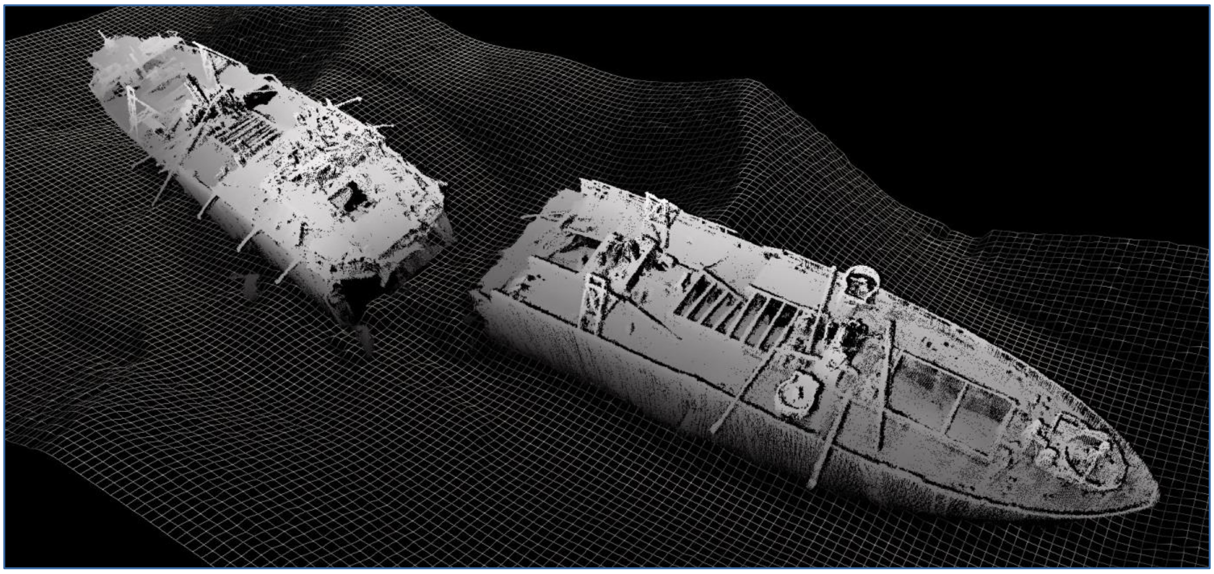
SS RICHARD MONTGOMERY

Survey and Hull Thickness Report 2013



Maritime & Coastguard Agency

September 2015

1. EXECUTIVE SUMMARY

1.1 In August 1944, the US Liberty Ship SS Richard Montgomery grounded in the Thames Estuary and, despite immediate attempts to salvage the cargo of munitions, the ship sank before the salvage operation could be completed. Approximately 1400 tons of explosives remain in the forward section of the wreck. The wreck of the SS Richard Montgomery is a designated dangerous wreck under section 2 of the Protection of Wrecks Act 1973 and there is a prohibited area around the wreck. The wreck has been the subject of regular surveys using a variety of methods.

1.2 The 2013 multibeam sonar and laser scanning survey of the SS Richard Montgomery was conducted on the 13th and 14th January 2014. Initially scheduled for October 2013, the delayed start of the survey resulted mainly from prolonged very poor weather and tidal surges during the autumn and winter of 2013.

1.3 As in the 2012 survey, the Port of London Authority vessels MV Galloper and MV Yantlet were used to carry out the data acquisition. The MV Galloper, the smaller of the two vessels, was used to access the shallow areas around the wreck and the MV Yantlet acquired the seabed data surrounding the wreck site. In addition to this, and separate from the multibeam survey work, a hull thickness assessment was undertaken by a Ministry of Defence dive team. This too was affected by the continued poor weather and therefore this work was split into two phases to fit around suitable weather windows.

1.4 The scope of the survey work included a full multibeam sonar survey of the wreck of the SS Richard Montgomery and the surrounding seabed out to a minimum distance of 400m from the wreck and laser scanning of the upstanding wreck features. The work included the production of a dataset which could be compared to those acquired in previous surveys, the identification of any areas of change or deterioration and the location of other objects on the seabed in the area around the wreck.

1.5 The hull thickness assessment used an ultrasonic thickness gauge to provide a repeat of the methodology used during the last diver survey in 2003 to allow a comparable set of results to be generated. To make best use of the dive team whilst they were deployed on the wreck, additional, secondary tasks were identified which included the trialling of a number of different sonar units and the deployment of current meters and a water sonde.

