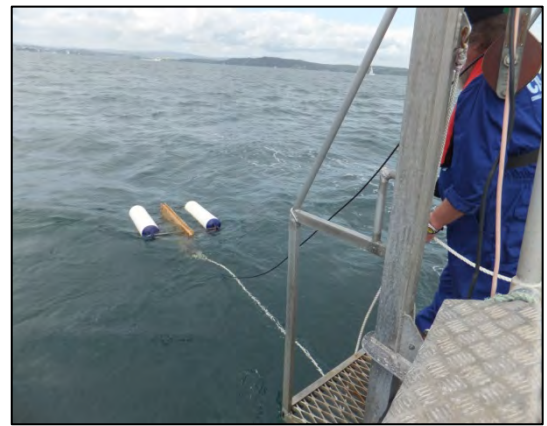
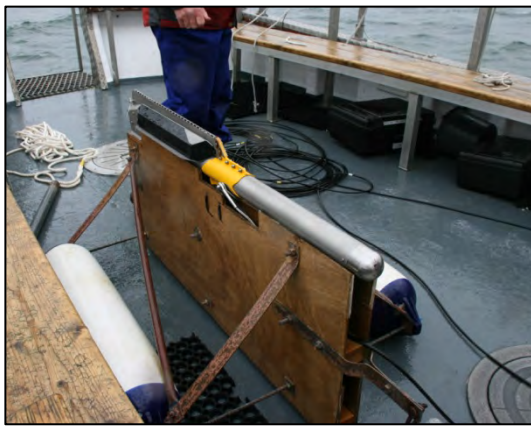


Figure 4. C-Max CM2 EDF towfish attached to flotation device for the inshore parts of the survey

- 2.1.7 Power for the sidescan and laptop computer was provided by independent battery supply via a sine wave corrected mains inverter. For the shallower parts of the survey (inshore sector) the sidescan tow fish was secured to a small flotation device which kept the towfish at a constant depth of 0.50m and avoided the danger of the towfish colliding with the seabed. For this survey the frequency was set at 325kHz and the range at 50m.
- 2.1.8 The sidescan survey was undertaken in three sections. The most southerly (offshore) was 1.2km long and consisted of 10 survey lines spaced 40m apart. The middle area (intermediate) was also 1.2km long and consisted of nine survey lines with 40m line spacing. The northern search area (inshore) was 1.2km long and consisted of nine survey lines spaced 30m apart (Figure 6 at the end of this report). The inshore search area was planned to have 11 survey lines but the two most northerly lines were omitted as it proved impossible to get the survey vessel that close to the shore safely.

Magnetometer

- 2.1.9 Magnetometer data was acquired to identify ferrous material on or potentially within the seabed. The magnetometer was towed from the vessel and run with a line spacing of 15 metres. The orientation of the lines was essentially east to west. The system used was a Geometrix 881, Caesium Vapour magnetometer making measurements at 4Hz with logging and processing using Site Searcher software from 3H Consulting Ltd. Water depths were obtained from the survey vessel's echo sounder.



Figure 5. Magnetometer with flotation device attached.

- 2.1.10 The unit was towed at an average speed of 4.5 knots. Line spacing was 15m and the length of the lines was 1000m and the fish was towed at a depth of 4m. As with the sidescan unit, the magnetometer was attached to a float for the shallow waters (see Figure 5 above).
- 2.1.11 For both magnetometer surveys the surface positions were provided by a Garmin 76CSx GPS receiver aided by WAAS corrections giving an estimated precision of better than 2m. Offsets from GPS antenna to tow point were corrected for in the Site Searcher software used for data collection. Towfish position was calculated from the corrected tow point and layback in real time by the data collection software.
- 2.1.12 For a 15m runline spacing with the towfish at 4m and minimum anomaly size of 3nT the calculated minimum mass is denoted in the table below. So in the shallower parts of the site we can detect iron objects as small as 64kg, but at the southern end this limit increases to objects larger than 1.2 tonnes.
- 2.1.13 The primary search area was divided into three blocks. The North block includes the shallowest water and the main part of the Inshore site, the Middle block is in the centre and the South block includes the Offshore site and the area to the south of it. The North block was 1200m x 250m and the Middle and South blocks 1200m x 360m, all heading 90° True.
- 2.1.14 The area between the northern edge of the North block and the coastline was considered too shallow to operate in safely using the survey vessel (*Maid Maggie II*) so it was not included in the original specification. However some survey lines closest inshore were collected in that area by Pete Holt of Promare (SHIPS Project) on July 27, 2012 using a rigid inflatable boat and the results have been included here.
- 2.1.15 This furthest inshore survey was undertaken using an Aquascan AX2000 proton magnetometer set to take measurements every 2 seconds. The towfish was kept close to the surface at slow speeds using a float towed from the rear of the towfish. For the magnetometer's track plot, showing colour-weighted runlines.
- 2.1.16 Survey lines were run over the planned search area and extended beyond this to the east and west. An unexplored area still remains between the northern edge of the North block and the lines run in the shallowest water up against the southern shore, this triangular area is 1500m long, 130m wide to the west and 20m wide to the east. A survey in this area can only be completed safely using the same small boat method used for the inshore survey.

