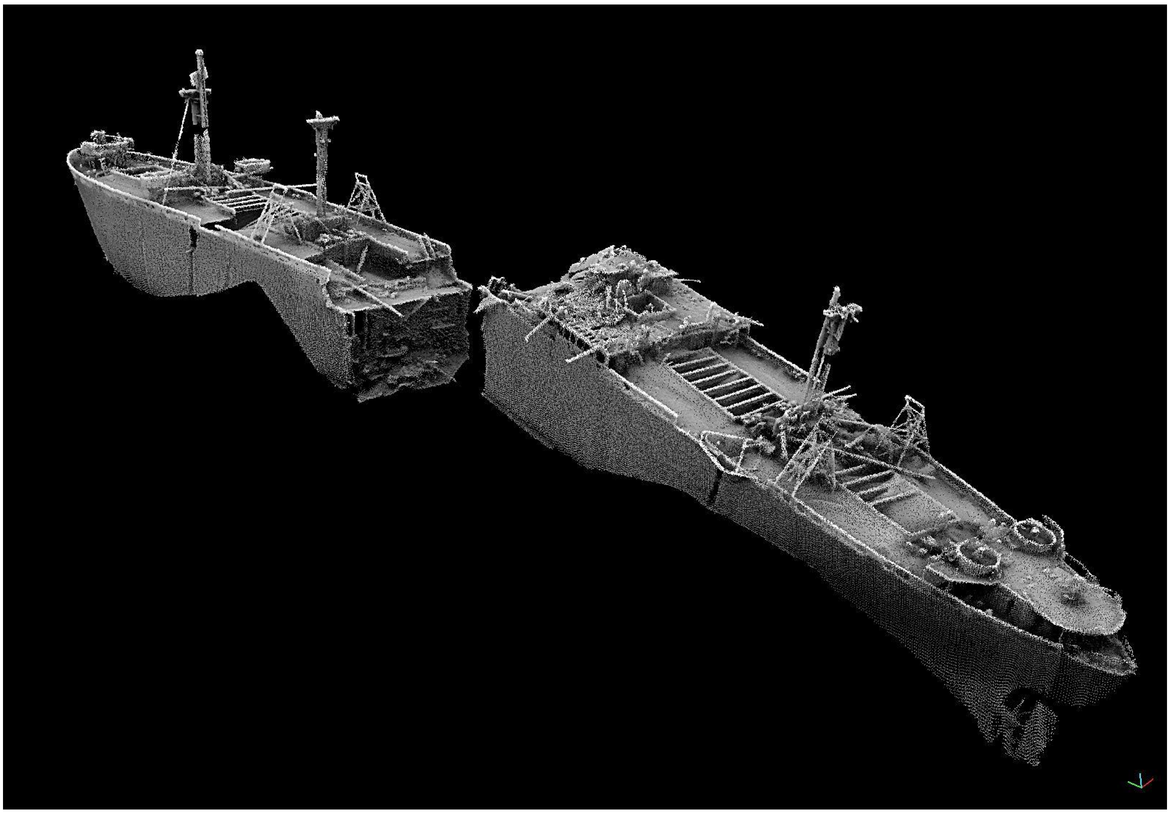
Maritime & Coastguard Agency

SS RICHARD MONTGOMERY
Survey & Sub-Bottom Profiling Report 2014



Maritime and Coastguard Agency
September 2015

1. EXECUTIVE SUMMARY

1.1 The SS Richard Montgomery was a US Liberty Ship which went aground in the Thames Estuary in August 1944 whilst carrying a cargo of munitions. Although salvage operations were begun immediately, the vessel broke in two, flooded and sank before the salvage operations could be completed. Approximately 1400 tons of explosives remain on board the wreck and, for this reason, the wreck is designated as a dangerous wreck under section 2 of the Protection of Wrecks Act 1973 and regular surveys are undertaken.

1.2 The scope of the 2014 survey of the SS Richard Montgomery included multibeam sonar, laser scanning and sub-bottom profiling. Multibeam sonar and laser scanning are regular features of SS Richard Montgomery surveys, but this is the first time that sub-bottom profiling work has been undertaken around the wreck. Due to a number of factors, the survey work took place in three phases. The laser data and seabed bathymetry was acquired on the 10th October 2014, the wreck bathymetry was collected on the 24th October 2014 and the sub-bottom profiling took place on 10th March 2015.

1.3 The survey covers the entire wreck and surrounding seabed in detail. However, five main areas where more accelerated levels of deterioration have been noted in previous years receive close scrutiny. Of these five areas, only one showed evidence of deterioration since the last survey. That area was the deck plating adjacent to Hold 2 which showed continued subsidence since 2013 and has dropped by a further 25cm, possibly as a result of increased sediment load.

1.4 In general terms, continued deterioration was noted in some areas, whilst others showed no evidence of change. The following are some of the main points from the 2014 survey results:

- Deposition and reworking of sediment was noted in all holds and was most evident in Hold 2.
- The Break in the gunnel on the port side of Hold 2 has increased its angle of lean towards the east.
- A hole in the hull plating of the port side of Hold 2 has been difficult to insonify in the past but was detectable in 2014.
- A number of the holes along the port side of the boat deck on the Aft section have increased in size.

- Some evidence of subsidence was identified in the collapsed section of the boat deck.

- The structures on the forward end of the Aft Section which overhang the split between the two sections of the wreck show evidence of subsidence.

- The forward lifeboat davit on the starboard side appears to have subsided at its distal end by up to 0.16m since the 2013 survey.

- Examination of the seabed data showed that the Medway Approach Channel remains free of debris from the wreck and the scouring from the wreck site does not extend to interfere with the dredged channel wall.

- No significant changes were noted in the sediment and scour around the wreck, with some minor re-working of sediments and some deposition immediately at the foot of the bow. No significant changes that were likely to effect the stability of either section of the wreck were observed.

- The known seabed targets were each relocated and an additional 12 items were reported on, including what is possibly a third wreck within the survey area. This is due to backscatter data being utilised to aid object detection in the 2014 survey (see section 5.13).

- Across much of the wreck, no measurable changes were found.

- The sub-bottom profiling identified two main reflectors in the seismic profiles although results were impacted by a number of factors including the strong current in the Thames Estuary.

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2. INTRODUCTION

2.1 The SS Richard Montgomery (SSRM) was a US Liberty Ship built in 1943. In August 1944, the ship left the US with a cargo of munitions and travelled across the Atlantic in convoy bound for the UK and then on to France.

2.2 The SSRM arrived in the Thames Estuary and, on 20th of August 1944, orders were received from HMS Leigh (Southend pier) to anchor off Great Nore. It was the height of a spring tide giving a depth of water of approximately 33ft. This was too shallow for the heavily laden vessel and, as the tide fell the SSRM dragged its anchor and went aground on Sheerness Middle Sand, a sandbank running east from the Isle of Grain and to the north of the Medway Approach Channel. By that evening, the vessel was already reported to be badly hogged and an explosive like sound was heard. This sound was the steel hull plates splitting forward of the bridge. On 23rd August, stevedores from Gravesend were brought in and the discharge of the cargo began. However, on the afternoon of the following day, the ship's hull cracked further and the bow holds flooded. By the 8th of September, the ship broke its back completely. Divers reported that the crack extended down both sides of the hull with the vessel clearly open on the starboard side, but the cargo discharge continued. Royal Navy personnel were brought in to finish the cargo removal but they were hampered by deteriorating weather and safety fears as the vessel gradually sank. The salvage operation was abandoned with approximately 1400 tons (NEQ)[1] of munitions remaining within the forward section of the vessel in holds 1, 2 and 3.

2.3 The vessel remains on Sheerness Middle Sand, lying in two sections in its own scour pit and sitting on exposed bedrock which is believed to be London Clay. The SSRM lies across the tide and all three masts are visible above the water at all states of the tide.

2.4 The wreck is designated as a dangerous wreck under section 2 of the Protection of Wrecks Act 1973. There is a prohibited area around the wreck and it is an offence to enter within this area without the written permission of the Secretary of State. The wreck is clearly marked on the relevant Admiralty Charts, the prohibited area is marked with four lit cardinal buoys and twelve red danger buoys and the wreck is under 24hr surveillance by Medway Port Authority (Peel Ports, Port of Sheerness Ltd) under contract to the Maritime and Coastguard Agency.

2.5 Although the wreck is considered to be stable if left undisturbed, the wreck is regularly monitored. Surveys of the wreck are undertaken in order to provide information on its condition, to identify any changes or deterioration and to inform future management strategy. A variety of methods have been used to monitor the wreck. Since 2002, multibeam sonar technology has been the favoured method of survey. Although from time to time diving operations are carried out on the wreck (most recently in 2013), for general surveying multibeam sonar is faster, more cost-effective and provides greater levels of detail, repeatability and reliability. This is in part due to the very poor visibility and high tidal range in the Thames Estuary which makes diving operations very challenging.

[1] NEQ = Net Explosive Quantity

2.6 Similar to previous years, the 2014 survey required a multibeam sonar survey and laser scanning but new to 2014 was the addition of sub-bottom profiling. Also in a slight difference to previous years, for 2014 backscatter data was processed to provide enhanced seabed imagery across the survey area with the aim of improving object detection.

3. THE SURVEY

3.1 Survey Requirements

3.1.1 As in 2013, the requirements of the 2014 survey were three-fold. A multibeam echo sounder (MBES) survey was to be undertaken of the wreck itself and of the seabed out to 400m distant from the wreck, including the edge of the dredged channel. This was to be fully georeferenced and the results were to be analysed and compared to previous survey data in order to identify any areas of change or deterioration. Any changes or deterioration were to be quantified and particular attention paid to areas that have previously been identified as having higher levels of deterioration than are noted across the rest of the wreck. Secondly, laser scanning was to be undertaken on those areas of the wreck which are visible above the waterline. Again, this data was to be compared to previous datasets in order to identify any changes or deterioration, and was also to be fully integrated into the MBES data in order to provide a picture of the wreck in its entirety both above and below the water. Finally, sub-bottom profiling was to be undertaken within the survey area. This is the first time that sub-bottom profiling has taken place around the wreck and the aim was to provide a greater understanding of the seabed environment and, in particular, to try to establish the base material that the wreck is resting on and the nature of the banks surrounding the wreck.

3.1.2 The 2014 survey of the SSRM was undertaken in three phases. This was due to a variety of factors including the weather, tidal restrictions and the availability of suitable survey vessels. The laser data and seabed bathymetry was acquired on the 10th October 2014, the wreck bathymetry was collected on the 24th October 2014 and the sub-bottom profiling took place on 10th March 2015.