1.6 Whilst the wreck in its entirety was surveyed, following on from the results of previous survey work, particular attention was paid to a number of areas around the wreck which have shown progressive deterioration. These include the large crack in the hull on the port side of Hold 2, collapsed deck plating on the port side of Hold 2, a split in the hull plating on the starboard side of the stern section and the bulkhead aft of Hold 3. The hull thickness work focused on datum points on the port side of the bow section which were established during the previous hull thickness assessment in 2003.

1.7 In summary, the key results of these two pieces of work are:

1.7.1 The dimensions of the crack in the hull at Hold 2 have increased slightly from 2.69m by 1.29m in 2012 to 2.77m by 1.54m in 2013.

1.7.2 The collapsed deck plating at Hold 2 has dropped by a further 20cm since 2012, although the deck on either side has not moved.

1.7.3 The aperture in the starboard side of the bulkhead aft of Hold 3 showed no increase in dimensions.

1.7.4 An aperture and crack in the stern section, starboard side is difficult to insonify, but 2013 data shows distorted hull plating above an aperture of 1.2m by 0.9m.

1.7.5 On the port side of the stern section the area of collapsed decking has not moved since 2012 although the area around it exhibits subsidence and the adjacent split in hull plating extends down to the seabed.

1.7.6 The remaining debris of the engine room and accommodation block on the stern section shows little measurable change, although surface difference suggests some subsidence.

1.7.7 Increased sediment deposits within the holds was noted, possibly due to the autumn storms and tidal surges which preceded the survey.

1.7.8 One of the mast-mounted warning signs is no longer in situ. Consideration will be given to replacing the sign.

1.7.9 The seabed around the wreck shows subtle evidence of reworking with changes suggesting that the wreck is lying mostly on the harder bed rock. The diver survey confirmed that the wreck is sitting on a hard surface, probably London Clay.

1.7.10 The hull thickness readings showed that, on average, steel thickness had reduced by 2.3mm since 2003. In some areas, the hull was perforated by the divers' cleaning tool and in other areas thicknesses of up to 16.8mm were recorded, leaving an average of c.11mm of steel remaining across the wreck.

1.7.11 Thickness readings showed that the most evident deterioration was around Hold 2, which confirms the results of successive multibeam surveys which have also identified the area around Hold 2 as showing the most deterioration.

1.7.12 The mast thickness readings demonstrated that the masts are in good condition with thickness readings ranging from 25mm to 29mm, more than was found at any of the datum points on the hull.

1.7.13 Over much of the wreck, the multibeam and laser data found no measurable changes.

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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 bound for the UK and then on to France. After arriving in the Thames Estuary, the vessel dragged its anchor and, on the falling tide, foundered on Sheerness Middle Sand, a sand bank running east from the Isle of Grain and to the north of the Medway Approach Channel. Almost immediately, the vessel hogged and the hull plates forward of the bridge began to split. A salvage operation began and approximately half of the cargo was discharged. However, the ship broke its back, the forward section became completely flooded and, eventually, in September 1944, the salvage operation was abandoned.

2.2 Although the stern section of the wreck was cleared during the salvage operation, approximately 1400 tons (Net Explosive Quantity) of munitions remain in the forward section in holds 1, 2 and 3. The wreck lies in two sections across the tide and close to the Medway Approach Channel. Her masts are clearly visible above the water at all states of the tide and the seabed around the wreck has gradually scoured away leaving the wreck in approximately 15m of water.

2.3 The wreck is designated under section 2 of the Protection of Wrecks Act 1973[1]. 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 around the wreck is ringed with four lit cardinal buoys and twelve red danger buoys and the wreck is under 24 hour surveillance by Medway Port Authority under contract to the Maritime and Coastguard Agency.

2.4 Whilst the risk of explosion is considered to be low, 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 help inform future management strategy. The SSRM has been subjected to regular surveys since its grounding, with a variety of methods utilised to monitor the site. Since 2002, multibeam sonar technology has been employed for these surveys. Although diving surveys have been carried out on the wreck, for general surveying multibeam sonar is currently preferred because it is faster, more cost effective and provides a greater level of detail, accuracy, repeatability and reliability than could be achieved through a diving survey. This is in part due to the very poor visibility and high tidal range in the Thames Estuary which makes diving operations very challenging. However, divers were employed on the wreck in 2013 in order to carry out the hull thickness assessment. This is the first time that divers have been employed on the wreck since the last hull thickness assessment in 2003.