Water depth	Altitude	Slant distance	Minimum mass (kg)
10m	5m	9m	64
15m	10m	13m	400
20m	15m	17m	1200

Multibeam

- 2.1.17 The multibeam sonar head was mounted on a purpose-built deployment pole fitted to the survey vessel *Seeker* (see Figure 6). The site was first mapped using 400 kHz sonar with 0.5° beams, then switched to using the new ultra-high resolution 700 kHz with 0.3° beams producing even finer detail over the same areas.



Figure 6. Sonar head mounted on pole off *Seeker*

- 2.1.18 Prior to the survey a base station had been setup over a previously set coordinate point at Rame Head. This provided real time RTK position corrections to the vessel mounted GPS system. A Hemisphere DGPS Vector Sensor was used to supply time stamping in the form of a PPS pulse to the multibeam and pc systems. Vessel motion and heading was supplied by using a iXsea Hydrins system. Prior to the survey commencing a sound velocity profile was taken using a Valeport MiniSVP, which gathered sound velocity data through the water column to the sea floor. This was used to provide ray bending corrections to the multibeam data.
- 2.1.19 All survey data was cleaned within the QPS QINSy and Qloud software. Final products in the form of XYZ, charts and images were produced using QPS and Fledermaus software combinations.
- 2.1.20 All the multibeam raw data and images, both 3D and in tiff format, can be viewed on the DVD available with the hardcopy of this report. (An index to the DVD's contents is found in Appendix One.)

3 RESULTS

Sidescan sonar

- 3.1.1 The sidescan data was reviewed using the same Maxview software used to collect the data. Targets were selected and a sequential target number allocated, followed by the area and runline number. An image of each target was also taken, to aid subsequent diver searching of the targets – these images appear on the DVD which accompanies the hardcopy of this report.
- 3.1.2 Overall, the data quality was good in the middle and southern search areas where the towfish was deployed conventionally (towed through the water). The data was more affected by wave noise in the northern area (inshore) where the towfish was attached to the flotation device, and thus more susceptible to wave action. This wave noise exhibits itself as dark horizontal lines on the sonar display.
- 3.1.3 All the sidescan sonar data collected as part of this project is available on the DVD and can be viewed using the free Maxview viewer available for download from the C-Max website at www.cmaxsonar/downloads.html.
- 3.1.4 In total 49 targets were selected from the sidescan sonar data. It is always difficult to identify small sidescan sonar targets when they lie on rocky ground due to the multiple hard reflectors and shadows created by dense rocks. As much of this site consists of rocky ground and reefs, we should perhaps not expect too much from the sidescan sonar target list.
- 3.1.5 One indication of this is the very poor correlation between the magnetic and sonar targets. In fact there were only two correlations between the magnetic and sonar targets. Similarly, only one of the known features of the site was selected as a target from the sonar data. This was 3m from the recorded position of anchor D and thus is almost certainly that anchor.
- 3.1.6 The sidescan sonar data was mosaicked together using SonarWiz software version V5.04.0007.
- 3.1.7 Due to the difficulty of identifying small sonar targets on the predominantly rocky seabed found on the *Coronation* site, only one of the known targets (anchor D) was selected as a sonar target. Two sonar targets are relatively close to magnetic targets located in this survey. The remaining sonar targets should be investigated by divers to ascertain their nature – but at least some will doubtless prove to be oddly shaped rocks.

Magnetometer

- 3.1.8 A total of 60 anomalies were found of which 15 are associated with known guns, anchors or other objects leaving 45 targets to investigate, of which 19 had been detected already on previous surveys.
- 3.1.9 The list of targets gives the position for each target and the water depth at that point. The anomaly value shown (nT) is the maximum peak to peak magnetic signal

variation over the object on any data collection run. The estimated minimum mass of the target in tonnes is based on the anomaly size and the assumption that the target is at seabed level and directly under the towfish.