3.2 MBES and Laser Survey Methodology and Data Processing

3.2.1 The 2014 survey was carried out by MMT Ltd and again utilised the Port of London Authority (PLA) survey vessel MV Galloper. The use of a small vessel such as the Galloper is essential when acquiring the wreck data as the shallow draught enables the multibeam to pass directly over the top of structures to provide optimal coverage. In addition to previous survey plans, a new line across the wreck immediately aft of the bridge deck was run in order to provide the best coverage possible.

3.2.2 Survey operations were performed on the 10th and 24th of October 2014 as the tidal cycle was timed to utilise high water during daylight hours. Seabed bathymetry and the laser data of the exposed masts were acquired on the 10th October and the wreck survey was carried out on the 24th. The lines of the seabed survey were orientated east to west to minimise the effects of the strong tidal currents on vessel handling and to reduce data gaps by running parallel to the crests of the sandwaves situated to the west of the wreck.

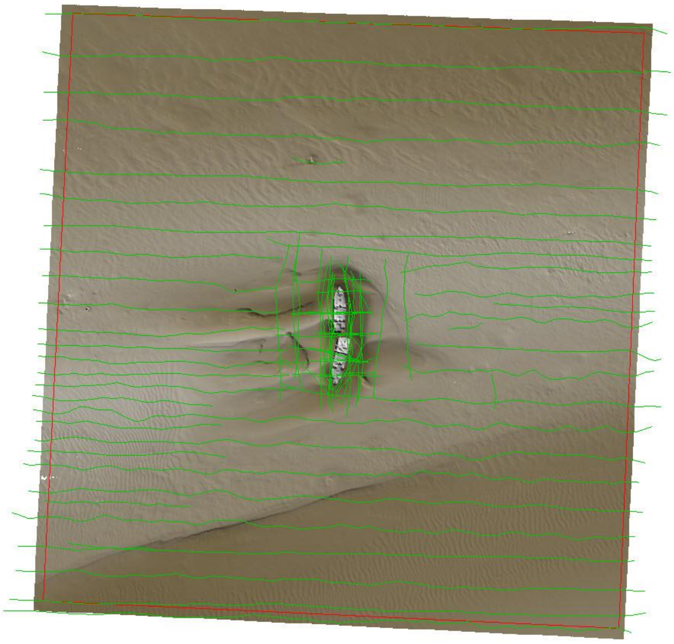


Figure 1. 2014 multibeam survey lines

3.2.3 The survey vessel Galloper is equipped with a Reson 7125 MBES unit and Applanix POS MV 320 inertial system for positioning. In a departure from previous methodology, this small vessel was used for both the seabed and wreck survey rather than utilising a larger survey vessel for the seabed area and the smaller one for work close to and over the wreck. The system specification ensures that the beams are properly formed in shallow water and provides the clearest digitisation. The single system provided the highest quality bathymetry data across the full survey.

3.2.4 For the structure above the water, an Applanix Landmark Marine Laser system was used. This combines an Optech Iris-3D Laser Scanner and Applanix POS MV 320 inertial system to provide a fully integrated marine vessel based mobile mapping solution for producing accurately georeferenced LiDAR point cloud data. It complements the MBES data to create a complete image of the wreck's structures which extend above the water line. The POS MV provides position, roll, pitch and heading information to correct the range and angle information generated from the laser scanner and allows the user to generate a geo-referenced point cloud. Both parts of the system are fitted to a custom-made mounting bracket with the POS MV Inertial Motion Unit next to the scanner and the GPS antennae placed on arms reaching either side. The offsets between each component of the system are fixed which enables rapid mobilisation of the scanner without the need to take measurements prior to every survey operation.

3.2.5 POS MV 320 inertial systems were used to output real-time position, attitude and heading data. The sensor outputs heading and attitude to an accuracy of 0.02° and 0.01°, respectively.

3.2.6 The acquisition software package QINSy was installed on the survey vessel for the hydrographic work. QINSy is an integrated navigation system software package that allows the combination of multiple sensors to produce accurate XYZ data.

3.2.7 The tidal solution employed to reduce the sonar data relative to Chart Datum is achieved through the use of the vessel's GPS equipment as a real-time tide gauge. The GPS antennae are known heights in relation to the WGS84 reference ellipsoid. This information, combined with the UKHO's Vertical Offshore Reference Frame (VORF) model, which contains the separation values between the WGS84 ellipsoid and a Chart Datum referenced geoid model, is used to calculate the tidal height of the multibeam sonar throughout the survey and reduces the soundings' depth to match this datum.

3.2.8 Once the data has been collected, raw multibeam data is taken into a processing software package and a 3D point cloud is generated for detailed analysis. A number of software packages were used to produce the final XYZ solution.

3.2.9 Raw data was logged in the .XTF format by QINSy and then converted into Caris HIPS format for post-processing. The positional data logged by the POS MV is also post-processed so that any inaccuracies can be removed and a positional solution with an accuracy of >5 cm could be produced in the form of an SBET (Smoothed Best Estimate of Trajectory). A GPS height/tide solution was derived from the VORF model and the bathymetry data reduced to Chart Datum. In the final stage of processing the bathymetry data was merged with a vessel configuration file containing the calibration values obtained during the mobilisation of the vessel. A BASE[2] surface is then generated in CARIS and this gridded DTM (digital terrain model) is used to highlight any height or positional errors within the dataset. Across the surrounding seabed the standard deviation values within the dataset are less than 0.1m.

3.2.10 Once the data had been taken through Caris HIPS it was then loaded into the QPS program DMagic and from that a PFM structure was built. The PFM was loaded into Fledermaus which allowed the data to be viewed in three dimensions so that it could undergo cleaning and editing procedures. Once cleaning had been completed a point cloud could then be exported that would be used in the analysis of the wreck structure.

3.2.11 The methodology and results of the sub-bottom profiling are covered in section 6.

4. SURVEY RESULTS

4.1 The survey of the SSRM draws together a number of survey techniques to produce a combined dataset which can be used to analyse the structure of the wreck and the surrounding seabed in fine detail. The 2014 survey involved the use of multibeam sonar and 3D laser scanner in conjunction with photographic equipment to build up a comprehensive understanding of the current state of the wreck.

[2] BASE = bathymetry associated with statistical error

4.2 Following the principle methods that have previously been utilised ensured that the 2014 dataset would be of a similarly high standard. The manoeuvrable and relatively shallow drafted MV Galloper was able to acquire the data over the wreck ensuring that the best possible positions to insonify the structures were reached whilst maintaining the maximum degree of safety. Repeatedly running lines produced sufficient levels of data redundancy so that only the best lines made it into the final, cleaned dataset from which clear images and effective comparisons with previous survey data could be made.

4.3 A bi-product of the bathymetric data is backscatter information which generates an acoustic image of the seafloor and shows variations based on the reflectivity of the seabed surface. High resolutions can be achieved which could help to visually inspect artefacts shown in the bathymetric surface. Details of the backscatter component of the data can be found in section 5.13.

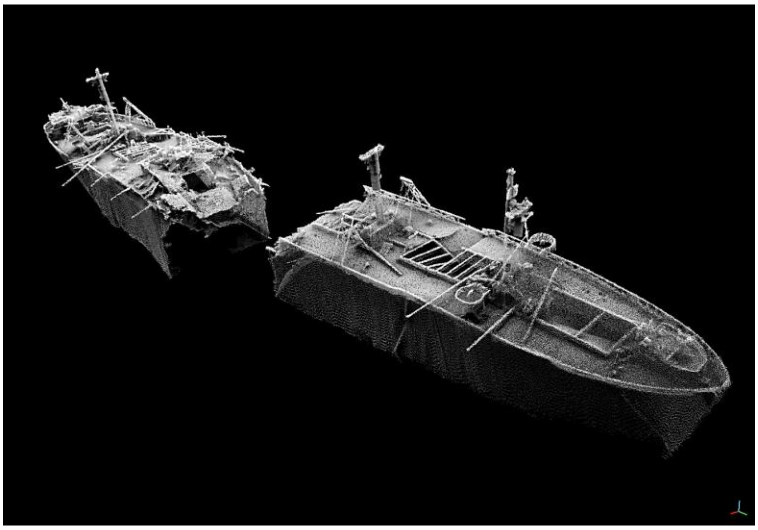


Figure 2. View of the wreck from the starboard bow from the 2014 data

4.4 In previous surveys, three key factors have been identified which impact on the stability and rate of deterioration of the wreck. These are, the condition of the hull structure; the local environment around the wreck; and the condition of the munitions within the forward section of the wreck (the stern section having been salvaged). These three factors are expanded on below.

4.5 The Hull Structure

4.5.1 Previous surveys have identified five key areas of the hull where deterioration is notably more advanced than across the rest of the wreck. Originally four key areas, a fifth was added following the 2013 survey. The survey results for these five key locations will be discussed first, followed by the results across the rest of the wreck.

4.5.2 The locations of these five areas can be seen in the plan view of the wreck site shown below. On assessing the 2014 survey data, in only one of these five key locations was any change observed.

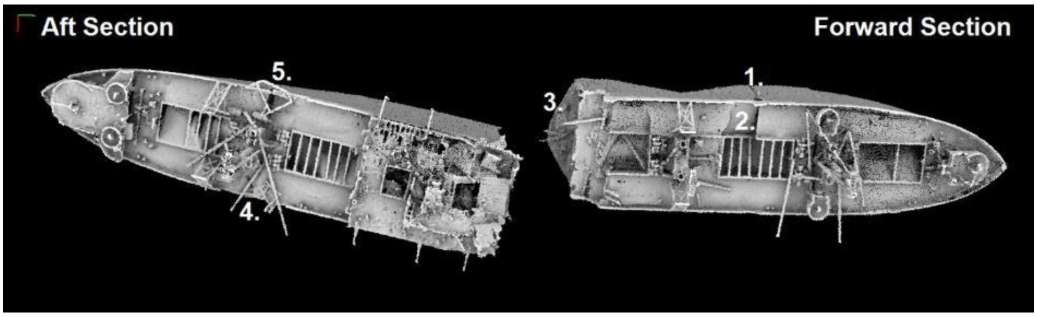


Figure 3. Overview of the wreck with locations of key areas

Table 1: Key Locations on the S.S. Richard Montgomery

Key Location Number	Feature	Location	Change Observed in 2014
Area 1	Crack in Hull	Port Side, Forward Section (Near Hold 2)	NO
Area 2	Collapse of Cargo Hold Deck	Port Side, Forward Section (Near Hold 2)	YES
Area 3	Aperture	Aft End of Forward Section	NO
Area 4	Splitting of Hull	Starboard Side, Aft Section (Near Aft Mast House)	NO
Area 5	Split in Deck & Hull Plating	Port Side, Aft Section (Near Aft Mast House)	NO

4.5.3 Area 1 is a crack in the hull on the port side of the forward section at Hold 2. Visual assessment of the crack suggested that there had been little change in its dimensions since the 2013 survey was completed. Also visible in the 2014 dataset was the vertically orientated bend in the hull plate below the crack which was identified in the last survey. Measurements of the maximum height and width confirmed that there had been no significant change.