[1] Text of the Protection of Wrecks Act 1973 Protection of Wrecks Act 1973

3. THE SURVEY

3.1 Survey Requirements

3.1.1 The requirements of the 2013 survey were three-fold. A multibeam echo sounder (MBES) survey of the wreck and the surrounding area was required, the results of which were then to be analysed and compared with previous survey results in order to identify any areas of change or deterioration. Any changes or deterioration were to be quantified, with particular attention paid to areas where greater levels of deterioration have been noted in the past. Secondly, laser scanning of the upstanding wreck structure which is visible above the waterline was to be undertaken. Again, this was to be compared with previous laser data in order to identify any changes. Finally, an ultrasonic hull thickness assessment was required. This thickness assessment has been undertaken on the wreck at approximately ten-year intervals, the last being in 2003.

3.1.2 The MBES survey includes the wreck, the seabed immediately adjacent to the wreck and an area of seabed out to 400m distant from the wreck. The objective of this seabed survey was to identify loose or isolated debris within the survey area, highlight the level of sediment build up immediately adjacent to the wreck and identify any changes in seabed topography.

3.1.3 The 2013 MBES survey of the SSRM actually took place on the 13th and 14th January 2014. Originally scheduled for October 2013, a prolonged period of high winds, heavy rain and tidal surges during the Autumn and Winter of 2013 repeatedly delayed the survey work. Bad weather also impacted on plans for the hull thickness assessment. In order to fit diving operations around the available weather and tidal windows, the work had to be split into two phases. The first half of the hull thickness readings were taken in March 2013 and the remaining thickness readings were completed in September 2013.

3.2 MBES and Laser Survey Methodology

3.2.1 The 2013 MBES and laser scanning survey of the SSRM was undertaken by MMT UK Ltd utilising the Port of London Authority (PLA) survey vessels MV Galloper and MV Yantlet. The MV Galloper is a 7.9m Cheetah Marine Catamaran and the MV Yantlet a 13.4m Souter Marine Catamaran. Each vessel was fitted with a single head Reson Multibeam system (these were a 7125 and 8125H, respectively) and a POS MV 320 system for accurate positioning of the data. Both of these vessels have been used in previous surveys of the SSRM and provide a reliable and repeatable survey platform. Two vessels were used in order to most efficiently cover the entirety of the survey area, with the smaller of the two vessels surveying close in to the wreck and directly over the top, whilst the larger vessel conducted the seabed survey and laser scanning. Previous surveys have shown this to be an effective methodology for this work.

3.2.2 MV Galloper ran survey lines north to south at various distances in parallel to the wreck structure and, at intervals where there were no obstructions, lines were run across the top of the wreck structure. MV Yantlet concentrated on the surrounding seabed and survey lines were run in an east to west orientation in order to minimise the influence of the strong tide on the handling of the survey vessel and to prevent gaps in the data.

3.2.3 Processing of the data collected during the survey utilised a selection of software packages so that a 3-dimensional point cloud could be produced which would be used for comparisons with survey data that had been rendered in previous years. An example of point cloud data produced from the 2013 data is shown below. The combination of processing techniques and software packages allowed for direct analysis of the wreck structure and also an understanding of its influence on the surrounding seabed.

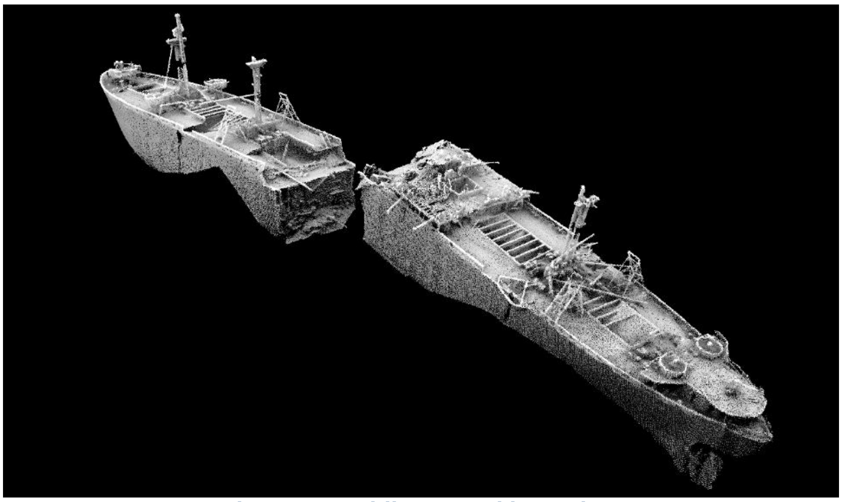


Figure 1. Multibeam and laser data

3.3 Survey Equipment, Software & Data Processing

3.3.1 The following section outlines the key survey equipment and software that was used to perform the 2013 survey of the wreck.