- 3.1.10 The estimated precision for the surface positioning was approximately 5m over the whole survey area, giving better than a 10m position estimate for each target, hence precise enough to be able to use divers to relocate any targets detected.
- 3.1.11 The size of the minimum detectable targets were as predicted. In the shallow part of the site it is expected that most targets larger than 200kg were located, in the 15m depth range anything larger than 500kg and in the 20m depth range anything larger than 1.5 tonnes were found.

Multibeam

- 3.1.12 The multibeam survey provides an excellent high resolution, topographical tool for management of the Survey Area.
- 3.1.13 Overlain by the sidescan and magnetometer results, it will facilitate ground-truthing by divers of potential archaeological remains/anomalies. Figure 7 at the end of the report indicates the extent of the multibeam survey and Figure 8 shows the magnetometer results overlain on the multibeam survey. Swathe Services were unable to get further inshore due to bad weather, it being too shallow for the equipment and vessel to operate safely.
- 3.1.14 There is no way of illustrating the detail on the printed page. The multibeam survey data can be viewed best digitally. The data can be viewed on the DVD available with the hardcopy of this report.
- 3.1.15 It is planned that the 3-dimensional imagery will be used to enhance the visitor display at Mount Edgecumbe Museum where *Coronation* artefacts will be on display from 2013. It is proposed to display on a digital screen the animated display as a moving image of the Survey Area for a better topographical understanding of the site.
- 3.1.16 The *Coronation* team intends, weather and assets permitting, to enhance the multibeam survey in 2013 at no extra cost to English Heritage. This is possible because of our long term presence on the site.

4 CONCLUSIONS

- 4.1.1 Much of the geophysical data correlates with previous surveys conducted in 2010 and prior. A total of 60 magnetic anomalies were found of which 15 are associated with known guns, anchors or other objects leaving 45 targets to investigate, of which 19 had been detected already on previous surveys.
- 4.1.2 Due to the difficulty of identifying small sonar targets on the predominantly rocky seabed found in the Survey Area, only one of the known targets (anchor D) was selected as a sonar target. The remaining sonar targets should be investigated by divers to ascertain their nature – but at least some will doubtless prove to be oddly shaped rocks.
- 4.1.3 The multibeam survey provides an excellent 3-dimensional topographical view of the seabed which will enhance the ability of divers to ground-truth the Survey Area. Both the magnetometer and sidescan surveys went well beyond the designated areas.

Archive

- 4.1.4 The project archive containing raw data and other spatial data relating to the site, together with digital photographs are presented on a DVD made available with a hard copy of this report. Both English Heritage and the Licensed team have full copies of the report and the DVD.

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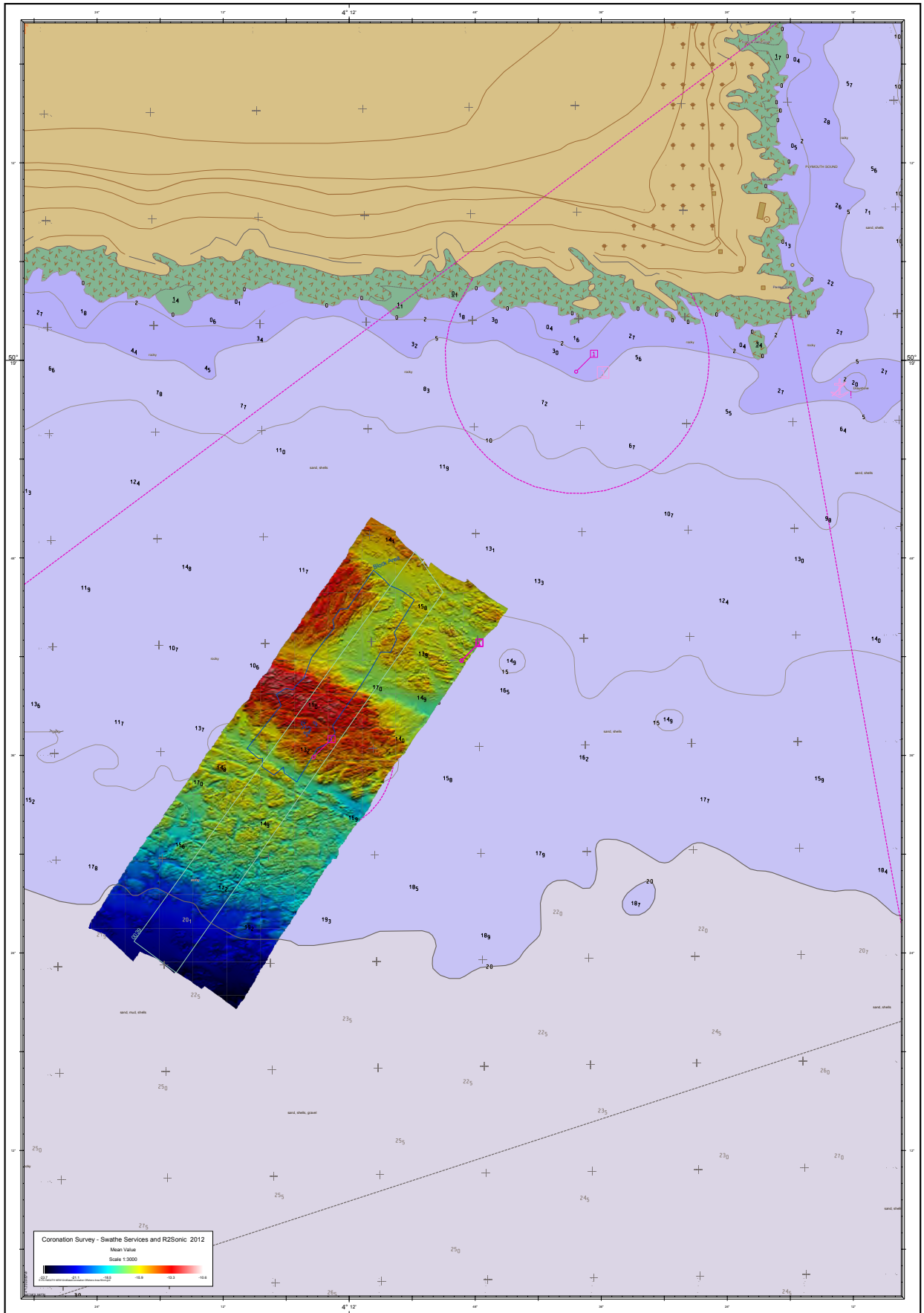