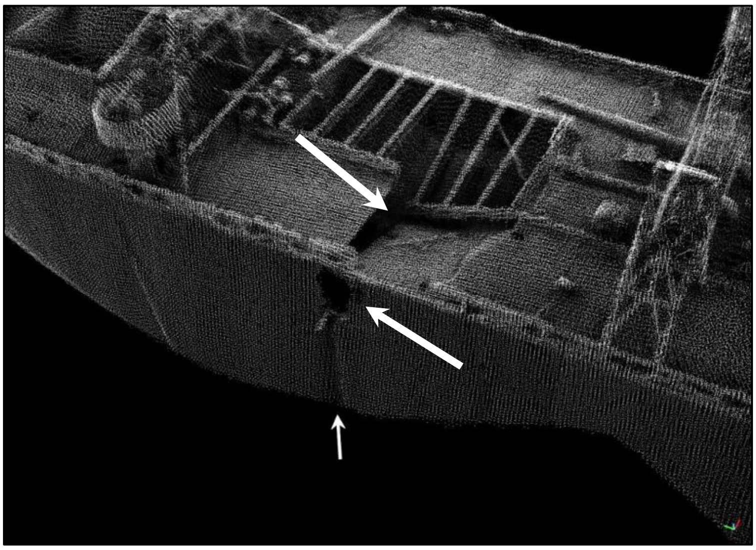


Figure 4. Crack in the hull at Hold 2 and collapsed deck plating at Hold 2

Table 2: Measurements of Crack in Hull Hold 2

Dimensions of Crack in Hull		
Year	Height (m)	Width (m)
2013	3.31	2.16
2014	3.40	2.10

4.5.4 Area 2 is an area of collapsed deck plating on the port side at Hold 2. This area was well defined in the dataset of the 2014 survey. Measurements taken indicated that subsidence of the deck plate was continuing. The distance between the in-situ deck plate and the subsiding section in the 2013 dataset was found to be 1.80m whereas in the 2014 data this had increased to 2.05 m. This subsidence is confined to the collapsed section of the deck. Adjacent to the collapsing deck plate the lower hatch cover of Hold 2 shows a large change in depth since the 2013 survey. A shoaling of the surface by up to 1.5m was observed and this is most likely the result of deposition of sand onto the cover. An increased sediment load may also be a contributing factor to the continued collapse of the deck plating.

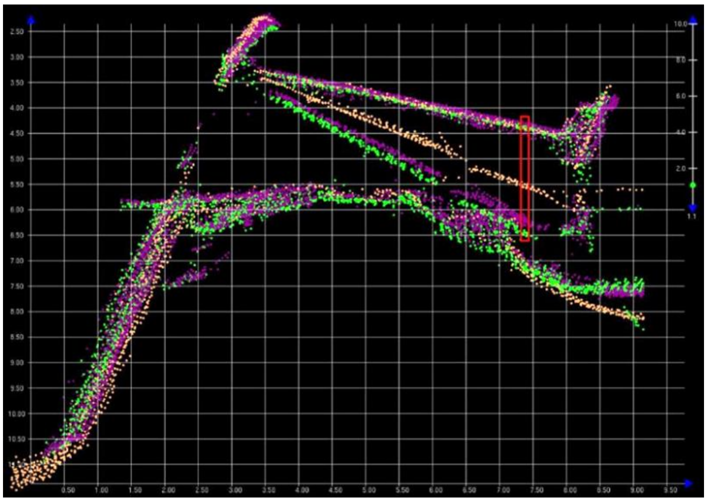


Figure 5. Collapse of deck plating from 2010 (orange), 2013 (purple) and 2014 (green)

Table 3: Results of data comparisons of the collapsing deck on the port side of Hold 2

	Dataset	Depth (m)	Magnitude of Collapse (m)	Collapse since Jan 2014 (m) [Date of 2013 survey]
Normal Deck Level (Forward of Collapsed Section)	All Datasets	4.35		
Collapsed Deck	2010	5.50	1.15	
	2013	6.15	1.80	
	2014	6.40	2.05	0.25

4.5.5 Area 3 is an aperture on the port side of the bulkhead at the aft end of Hold 3. This is of interest because it permits access to the interior of Hold 3 and it has been possible on some occasions to visualise what may be evidence of the cargo in Hold 3. Comparisons between the 2013 and 2014 datasets showed that no increase in the dimensions of the aperture had occurred. In fact, a small reduction of the width was recorded, although this is likely to correspond to a small difference in the positions from which the measurements were taken. As in 2013, the height of the aperture was measured at 4.10m. However, the width was measured as 1.70m in 2013 and 1.56 in 2014.

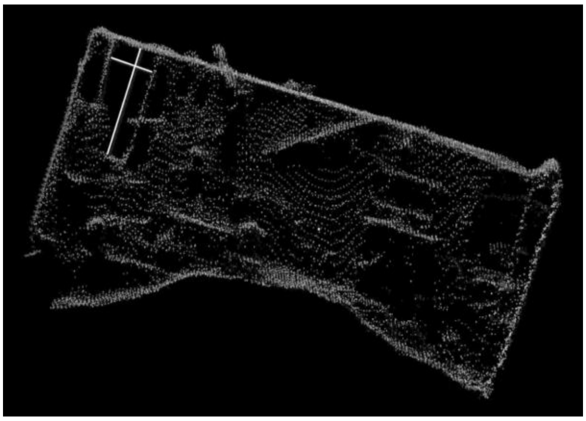


Figure 6. Hold 3 bulkhead Aperture. White lines show the locations of the measurements.

4.5.6 Area 4 is a split in the hull on the starboard side of the stern section. This feature has been once again clearly defined in the 2014 dataset. An effective comparison with the historical datasets in CARIS Subset Editor showed that there had been no increase in the width of the split in the hull plate between the 2013 and 2014 surveys. The slight misalignment of the two datasets is not considered to indicate movement of the hull as it is within the limits of accuracy of the positional equipment.

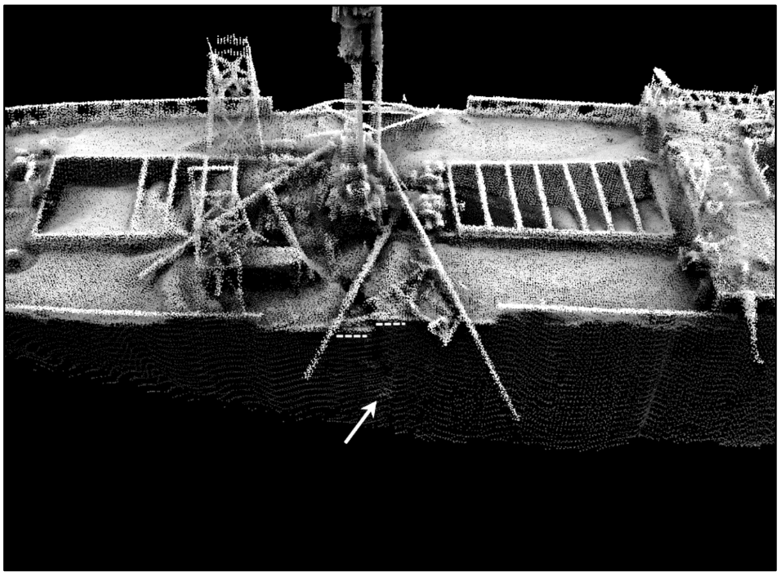


Figure 7. Misalignment of gunnel and associated split in hull – starboard side between Holds 5 & 4

4.5.7 Area 5 is a large split in the deck and hull plating on the port side of the stern section adjacent to the aft mast house. This area of structural deterioration was added to the key areas following the 2013 survey and is adjacent to similar deterioration on the starboard side of the hull at this location. The area was again well defined by the 2014 survey and assessment of the data suggests that there has been no further subsidence of the different levels of deck plate since the 2013 survey. Examination of the split in the hull plate from the port side indicated that there had been no identifiable deterioration since 2013. However as this is the site of recent noted structural shifting it will remain a key area in future surveys.

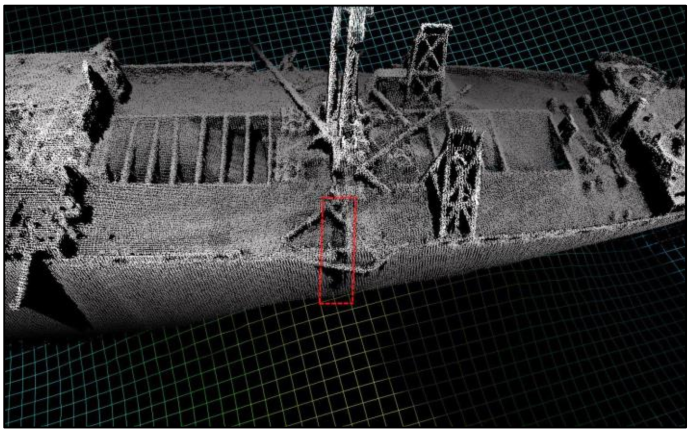


Figure 8. View of the split in deck and hull plating on port side of the Aft section

4.5.8 Across the rest of the wreck other features which have shown evidence of change or deterioration when compared with the 2013 dataset are detailed below. Comparisons with the 2010 benchmark dataset have also been made so that the progression of the changes can be understood over a longer period.

4.5.9 The break in the gunnel on the port side of Hold 2 has increased its angle of lean towards the east, possibly as a result of the movement of the adjacent collapsing deck plate. Close comparison of the datasets from 2013 and 2014 showed that the 2014 dataset was generally east of the 2013 position but by an amount that was not greater than the positional accuracy. Despite not being able to conclusively state that subsidence of the gunnel had occurred, the deck plating adjacent to Hold 2 has shown further collapse (as detailed above) so movement of the attached structures may be expected.

4.5.10 A hole in the hull plating on the port side of Hold 2 was identified in the 2014 dataset and as such is included as an area with detectable change. The dimensions of the hole are 35cm by 25cm and it was identified by soundings placed in the wreck interior suggesting that the hole was not an artefact of the multibeam system or a shadow created from a neighbouring structure.

4.5.11 A hole in the deck plating on the port side of Hold 2 was known from previous surveys and has shown no change in 2014. However, the 2014 survey data indicates a number of other holes close by. Three additional holes of a similar size are clear in the survey data, each measuring approximately 50cm x 50cm.

4.5.12 A number of the holes along the port side of the boat deck on the aft section are shown to have increased in size and some evidence of subsidence was identified in the collapsed section of the boat deck forward of the holes. Whilst some of the holes in this area appear to have remained consistent in size and shape between the two surveys, some holes slightly in-board show some evidence of change. This is due to the loss of deck plating around the edges of holes and in some cases this process has caused some smaller holes to merge into larger gaps in the deck.