3.3.2 A Reson 7125 multibeam sonar unit was used to survey the wreck structure as this system allows for shorter pulse lengths to be used over the wreck to ensure a clearer digitisation. For the surrounding seabed an 8125H system was used.

3.3.3 On both survey vessels Applanix POS MV 320 inertial systems were used to output real-time position, attitude and heading data with a heading and attitude accuracy of 0.02° and 0.01° respectively. The POS MV was integrated with both the Reson 7125 and 8125H to apply time stamp information to the swath data. As well as real-time data, the raw inertial and GPS data was recorded as raw sensor files. This meant that the data could be post-processed using POSPac MMS software and imported into the multibeam data at a later stage.

3.3.4 As in the 2012 survey QINSy, an integrated navigation system software package, was installed on the survey vessels for the data acquisition.

3.3.5 Once the survey data had been collected, raw multibeam data was turned into a 3D point cloud so that analysis could be undertaken. A number of software packages were used to produce the final XYZ solution for the SSRM.

3.3.6 Raw data was logged in the .XTF format by QINSy; these files were then converted into Caris HIPS format for post-processing. The raw data files from the POS MV was post-processed so that any inaccuracies in the online navigation solution could be removed and a positional solution with an accuracy of >5cm could be produced in the form of a Smoothed Best Estimate of Trajectory (SBET).

3.3.7 With the bathymetry data converted into the Caris HIPS format, the online position and height data could be overwritten by the SBET file. The bathymetry data was reduced to Chart Datum and, 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 vessels.

3.3.8 A gridded digital terrain model (DTM) was produced and used to highlight any errors in height or position within the dataset. This was an important quality control process given that the data had been collected on two different vessels using different sonar equipment operating at different frequencies which could have manifested itself as variations in depth across the surface where the data from the two vessels overlapped.

3.3.9 Across the surrounding seabed the standard deviation values between the two datasets are less than 0.1m.

Fig. 2 Caris BASE surface coloured by height

3.3.10 The QPS program DMagic was used to build a PFM structure which allows the data to be viewed in three dimensions and facilitates the data cleaning and editing procedures. Data points that were not needed or which were multibeam artefacts were then flagged as rejected using the 3D editor function. Once cleaned, a point cloud could then be exported that would be used in the analysis of the wreck structure.

3.3.11 For the laser survey, weather and tidal conditions resulted in a number of postponements and the laser survey did not take place until March 2014. The data was acquired over a low tide in order that the laser scans overlapped with the bathymetry.

3.3.12 The Laser system itself consisted of two components, an Optech ILRIS 3D Laser scanner and an Applanix POS MV. As with the sonar, the POS MV is used to correct the system for roll / pitch / heading errors. **Error! Reference source not found.**The Laser mounting bracket was also fitted with a DSLR camera which allowed geo-referenced photographs to be taken around the wreck site. A previous laser survey was conducted in 2009, however due to differences in the way that data was collected and processed in 2009, adjustments were made to the datasets to allow for direct comparisons between 2009 and 2013 and the 2009 data was given a 50cm vertical offset to compensate for the difference and to align it with the 2013 data set.

3.3.13 The methodology, equipment and results of the hull thickness assessment and other work carried out by Ministry of Defence divers is outlined in section 6.

4. SURVEY RESULTS

4.1 Following the principle method of the 2012 wreck survey, in particular the use of two survey vessels, ensured that the dataset was of a similarly high standard to the previous year. Utilising the manoeuvrable and shallow draughted MV Galloper to acquire the data over the wreck ensured 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 were used in the final, cleaned dataset from which clear images and effective comparisons with previous survey data could be made.

4.2 In general terms, the data demonstrates that, over much of the wreck little or no measureable change has occurred since the previous survey. However, as in previous surveys, there are clearly some areas of the hull where the level of collapse and deterioration is more advanced than others and where changes and deterioration are noted year on year in the survey data. The 2013 survey data was no different. These areas of more advanced deterioration are detailed in 4.4 below.

4.3 The findings of the 2009 survey report set out three key factors which would affect the stability and deterioration of the wreck. These factors are the condition of the hull structure, the local environment around the wreck site and the condition of the munitions within the forward section (as the cargo in the stern section has been salvaged). These three factors are expanded on below in order to give an assessment of the current status of the wreck. However, it should be noted that although the MBES survey can provide some information about the munitions cargo, it cannot assess their condition.