Figure 7. Multibeam survey extent.

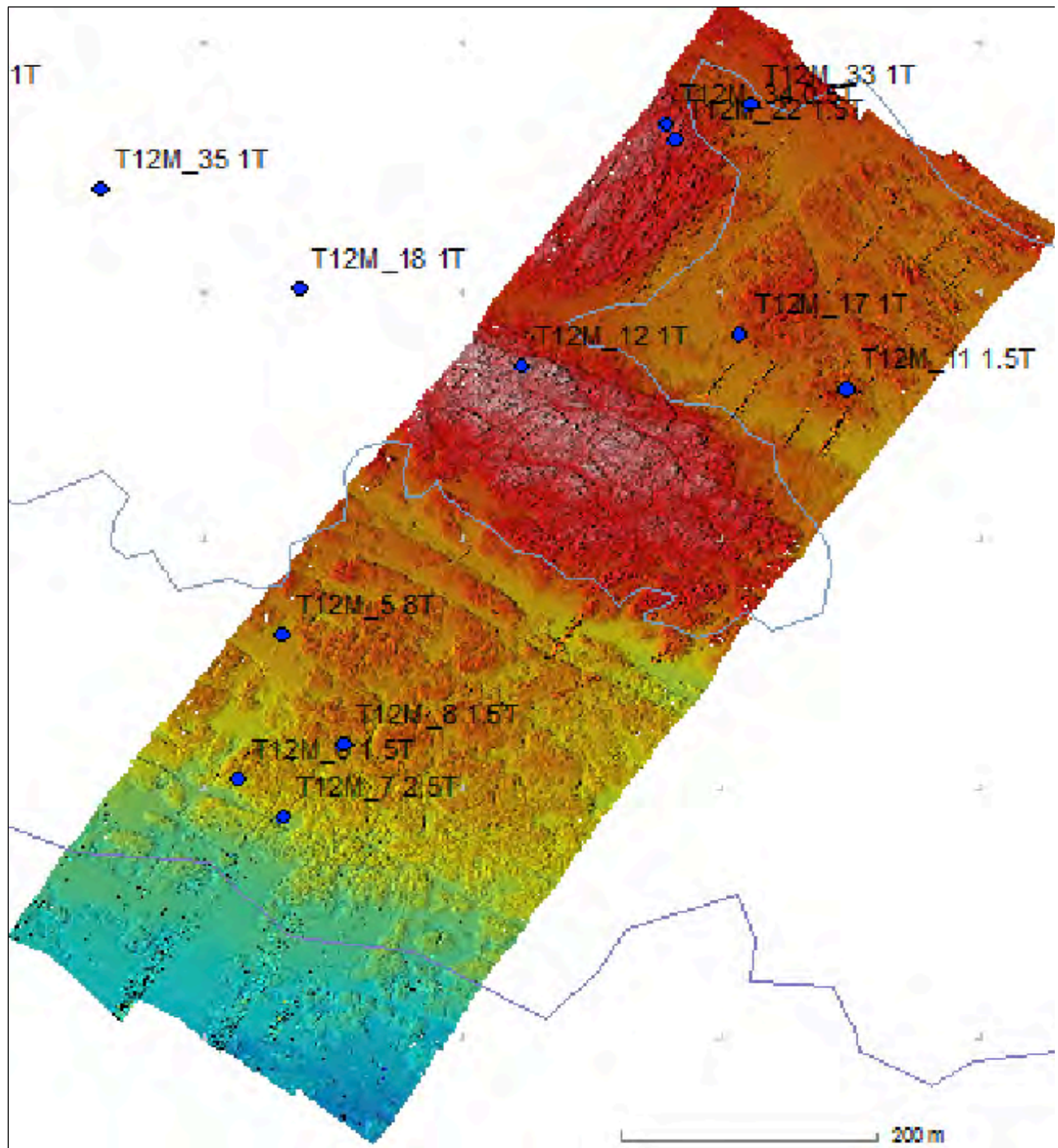


Figure 8. Magnetometer targets overlain on the multibeam survey.

APPENDIX ONE - DVD INDEX

1.1.1 As the data on the DVD is inherently unstable, it is recommended that it is uploaded as soon as possible to a computer hard drive. The DVD is split between the multibeam data and the sidescan and magnetometer data. The multibeam folder contains the following subfolders.

- *Coronation* Charts
- *Coronation* – Fledermaus
- Geotiff & Google Earth
- XYZ files
- Ultra High Resolution Block
- Data – QINSy db files

1.1.2 The sidescan and magnetometer folder contains the following subfolders:

- Sidescan runlines (viewable on C-Maxview viewer downloadable at www.cmaxsonar/downloads.html)
- Sidescan target images
- Magnetometer target images
- Sidescan target images
- Magnetometer track
- Sidescan track

APPENDIX TWO – HISTORIC GEOPHYSICAL SURVEYS

DATE	TYPE	POSITIONING METHOD (if known)	AREA COVERED	DATUM	OWNER	QUALITY
1972 OR 1974? (May 25-28 and May 31)	proton magnetometer	Positioned by sextant from boat	offshore and south of offshore	OSGB 36	Peter McBride	unknown
1975	proton magnetometer	sextant	?	OSGB 36	Peter McBride	unknown
1976-77	proton magnetometer	Decca Mk II	offshore site located	OSGB 36	Peter McBride	unknown
197?	acoustic positioning survey ping from offshore to inshore site with Sonardyne RangeMeter to establish length of site		ping from offshore to inshore	OSGB 36	Nigel Kelland	No data available