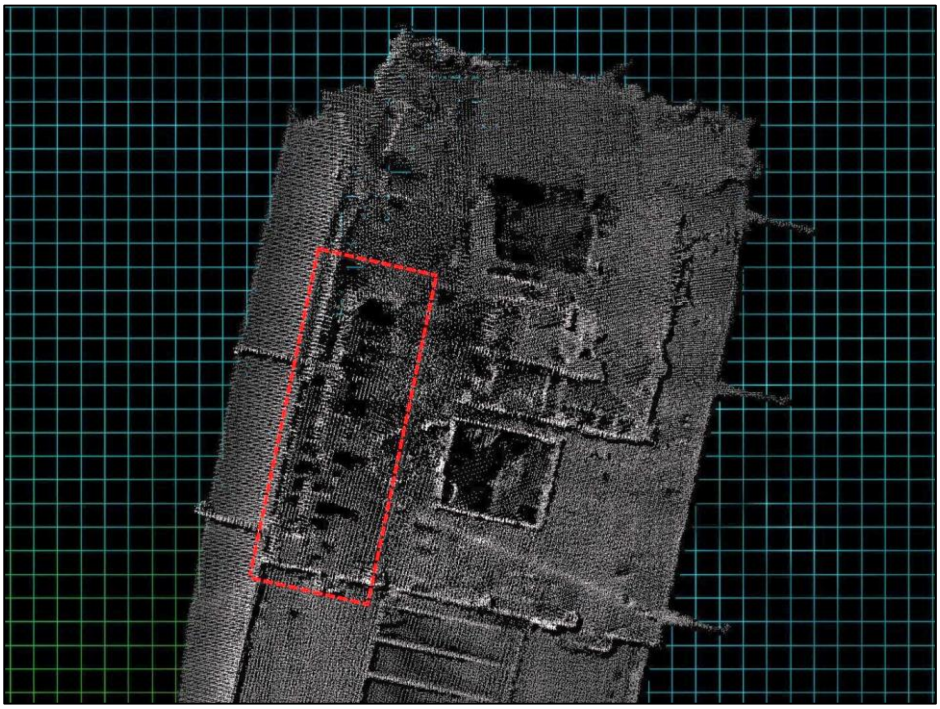
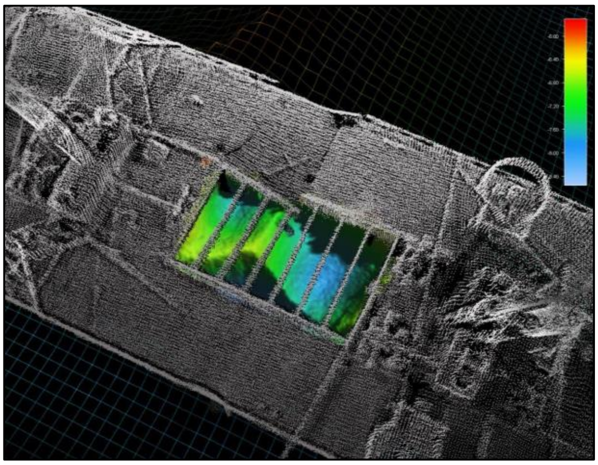


Figure 9. Plan view of the bridge deck with the holes in the boat deck highlighted on the port side

4.5.13 Over the lower hold covers of Holds 2, 3, 4 and 5 there has been some reworking or deposition of sediments. This is most evident at Hold 2 and may be associated with the ongoing subsidence of the deck plate along the port side. The survey vessel passed directly over the top of Hold 2 resulting in a high density of soundings over this area and showed the surface shoaling up to 1.5m near the aft end of the hatch. Hold 3 showed surface changes consistent with mobile sediment, but with less variability than is seen in Hold 2. This is probably due to Hold 3 being more exposed to the strong tidal current that passes between the sections of the wreck. Excellent coverage over Hold 4 was achieved during the 2014 survey, aided by the addition of survey lines aimed at covering the aft end of the boat deck area. The surface beneath the Hold 4 hatch cover supports showed evidence of some minor reworking of sediment infill, surface difference analysis determining that there had been a 30cm loss in height aft and a 30cm elevation forward. Similarly with Hold 5 surface difference analysis and examination of cross sections through combined datasets showed that the four remaining hatch cover supports have continued to remain static and some evidence of sediment reworking was evident on the lower hold cover.



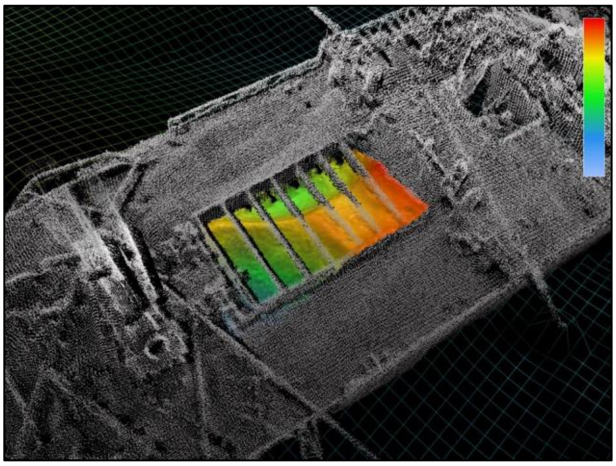


Fig. 10 & 11 Sediment surface showing the form of the infill over the lower hold cover of Hold 2 & 4

4.5.14 Situated on the forward end of the aft section of the wreck are the remains of the central superstructure. This is comprised the boat deck and bridge deck levels and would have been the locations of the smoke stack, engine room skylight and life boats. Two gun tubs were positioned at roof level at each end of the bridge deck. These structures are now a complex area of wreck structure and debris which in part overhangs the split between the two sections of the wreck. Some evidence of subsidence can be seen in this area, in particular associated with the overhanging forward part of these structures. Up to 25cm of subsidence is apparent and, although the same magnitude of collapse has not occurred in the immediate vicinity of the boat deck, the 2014 dataset is consistently positioned beneath soundings from 2013. The greatest magnitude of collapse is along the forward edge. The relatively short period of time between the surveys means that the degree of collapse is generally small. However comparisons with data from 2010 show that over this longer time period more significant subsidence can be seen.

4.5.15 On the boat deck level are remains of the upper sections of the central superstructure. These include a feature which was established in early reports to be the gunnery officer’s cabin. It is a box-like structure located between the engine room casing and the boiler casing. This and the aft and starboard bulkheads of the boat deck quarters are the upper-most remains of the superstructure. As has been noted in previous surveys, no structures identifiable as belonging to the bridge deck level quarters are present on the wreck; it is likely that these parts collapsed into the gap between the forward and aft sections some time ago.

4.5.16 The boiler room casing showed evidence of minor subsidence on the forward side but the aft edge remained stable. It is possible that this change was related to the small misalignment between the 2013 tilted head dataset and the 2014 survey but given the unstable nature of this area of the wreck it seemed appropriate to include it as a detected change.

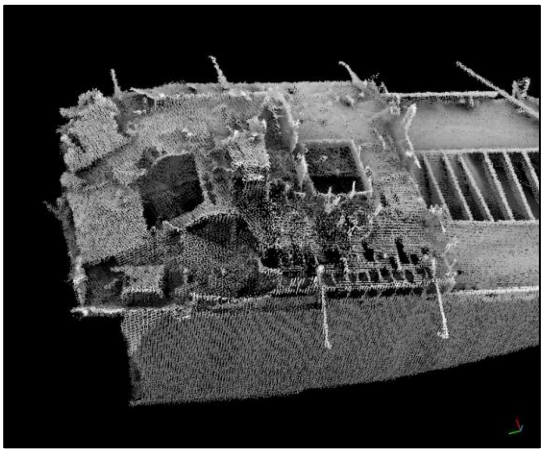


Figure 12. Forward end of the Aft Section; a region which has experienced structural changes over the last year

4.5.17 The collapsed boat deck on the port side of the forward end of the Aft Section has been the site of recent significant collapse in an overhanging structure which was observed in the 2013 report. On the left hand side of the image below, the 2010 data (orange) shows a near horizontal structure which in the 2013 dataset has tipped forwards to lie at an angle of approximately 65°. In the 2014 data this structure has continued to drop and now lies at approximately 83°. Across the collapsed boat deck region there is evidence of minor subsidence, typically around 0.1m.

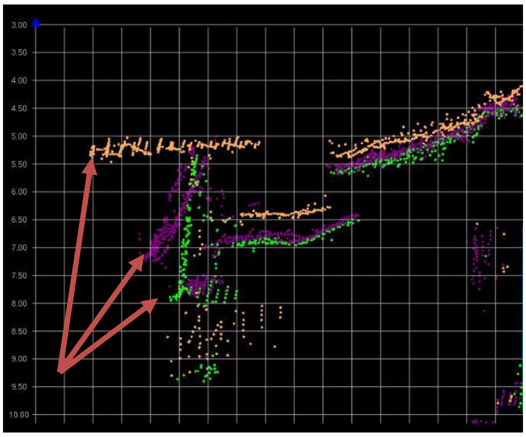


Figure 13. Cross section through collapsed Boat Deck. Data from 2010 [orange], 2013 [purple] and 2014 [green]

4.5.18 The structure identified as the gunnery officer's cabin is located amongst the debris of the central superstructure and was well defined in the 2014 dataset. Examination of cross-sections showed that the plate forming the top of the structure has subsided by up to 0.20m otherwise the appearance is very similar to the 2013 dataset. This structure and the bulkheads to the starboard side and to the aft are all that remains of the cabin space on the boat deck level.

4.5.19 Surface difference results indicated that the fore-most lifeboat davit on the starboard side of the boat deck had subsided since the 2013 survey. Examination of the area showed that, at the far end, the davit had subsided by 0.16m from its position in the 2013 dataset. This subsidence is associated with the continued collapse of the overhanging section of bridge deck at the forward end of the Aft Section.

4.6 Deformation of the Hull (Hogging)

4.6.1 As outlined in Section 2, contemporary reports explain that the SSRM showed signs of hogging immediately after grounding in 1944. Successive surveys have noted evidence of deformity in the hull however, the level of deformity and any increase is difficult to measure.

4.6.2 To determine whether any change had occurred in the deformity of the hull on the port side adjacent to Hold 2 a gridded surface was created. Surfaces from different years can then be easily compared. A visual comparison of the surfaces indicated that there had been no significant change during the period between the surveys.