4.4 The Hull Structure

4.4.1 The findings of the 2009 survey[2] identified four areas of the hull where deterioration was notably more advanced than across the rest of the wreck. The Report recommended that particular attention was paid to these areas in future surveys. These areas were again the focus of particular attention during the 2013 survey and a fifth area has been added to this. These key arears are identified in Figure 3 below. The survey results for these areas will be discussed first, followed by the results across the rest of the wreck.

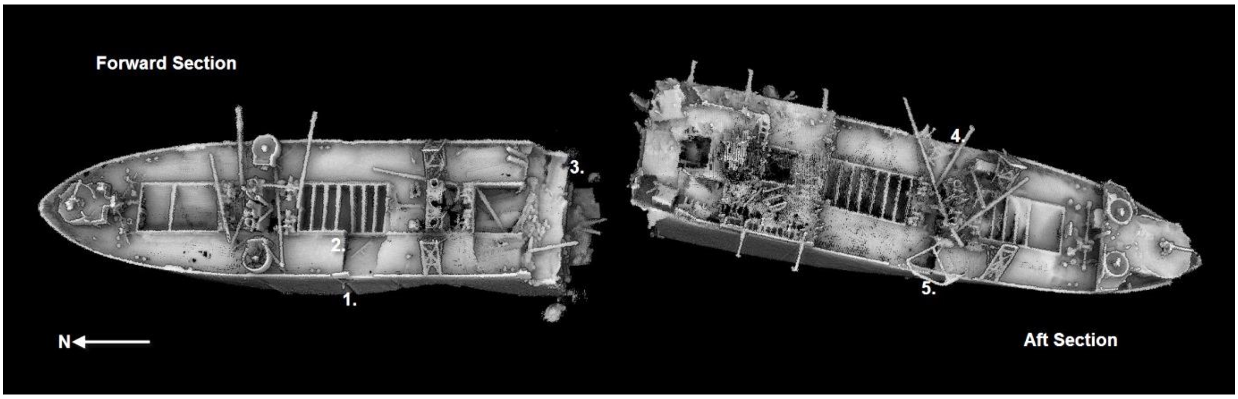


Figure 3. Overview of the wreck with locations of key areas.

4.4.2 Area 1 is the crack in the hull on the port side of the forward section at Hold 2. This consists of a hole in the hull plating just below deck level and a crack which extends to the seabed. This has been noted in survey reports since at least the 1970s.

4.4.3 The dimensions of the crack in the hull obtained from the 2012 dataset gave a length of 2.69m and a width of 1.29m. The results from the 2013 dataset show that the crack has increased in size and now measures 2.77m in length and 1.54m in width. This represents a change of 0.08m and 0.25m in length and width respectively.

4.4.4 Close examination of the data suggested that the size of the opening may extend past the limits determined by the previous survey. The 2013 data showed that the former base of the crack, when viewed from the west, is actually a piece of metal protruding from inside the hull and that the crack may reach below. There is also a smaller aperture located immediately

[2] The 2009 Survey Report can be found at https://www.gov.uk/government/publications/the-ss-richard-montgomery-information-and-survey-reports

to the right of the larger crack and for future surveys it may be practical to measure the full width across both of these, as it cannot be determined from the data whether the section dividing the two cracks has any significant structural integrity. The revised dimensions of this feature can be measured as 3.31m long and 2.16m wide. It is also apparent from the data that the hull directly beneath this crack has become distorted and there is an indented groove extending from this location down to the seabed (hull deformation is discussed in section 4.5).

4.4.5 It should be noted that the diver inspection of this hole and crack in the hull plating determined that the hole is smaller than the MBES data suggests (see section 6).

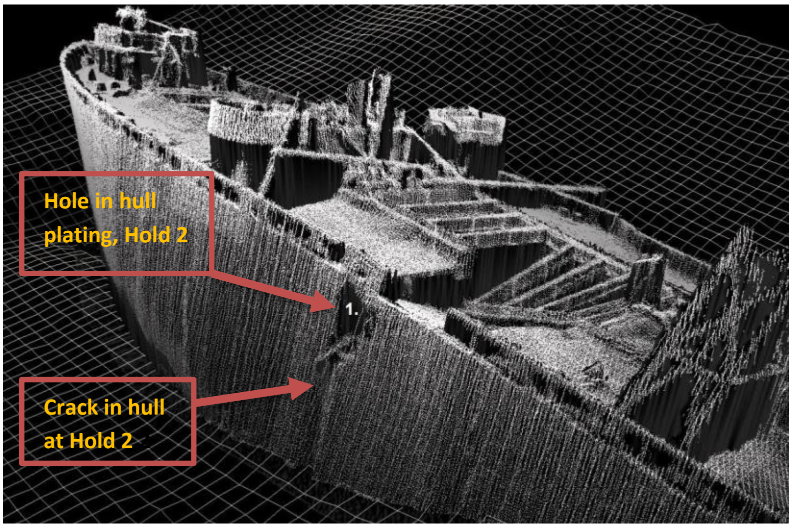


Fig 4 View of key area 1 - the crack in the hull on the port side of the forward section at Hold 2