1983, July	Aquascan portable proton magnetometer	horizontal sextants and shore transits	intermediate site and resurvey of inshore site - to learn about relationship between offshore, intermediate and inshore	OSGB 36	Penlee Exploration and Survey Team (PEST)/Peter McBride	good

DATE	TYPE	POSITIONING METHOD (if known)	AREA COVERED	DATUM	OWNER	QUALITY
1996, July 16	Aquascan AX2000 proton magnetometer and bathymetric survey using Furuno echosounder		all of intermediate site: top left - 50 18.76N 004 12.48W and bottom right - 50 18.56N 004 11.6W	WGS84	Peter Holt	low grade magnetometer but good quality DGPS. Has raw data
1996, August 18	acoustic positioning survey		offshore site	WGS84	Peter Holt	good
2003, October 16-17	multibeam Reson 8125		offshore and intermediate	WGS84	Wessex Archaeology/ NetSurvey	high quality
2007, July	multibeam EM3002, echosounder Kongsberg Simrad, GeoAcoustics sidescan 159D and Ixsea Octans III MRU	CNav DGPS	whole of known site	WGS84	Ian Hattam/Plymouth University	poor quality
2008	multibeam EM3002		offshore, intermediate and part of inshore	WGS84	Royal Navy	very low resolution
2010, October 14	magnetometer Geometrix 882, Vector US110	Hemisphere DGPS	half of inshore to northern extent of offshore site	WGS84	Peter Holt / Plymouth University	good, done during calm conditions

DATE	TYPE	POSITIONING METHOD (if known)	AREA COVERED	DATUM	OWNER	QUALITY
2010	multibeam R2Sonic (300 kHz), Applanix Pos MV MRU	CNav DGPS	whole of known site	WGS84	Jonathan Watkinson/Plymouth University	Poor processing