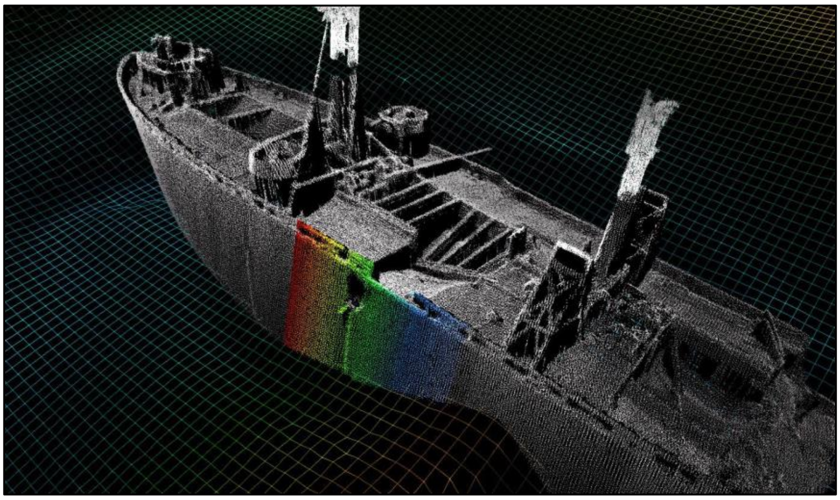


Figure 14. Overview of the Forward Section with the area of the hull gridded into a surface highlighted in colour

4.6.3 Further forward on the port side adjacent to the fore mast a region of distorted hull was well defined by the 2014 survey. However, examination of the point cloud data suggested that little change had occurred since the last survey and surface difference analysis of a gridded section of the hull also suggested that the shape of the buckled region remained consistent. There was some indication that the form of the hull had altered slightly with the hull deviating towards the bottom left of the gridded surface. This is most likely caused by slight positional misalignments.

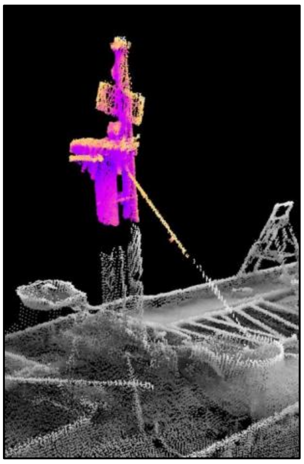
4.6.4 A series of features on the starboard side of the hull at Hold 2 have been grouped together in previous survey reports as they relate to the same structural distortion. The starboard hull shows a number of creases and discontinuities. This area can be difficult to insonify due to the angle of list and overhanging debris. However, it has been well captured in the 2014 dataset. Comparison of multiple datasets (2010, 2013 and 2014) shows that the angle of crease has remained constant indicating that no deterioration had occurred. This conclusion was supported by the surface difference results on the deck adjacent to Hold 2. If the angle of the crease in the hull becomes more acute it is likely that the deck level will be pulled downwards.

4.6.5 Still on the starboard side of the forward section, holes in the hull and deck plating adjacent to a vertical discontinuity were identified in the 2013 data as being acoustic shadows rather than actual holes. The 2014 data continues to support this. Data was compared from 2010, 2013 and 2014 but drawing conclusions on this area of the hull is difficult as year on year changes may be caused by the position of the survey vessel rather than real changes in the wreck. The distorted hull plate however was well defined in the 2014 dataset. This shows the hull plate projecting out of the wreck in the upper and lower parts and into the hull in between. Also notable is the degree of bend in the hull plate here. Assessments of datasets from 2010, 2013 and 2014 indicated that there had been no significant increase in the outward projection of the hull plate when compared with the previous datasets.

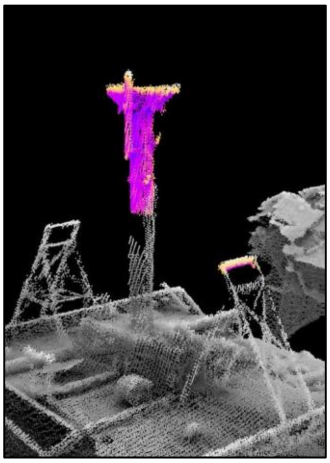
4.7 Masts and Booms

4.7.1 All three masts on the SSRM are in place and are visible above the water at all states of the tide. These are surveyed with a combination of multibeam sonar for the areas below the waterline and laser scanning and photography for the areas above the water.

Fore-Mast and Mast Stay Cable



Main Mast and top of Port Life-Raft Rack



Mizzen Mast

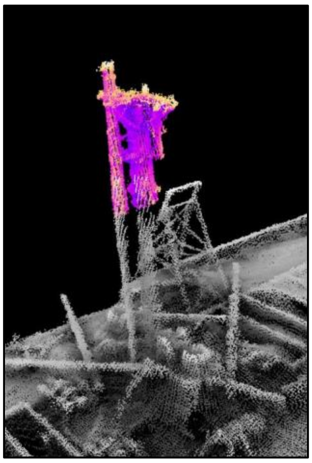


Fig. 15, 16 & 17. Combined laser (coloured) and sonar data (grey) acquired during the 2014 survey.

4.7.2 Dense coverage of the fore mast area was achieved in the 2014 dataset and none of the features in this area exhibited any evidence of deterioration since the last survey. The single mast stay cable remains attached and was well picked out in both datasets. The cargo handling booms, which were originally all attached to the foremast and mast house were all assessed in the data and, using a combination of point cloud imagery, surface difference analysis and cross-sections, no evidence of deterioration since the last survey was found.

4.7.3 Dense coverage was also achieved in the area around the main mast and mast house. Various comparisons between the datasets showed no evidence of deterioration of the mast or mast house when compared to 2010 and 2013. The cargo handling booms lying across the deck showed no evidence of movement or deterioration since 2010.

4.7.4 The mizzen mast displayed the best coverage of the three masts in the 2014 survey. On the forward side of the mast the laser and sonar datasets overlap providing, for the first time, a continuous dataset over this structure (see fig. 17 above). The upper mast structures have been well captured by the laser with the cable stay ends, chains and twisted flaps of metal identifiable in the point cloud. The mast house was well defined with high density and excellent coverage over this area which was achieved by running lines across the fore and aft ends of Hold 4. There was good alignment of the datasets from 2010, 2013 and 2014 and this showed no indication of subsidence or deterioration of the structures.

4.7.5 Three of the mizzen mast cargo handling booms can be seen in the multibeam data lying across the deck. Of these, two showed no evidence of change or deterioration. One showed no evidence of change or deterioration since 2013 but comparisons to the 2010 dataset indicated that some subsidence had occurred.

4.7.6 The 2013 survey showed that one of the stays on the fore mast had become completely detached and was found lying on the deck below and the warning sign on the main mast was no longer in situ, having become detached between the diver survey in September 2013 and the laser scanning in January 2014 (delayed from October 2013). No such changes were noted in the 2014 survey.

4.8 Areas with no Detectable Change

4.8.1 This section of the report covers some of the features of the wreck which have shown no evidence of deterioration or subsidence when compared with the multibeam datasets acquired during recent surveys. The 2014 dataset was compared to the 2013 survey in order to identify any changes which have occurred over the last year and then compared with a bench-line dataset from 2010 in order to identify more long-term trends.

4.8.2 Some of the areas which showed no changes in 2014 are:

- A hole noted in previous surveys in the deck plating on the port side of Hold 2 has not changed in dimensions since 2013.
- Holes in the deck plating on the port side of Hold 1 were visually inspected and showed no identifiable deterioration. The holes range in size from 0.5m to 0.7m across their longest axis.
- Examination of the point cloud data for 2014 suggested that there had been no identifiable deterioration in the area of collapsed deck and hatch coaming at Hold 3. Surface difference analysis suggested that subsidence of less than 10cm had taken place however this is thought to be a misalignment of the data resulting from the use of the tilt mechanism during data acquisition. Comparisons of the 2014 and 2010 dataset showed a close match suggesting that the area has remained stable in recent years.

- A split in the deck plating on the starboard side of the stern section adjacent to the mizzen mast is associated with a split in the hull plating and an area of collapsed deck beneath one of the booms. Multiple datasets were compared and no progression of collapse was evident and datasets from 2014, 2013 and 2010 were well aligned.

- A section of the boat deck which has been reported as missing in previous survey data was identified in 2013 as still being in situ. The 2014 data again identified this section of boat deck and whilst some slight subsidence may be indicated, this was inconclusive.

- The remaining hatch cover support at Hold 1 was found to be still in situ and comparisons with data from 2014, 2013 and 2010 suggest no deterioration has occurred during this period.

- At Hold 2, six hatch cover supports remain in situ. Surface difference analysis suggests that they have remained static since 2013. Although close examination of the cross sections suggests that the 2014 data may lie slightly beneath the previous survey in the area close to the collapsed deck plate.

- Hatch cover supports at Holds 3 and 4 showed no evidence of change since the last survey.

- No significant structural deterioration has occurred in the area around the engine room skylight and engine room casing.

- Each of the remaining gun tubs were assessed and none showed any evidence of deterioration since the 2013 survey.

- Liferaft racks on both the bow and stern sections of the wreck were inspected and no evidence of change or deterioration was found. Similarly, the anti-torpedo net cage was clearly captured in the 2014 data and surface difference analysis and comparisons with historical datasets indicated that no subsidence or deterioration has occurred since the last survey. Lifeboat davits also showed no evidence of change.

- The rudder and propeller were clearly visible in the 2014 survey data and no changes were noted.

- The mass of debris on the seabed adjacent to Hold 3 includes what are probably hatch cover supports from Hold 3, cargo handling booms and lifeboat davits from the boat deck. The presence of a vertical boiler has been mentioned in historical datasets but is not identifiable in the debris. Surface difference analysis in this region showed that some small scale changes had occurred but these are likely to be the result of sediment movement as the structures present did not reflect the same magnitude of movement.

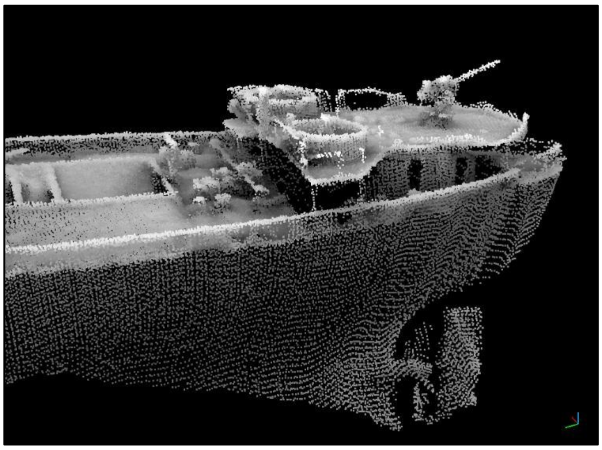


Figure 20. Point cloud showing the stern gun tub, rudder and propeller

4.9 Vessel List & Orientation

4.9.1 The wreck of the Richard Montgomery split into two sections on the 8th September 1944. Since then no further break-up of the wreck on such a scale has taken place and the two sections lie approximately 8m apart. For the purposes of this report the two sections are referred to as the forward or bow section and the aft or stern section.