4.4.6 Area 2 is the area of collapsed deck plating along the port side of Hold 2. This area is shown in figure 5 below.

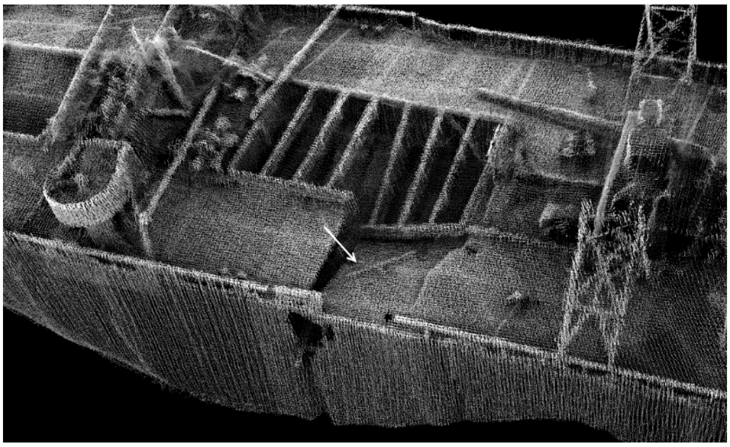


Fig. 5 3D point cloud showing the location of the collapsed deck plate on the port side of Hold 2.

4.4.7 The collapse of the deck plating along the port side of Hold 2 has been well defined in the 2013 dataset. Figure 6 below shows a cross-section through the data from the collapsed deck area with surface difference analysis. The data suggests that the area of collapse has dropped a further 20cm since the last survey, whilst the deck plating forward and aft of the collapsed section has not moved in the last year. Table 1 below shows the depths of the collapsed sections from the 2010, 2012 and 2013 datasets. The results suggest that the rate of collapse of the deck at this location is reducing.

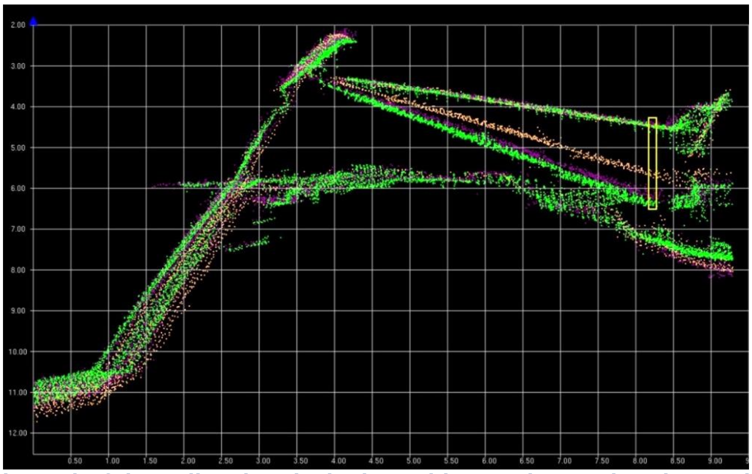


Fig. 6 2013 data (green) of the collapsing deck plate with 2010 (orange) and 2012 data (purple). The yellow box marks the position where the measurements were obtained.

Table 1 – Comparison of deck collapse on the portside of Hold 2.

	Dataset	Depth (m)	Magnitude of Collapse (m)	Inter-survey Collapse Magnitude ($year_{n+1}$ - $year_n$) (m)
Normal Deck Level (Forward of Collapsed Section)	All Datasets	4.45		
Collapsed Deck	2010	5.62	1.17	
	2012	6.13	1.68	0.51
	2013	6.33	1.88	0.20

4.4.8 Area 3 is the aperture in the starboard side of the bulkhead at the aft end of Hold 3. Comparison of the 2012 and 2013 datasets indicate that there has been no increase in the dimensions of this aperture between the two surveys.