4.9.2 In assessing the orientation of the forward section, profiles were generated across the beam aft of Hold 2 and along the length of the deck on the starboard side (where there is no evidence of localised subsidence). This showed that the wreck has remained in a stable position since the 2010 survey. The angle of list across the beam was calculated to be 18°, dipping to the east. The forward section is pitched forward with the bow lower than the aft. A marked increase in the angle of the deck forward of the fore mast is evident which means that no single angle of pitch can be determined.

4.9.3 The aft section is orientated with the stern pointing towards 194°. Measuring the angle of list across the beam on the aft end of the Boat Deck indicated that this section was dipping to the east-south-east by 15°. The effect of hogging along the length of the wreck meant that the angle of pitch increased towards the stern so it was not possible to calculate a single angle. However, the profiles showed that the aft section of the wreck had remained stable since 2010.

4.9.4 The two sections of the wreck are located at the positions given in the table below. The stated positions are located in an approximately central location in each of the sections of the wreck. The positions of the centres of the wreck sections established in the 2012 survey are still valid.

Table 4: Central positions of the Forward & Aft Sections of the wreck

Section	X	Y
Forward Section	346139.5	5704071.2
Aft Section	346140.4	5704001.2

4.10 Condition of the Munitions Cargo

4.10.1 As outlined in previous survey reports, the multibeam sonar and laser scanning survey techniques used to collect data on the wreck structure cannot be used to accurately predict the amount or condition of the munitions cargo. However, there are some areas of the wreck where previous survey data has been able to utilise cracks and apertures in the deck and hull plating to try to visualise the cargo inside. This data is difficult to interpret with any certainty.

4.10.2 The perforations in the deck plate along the port side of Hold 1 have on occasion allowed for the penetration of sonar beams into the hull. Unfortunately, this was not achieved in 2014.

4.10.3 At the 'tween deck area of Hold 2 visualisation inside the hold is possible due to penetration through the crack in the port side of Hold 2 and the area of collapsed deck plating. Coverage of this area was very similar to that achieved in 2013 and no significant changes to the wreck interior were noted.

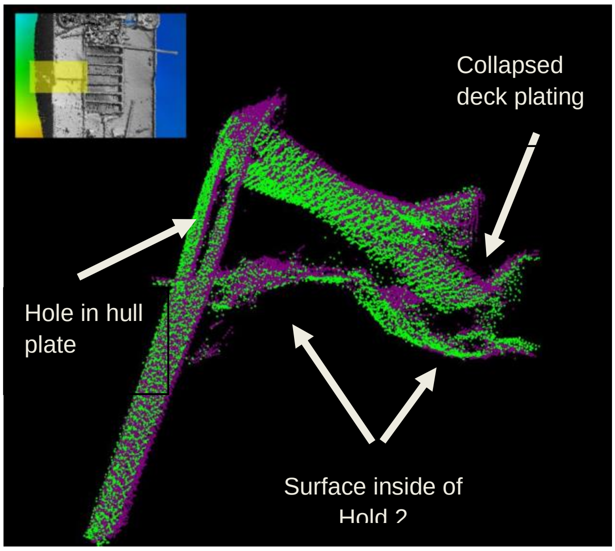


Figure 21. The interior of the hull at Hold 2 with 2014 (green) and 2013 (purple) datasets

4.10.4 At the aft end of Hold 3 'tween deck is an area of debris caused by the breaking of the vessel into two sections. Examination of cross sections and combined datasets for this area indicated that there had been no changes in the structures strewn across the tween deck area. Through apertures in the bulkhead at the aft end of Hold 3 it has, on occasion, been possible to visualise material inside of Hold 3. In the 2014 survey some insonification of the contents of Hold 3 was achieved. This showed the presence of a stack of material approximately 3.0 m in height with a jagged profile. The same least depth, 7m, which was determined by the 2013 survey was observed in this year's survey however the density of soundings was higher in 2013. Due to the limitations of the system and the poor access to the hold interior it was not possible to identify the nature of the contents.

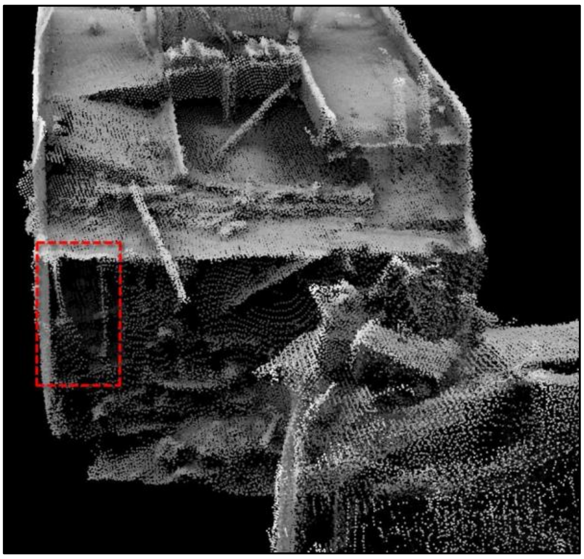


Fig 22. Hold 3 'tween deck and bulkhead with aperture

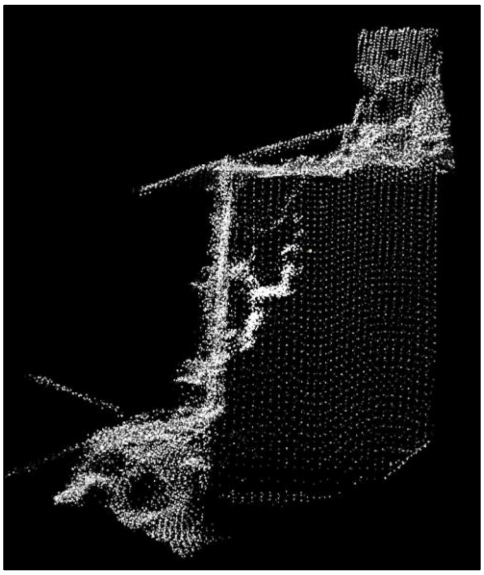


Fig. 23. Profile view showing zigzag shape of contents

5. SEABED ENVIRONMENT

5.1 Over the last 71 years, the wreckage of the SSRM has had a profound effect on the local seabed topography. The wreck lies on Sheerness Middle Sand which is an eastward projecting sand bar separating the deep waters of the Great Nore to the north and the Medway Approach Channel to the south. In order to determine the topographical changes caused by the wreck's interaction with the strong tidal streams and to locate objects exposed or buried by the shifting sediments a high resolution multibeam survey was performed over an area measuring 400m by 400m with the wreck at its centre. The digital terrain model (DTM) generated from 2014 survey data shows the deep scouring formed by erosion of the sediments surrounding the wreck. The use of surface difference analysis, as used over the wreck itself, highlights regions which have experienced deposition or erosion since the last survey.

5.2 The results of surface difference analysis performed on the bathymetry from the 2013 and 2014 surveys shows that seabed change is restricted to a few key sites. When taking the scale of the changes into account, the majority of the reworking observed constitutes changes of the order of +/-0.3m.

5.3 As in previous years, to assess the data the seabed around the wreck was split into three sections. Area A covers the area of the dredged Medway Approach Channel, area B focuses on the scour patterns which have formed to the east and west of wreck; and area C examines the sediment formations in the immediate vicinity of the wreck with the aim of identifying any changes which may affect the support of the two sections of the wreck.

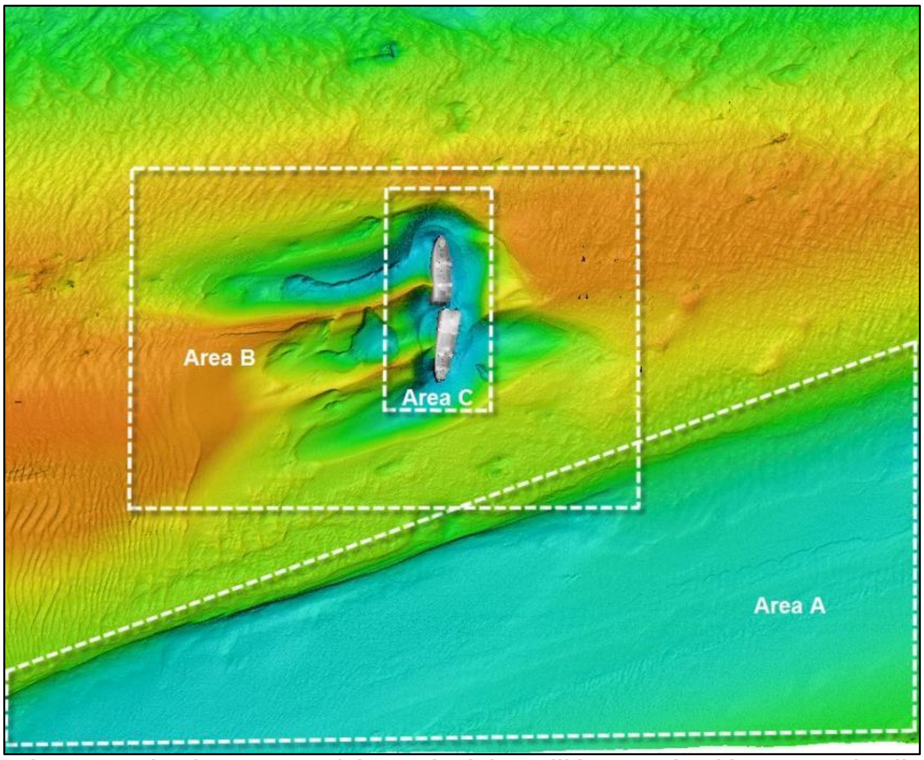


Figure 24. The three areas of the seabed that will be examined in greater detail

5.4 The assessment of area A showed that there had been relatively little change in the seabed topography in this area. Within the channel there is evidence of small degrees of sediment accumulation and erosion. The areas of accumulation had typically received +0.3m of sediment with a local maximum of +0.52m. Areas which have undergone erosion since 2013 have generally lost -0.25m of material and these areas are in the eastern and western sections of the survey area. The area exhibiting the greatest change is the wall of the dredged channel. This is likely to have resulted from a small repositioning of the slope which manifests as a height change in the surface difference above. The change is consistently an increase in depth (up to -1.6m) which suggested that the top of the channel had moved northwards by up to 5m, most likely as a result of slumping of the material on its upper section.

5.5 The DTM in the dredged channel was scrutinized in order to identify items of debris that have been transported from the wreck. No objects were found amongst the 0.20m high sand waves that are typical of this section of the survey area.

5.6 Examination of area B showed that in the scoured areas adjacent to the wreck the morphology of the seabed has remained largely unchanged with the exception of minor re-working of the finer structures. The area is dominated by two large ridges of sediment which have formed on the lee (west) sides of the forward and aft sections of the wreck. These ridges, in conjunction with the shoaler areas to the north and south of the wreck site, divide three, long, westerly orientated scours. The northern scour is the longest and the effect of the tide here can be seen right up to the border of the survey area, some 400m from the wreck. The two scours to the south are less extensive reaching approximately 250m from the wreck. On the eastern side of the wreck is a shoal which extends 160m from the wreck.