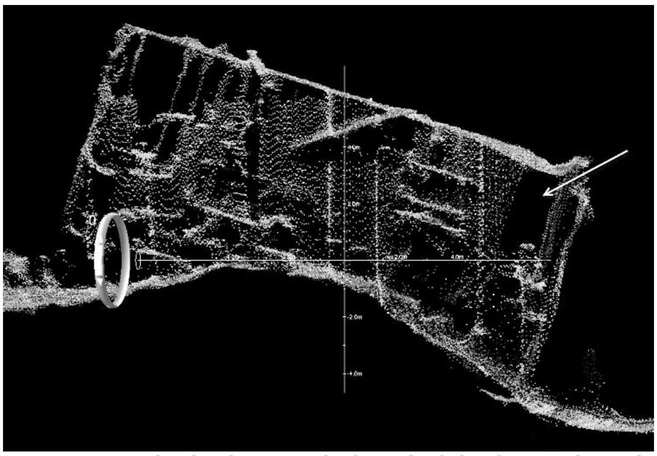


Fig. 7 Aperture in the fractured aft end of the forward section.

4.4.9 Area 4 is an area on the starboard side of the stern section which, in the 2009 dataset, appeared to show a split in the hull plating. Subsequent surveys did not relocate this split in hull plating and it was thought that the angle of list and overhanging debris may have created a shadow in the dataset which gave the appearance of a split. The 2012 survey data indicated the presence of a feature of some kind at this location but was inconclusive.

4.4.10 In the 2013 data an irregular sheet-like flap of metal can be seen protruding from the hull (figure 8 below). In order to determine what this data was showing, this section of the data was extracted and examined in the Fledermaus 3D editor where the distorted hull plate was seen above a hole in the wreck measuring 1.2m long and 0.9m wide. The data also suggested the presence of a split in the hull which extends from the top of the distorted hull plate to deck level. Although difficult to discern accurately, the split was measured to be 0.40m wide when viewed along the line of the hull looking towards the stern of the ship.

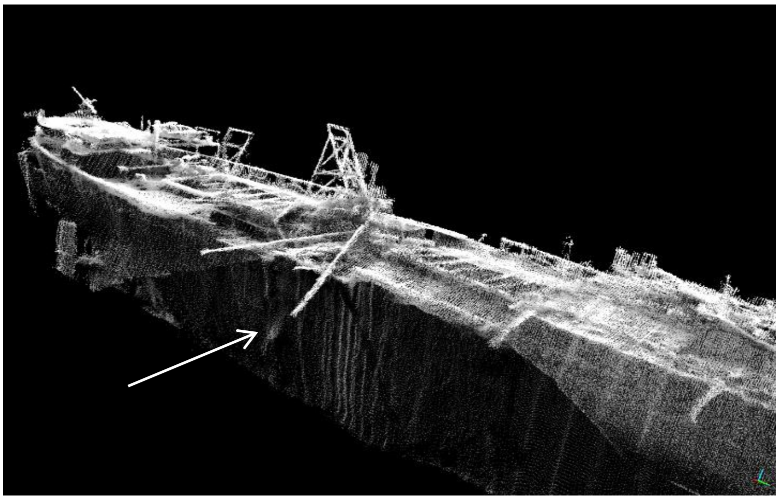


Fig. 8 Starboard side view of the aft section. Severe splitting is represented by a sheet of metal protruding from the hull (arrowed).

4.4.11 The results of the 2013 survey have suggested that a fifth area should be added to the list of key areas of focus. This Area 5 is a split in the deck plating on the port side of the stern section.

4.4.12 This feature was clearly defined in the 2013 dataset and shows that the deck plating in this area is collapsing into the wreck on the aft-port side of Hold 4. The collapsing deck plate is on the northern side of a split in the hull which extends from deck level down to the seabed, approximately 5.5m in length. The maximum width of this split is 0.85m which was measured just above the seabed. To obtain measurements of the depths of the collapsing deck a section through the survey data was extracted in the subset editor tool and examined. This showed the three levels of the deck and the extent of the collapse. On the southern side of the split the deck plate is in its 'normal' position at 4.53m depth, on the northern side of the split the deck has subsided to 5.58m depth, a partial collapse of 1.05m from the 'normal' deck position. The full extent of the collapse observed to date at 7.35m depth which is 2.82m below the 'normal' deck level. Comparisons with the 2012 dataset show that the collapsed decking at this location has not moved since the last survey, however the deck plate forward of the split is exhibiting ongoing subsidence.