5.7 Examination of the northern scour shows that change is restricted to the steep wall that runs along the northern side of the deep section of the scour. There has been a deepening along this slope which corresponds to a widening of the deep base of the scour. The maximum depth change which has occurred here is -2.25m at a point near to the western end. There has also been some deposition here which may have resulted from the material shifted from the slopes.

5.8 The central scour, which has formed as a result of the tidal flow being compressed between the two sections of the wreck, has remained static since the 2013 survey. The prominent deep section is the principal site of change with removal of sediment around the fringes and in the north and east and material has been deposited across the central area. The removal of sediments at the edges has caused a slight expansion in the width of the scour. Up to -1.8m of material has been lost at the edges with a maximum of +0.59m of additional material in the middle of the scour. Immediately to the west is a depression near the ridge which has had some localised sediment reworking. In the southern scour little change has occurred and the eastern scour has also seen little reworking since the 2013 survey.

5.9 In area C, the topography of the deep scour around the wreck has remained broadly similar to the 2013 dataset. This suggested that the sediments in this part of the survey area have reached an equilibrium over the years that the wreck has lain on Sheerness Middle Sand. Some change is apparent, most notably on the flanks of the scour to the north of the bows with some erosion on the upper slopes and deposition near the bottom of the slope. This probably reflects a slump in the sediment from higher up which has collected near the base. On the western side of the forward section, the south side of the steep sediment ridge shows erosion with up to -1.25m of material removed from the slope. Around the aft section of the wreck there have been only minor changes in depth.

5.10 The general overview of the changing topography since the 2013 survey shows that no large scale reworking of the sediments has occurred. The wreck appears to be supported in a similar manner as has been seen in other recent surveys and the contours generated from the 2014 dataset closely match the contours from the 2013 survey.

5.11 Over the shoal to the west of the scours an eastward shift of the -5m contour is apparent. This eastward shift of the contour has continued since 2010 and material appears to have been consistently acquired in this area. The -10m contour which borders the Medway Approach Channel has remained in close alignment with the contour generated from the 2013 dataset but with an isolated dip formed by the sinker for the South Montgomery buoy. When compared with the 2010 survey the contours have consistently shifted towards the north which highlights the erosion of the channel wall which has occurred in this time.

5.12 Over the shoal bank to the east of the wreck, the complex, small-scale features result in repositioning of the convoluted contours. The changes observed are slight and there has been little change in depths since 2010. Dividing the northern quarter of the survey site the -10m contour runs from west to east and remains consistent when compared with the 2010 and 2013 datasets.

5.13 Backscatter Data

5.13.1 For the 2014 survey report it was decided that the use of backscatter imagery data would be investigated in order to closely examine the seabed surface for any objects in addition to those which are already known.

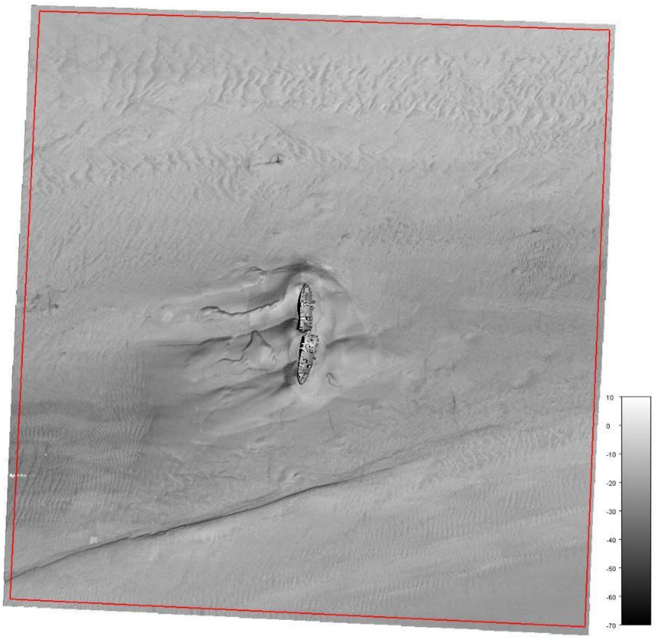


Figure 25. Backscatter results for the wreck site of the Richard Montgomery

5.13.2 Backscatter data is acquired simultaneously with the bathymetry as the sonar is able to record an intensity value from each returned ping along with the two-way travel time. The intensity value is determined by the texture of the sea floor and, therefore, can be used to highlight foreign objects on the seabed around the wreck. Backscatter data can also be processed to generate imagery with an improved resolution when compared with bathymetry data. During the processing of the 2014 dataset the final image produced has a resolution of 0.1m.

5.13.3 There are, however, a number of issues which restrict the ability of the surface to show fine scale structures in all areas. The data used to construct the image is raw and shows all the data acquired by the sonar, good or bad. Artefacts such as beam busts, which are cleaned out of the bathymetry surface, still remain in the backscatter image and the clearest picture is only possible in areas without overlapping lines. The processing algorithm attempts to smoothly merge the intensity values from different lines over the same area and the results of this averaging reduces the clarity of the final image.

5.13.4 Despite these issues, the use of the backscatter imagery in conjunction with the DTM of the seabed surface being coloured to highlight differences in standard deviation, has resulted in a number of additional targets being identified around the survey area.

5.13.5 In the 2013 report 40 objects were reported on the seabed within the survey area. The high resolution backscatter imagery helps to show objects which are composed of a different material to the surrounding seabed and, during the examination of this data an additional 12 objects were identified. These items have mostly been identified as chains and sinkers for current and previous marker buoys and most are along the line of the diamond shaped perimeter of the prohibited area. However, one much larger target appears to be an extensive area of debris in the far west of the survey area. Examination of the soundings in this area showed that the overall shape of the debris field was similar in profile to that of another target within the survey area which has previously been identified as probably the wreck of a Thames Barge. However, this new target is much larger measuring approximately 30m x 12m and may represent a third wreck within the survey area.

5.13.6 Another of the new features was located in close proximity to the aft section of the wreck. This is a small object measuring approximately 0.75m by 0.75m and with 0.25m exposed above the surrounding sediment. This object was identified by the presence of a small scour which has formed around its eastern side which suggested that it is more dense than the surrounding sediment. When comparing the 2013 and 2014 datasets this object can be located in both. It has not moved over the last year and may have been deposited relatively recently given that it could not be identified in data prior to 2013. Due to its small size there is insufficient data density to get a clear image. As the object lies only 30m from the hull of the aft section it is an object with potential importance. It is noted that during diving work carried out on the wreck in 2013, prior to the multibeam survey, two current meters were lost. At present, it is not possible to say whether this new target represents one of these lost current meters.

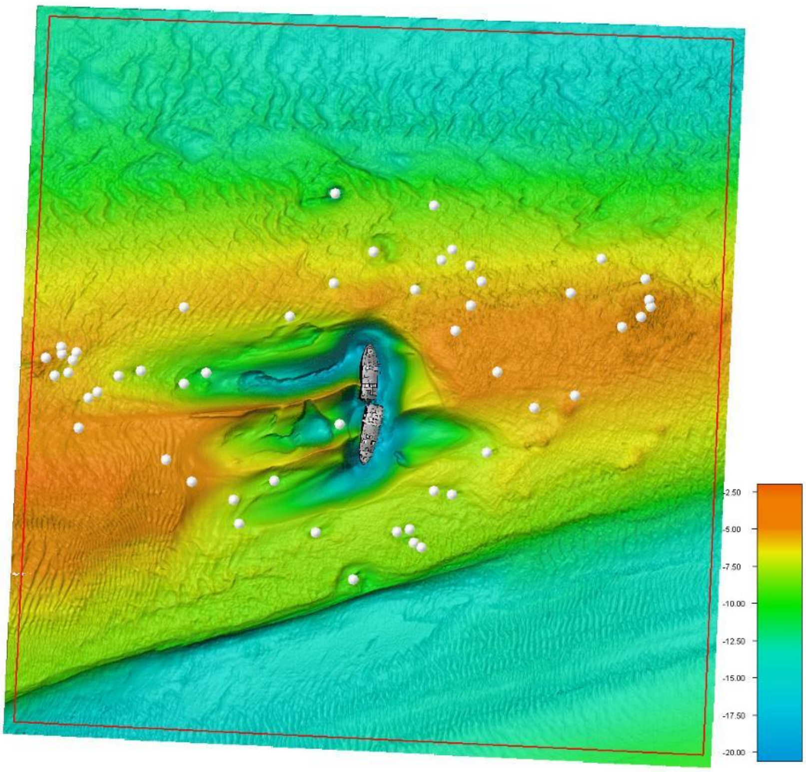


Figure 26. Locations of Seabed Targets

6. SUB-BOTTOM PROFILING

6.1 Whilst the SSRM and its surroundings have been the subject of regular surveys, new to the 2014 survey was the inclusion of a sub-bottom profiling survey which concentrated on the shallow sediments to establish the base material that the wreck is resting on and the nature of the banks surrounding the wreck.

6.2 Scope and Methodology

6.2.1 The sub-bottom profiling survey was undertaken on the 10th of March 2015 using the PLA vessel MV Yantlet to tow an ultra-high resolution single-channel seismic system, composed of a C-Boom boomer seismic source and C-Phone single-channel streamer. Data was acquired in SEG-Y format and processed in SonarWiz, producing one Fledermaus SD file for each profile for 3D visualisation, and also position and two-way travel time of the reflectors identified allowing for the estimation of the sediment depth.

6.2.2 The objective was to perform a sub-bottom profiling survey of the area around the wreck with a series of survey lines run parallel to the wreck as well as cross-cutting survey lines, to a vertical resolution of no less than 10cm. The work concentrated on the shallow sediments to establish the base material that the wreck is resting on and the nature of the banks surrounding the wreck.

6.2.3 For each profile, the aim was for the boundary between the seabed sediment layer and the underlying clay to be identified and highlighted, and a measurement scale produced which would allow an estimation of the sediment depth. Any significant reflectors detected below the London Clay should also be highlighted. Survey lines were run following the 50m planned line spacing with deviations due to the need to manoeuvre between buoys. For increased safety, lines closer to the wreck were run at high water.

6.2.4 A C-Boom low voltage boomer plate mounted on a catamaran was used as seismic source (1760 Hz specified dominant frequency), operated at an average of 490 V (approximately 90 J). The firing rate was set to 5 pulses per second. A C-Phone single-channel streamer with 8 hydrophones spaced 20cm, pre-amplifier and analogue band-pass filter was used.

6.2.5 The boomer catamaran was at first mounted at the bow between the twin-hulls, and the streamer was suspended from a pole to port side, with the mid-point located approximately on the control node T8. However, this setup proved effective only at speeds up to 1.5-2 knots as at higher speeds the wake generated by the bow of the twin-hull overlapped the boomer plate scattering the transmitted signal. This configuration could probably be used upstream but in this part of the estuary the tidal current is stronger and the vessel has to navigate at higher speeds. Therefore, the catamaran with the boomer plate and the streamer had to be towed behind the vessel, away from the wake, approximately 15-20cm below the surface (less than ¼ wavelength of the signal's dominant frequency).

6.2.6 The noise generated by the water jet propulsion of the vessel allowed for relatively clean seismic records at speeds up to 3.5 knots. However, in order to steer between the buoys, the vessel had to increase speed on the north-south lines, reducing the quality of the seismic profiles. The east-west lines had to be run with the tide because even at lower vessel speeds, the tidal current pitched up the boomer plate when it was towed against the tidal current, scattering the signal.

6.2.7 The analogue signal was digitised in the DA4G 2000 geophysical acquisition system, sampled at 40 kHz, with a 102.4ms recording window (4096 samples per trace), with 0ms delay It was recorded by the GeoSurvey software in 16 bit signed integer SEG-Y data format. The position recorded in the seismic file was the position of the control node T8, which was transversally located mid-distance between the boomer plate and the streamer.

6.2.8 MBES data was acquired simultaneously with ultra-high resolution single-channel seismic profiles in order to allow for vertical corrections in post-processing. The survey was carried out using the single-head multibeam sonar Reson 8125H fitted on MV Yantlet, the Applanix POS MV 320 inertial system that outputs real-time position, attitude and heading data, and the acquisition software package QINSy. Geodetic parameters for the survey were defined by the MCA.

6.2.9 The ultra-high resolution single-channel seismic data was processed in SonarWiz 5 V5.08.0011. The original SEG-Y files were imported and converted internally to SonarWiz CSF data format. Positioning was corrected for the difference between the control node T8 used as reference point, and the mid-point between the boomer and the streamer. A 33m layback was applied to survey lines up to and including 100315.141209.sgy, and a 41m layback was applied from line 100315.143117.sgy on. The seabed was digitised on all seismic profiles and moved to the correct position using as reference a 1m bathymetric grid, generated from MBES data acquired simultaneously with the boomer survey. The digital signal was processed using a 300-6000 kHz band-pass filter, automatic gain control, and stacking of 3 traces. Seismic profiles were then displayed with the full wave and a linear grey palette.

6.3 Sub-Bottom Profiling Results

6.3.1 Seismic profiles show overlapping of the first multiple and primary reflections as a consequence of the shallow water depth. Also, there was a high noise level within the bandwidth of the seismic signal caused by the water jet propulsion of the vessel. Both of these factors contributed to the degradation of the seismic record.

6.3.2 Two main reflectors were identified and digitised. The first reflector, approximately 2m from the seabed, deepening in certain areas to a maximum of 5m (considering 1600 m/s sound speed in the sediment) to the south in the Medway approach channel. This reflector marks the base of a first sequence of loose sediments with high porosity, probably sand, and probably corresponds to the top of the Holocene alluvium, which may continue up to the second reflector. The second sequence may be composed of more compact alluvium sediments, probably mostly composed by sand. Although it is possible to observe some reflectors inside this alluvium sequence, none are conspicuous enough to be followed between seismic profiles, especially considering the high noise level of north-south profiles.

6.3.4 The second reflector, with variable geometry, 5m to 25m from the seabed (considering 1650 m/s sound speed in the sediment), probably corresponds to the interface between the alluvium and the stiff clay of the London Clay Formation.

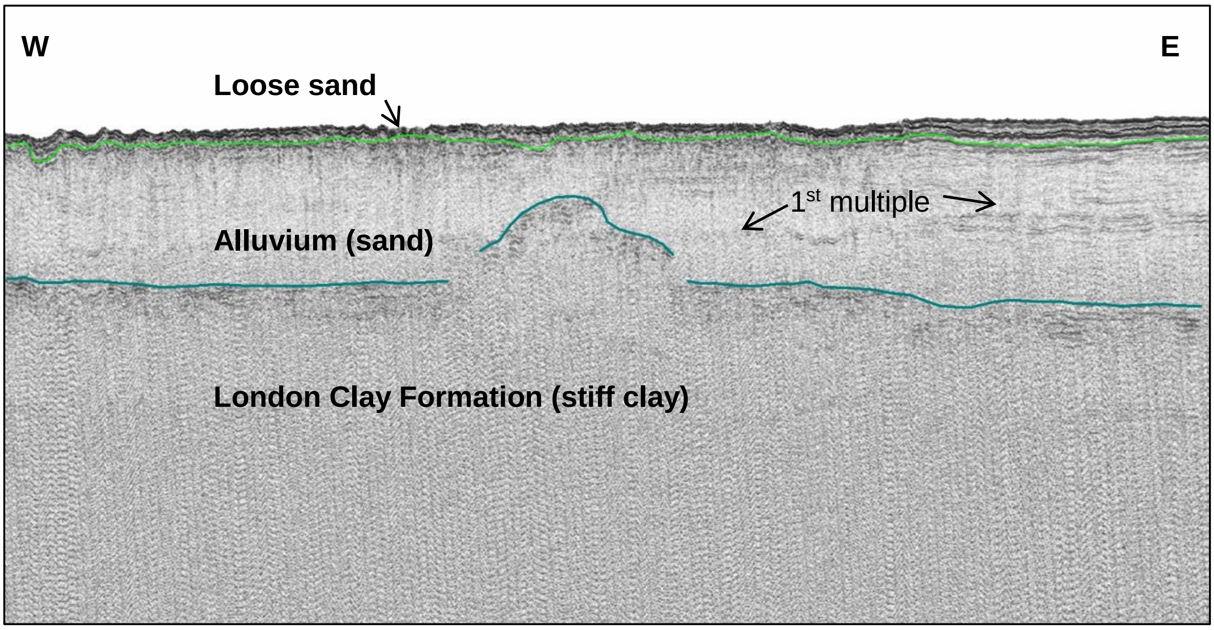


Figure 27. W-E boomer seismic profile 100315.133144.sgy, north of the survey area. Two reflectors were digitized; one probably corresponds to the top of pre-Holocene stiff Clay (turquoise) and the other to the base of the top unit comprising mobile loose sands (light-green).

6.3.5 The digitised reflectors were exported as two-way time ASCII files. Seismic profiles were exported to QPS Fledermaus V7 SD files for 3D visualisation (on these profiles two-way travel time is converted to Z using 1500 m/s sound speed).

6.4 Conclusions of Sub-Bottom Profiling

6.4.1 Two main reflectors were identified in the seismic profiles. One probably corresponding to the base of more recent loose sediments which forms the top of a thicker Holocene alluvium sequence, and another on the base of the alluvium, over the stiff clay of the London Clay Formation. Reflectors in seismic sections correspond to impedance contrasts and without ground-truthing it is not possible to match observed seismic facies with type of material and stratigraphic sequences. For this reason, core samples could be considered for the validation of the seismic survey.

6.4.2 The propulsion of the vessel had a negative impact on the quality of the seismic record. For future surveys of this type a vessel with a different type of propulsion, with lower generated noise and preferably in a different bandwidth should be used.

6.4.3 The tidal current also had a negative impact in the signal-to-noise ratio, scattering the signal transmitted by the boomer plate when the vessel increased speed to steer against the current and consequently engine noise increased. This was particularly the case when steering between the buoys and along the north-south profiles.

6.4.4 The tidal current in the Thames Estuary impacts on all of the survey work undertaken on the wreck. However, use of a chirp sub-bottom profiler could be considered in any future sub bottom work since it provides higher resolution, it is less sensitive to environmental noise (due to the frequency and amplitude modulated pulse and application of a matching filter), and in certain configurations may be fixed to the hull and thereby improve position certainty. However, since a reduced penetration is expected, this type of survey should be considered as a complement to the current survey.

7. CONCLUSIONS

7.1 The 2014 annual survey of the wreck of the SSRM has produced a high density dataset with the most complete coverage of the wreck to date. For the first time an overlap between the laser and sonar data has been achieved on the main and mizzen masts. This shows the precise alignment of the datasets and validates the methods used during data acquisition and processing.

7.2 Close inspection of the wreck's structures was performed and images produced show the high level of detail which can be achieved.

7.3 The examination of this year's dataset and comparison with historical survey data showed that a measurable deterioration of the wreck has continued. Subsidence of the order of 0.2m is apparent at a number of sites around the wreck. Other sections of the wreck show deterioration in the form of the expansion of pre-existing holes, such as the port side of the boat deck. Changes in the sediments deposited within the holds was again noted. This is most evident at Hold 2 where in parts an additional 1.5m of material has been deposited since the 2013 survey. It is not clear whether the deposited material remains trapped permanently. It is likely that the process ebbs and flows with the tides, but the additional loading observed at the time of the survey may provide the force necessary to promote further collapse of the adjacent deck plate.

7.4 Noteworthy for a lack of change is the split in the deck and hull on the port side of the aft section. Surface difference analysis conducted on products of the 2010 and 2014 datasets showed that the significant structural failures were still restricted to a small number of key areas around the wreck. Generally, the positions of the hull and deck, the masts and the bow and stern superstructure have remained quite stable over the last four years. This does not mean to say that the integrity of the hull is not in question as there are limitations to what the survey can detect. Additional work, such as the 2013 hull thickness assessment, is required to further determine weaknesses and corrosion. Surveys conducted with sonar and laser technology enable an overview of the gross state of the wreck to be achieved in areas where visual assessment is limited by the turbidity of the water and operations are restricted by the Thames Estuary tidal regime.

7.5 Analysis of the changing state of the seabed showed that the survey site undergoes small scale reworking with only small depths of sediments being deposited or eroded over wide areas. Greater degrees of change can be observed but these are restricted mostly to slumping of regions with steep gradients such as along the wall of the Medway Approach Channel and the walls of the scours. The main exception to this is a region on the shoal back to the west of the wreck which has seen up to 1.2m of material deposited over an area 150m long and 50m wide. The change over the last year appears to be part of a general trend of deposition in this region as comparison with the 2010 survey data showed that material has been acquired more widely over this region.

7.6 Utilisation of Backscatter imagery with the DTM coloured to show areas of data with high standard deviation has been an effective tool in identifying new objects on the seabed and should be considered again in future surveys.

7.7 For any future sub-bottom profiling work a vessel with a propulsion system with low generated noise and preferably in a different bandwidth should be used. A chirp sub-bottom profiler could be considered in any future sub-bottom work since it is less sensitive to environmental noise. However, since a reduced penetration would be expected this type of survey should be considered as a complement to the current survey.