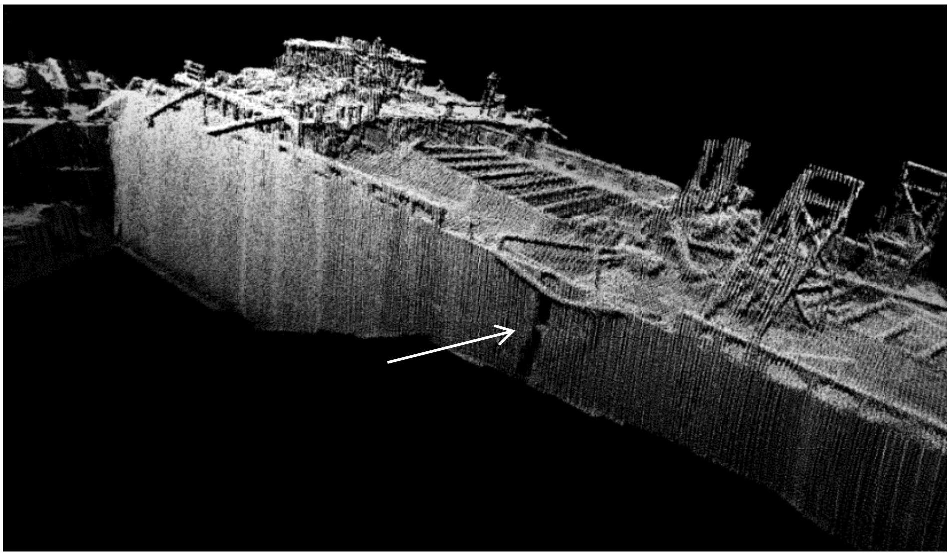
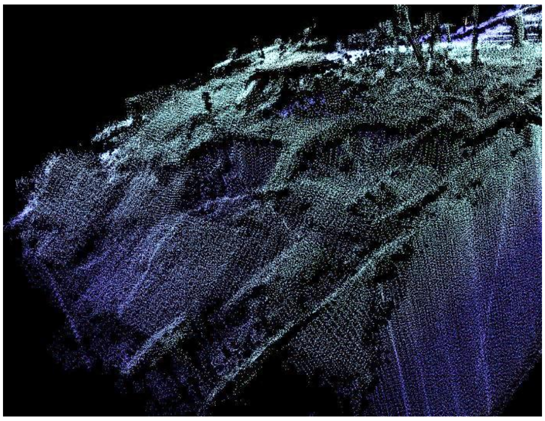
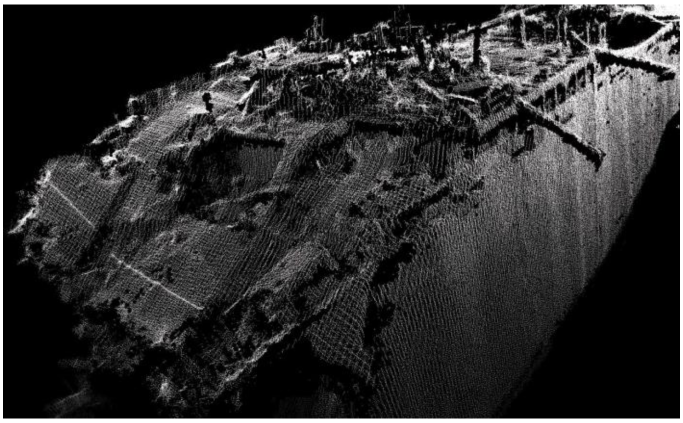


Fig. 9 View of the split in the port side of the aft section, in the 2013 dataset.

4.4.13 Across the rest of the hull structure, a number of other areas demonstrate some level of change or deterioration since the 2012 survey. The following is an outline of those areas.

4.4.14 Comparison of the point cloud imagery did not suggest that any change in the position of the gunnel on the port side of the forward section had occurred since the last survey. However, examination of the combined datasets in Caris showed that the rail had subsided and was leaning further towards the middle of the ship. Measurements taken from Caris showed that the gunnel had moved approximately 0.11m from its position in 2012.

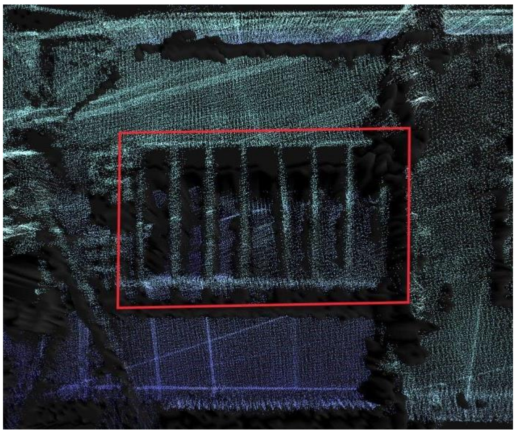
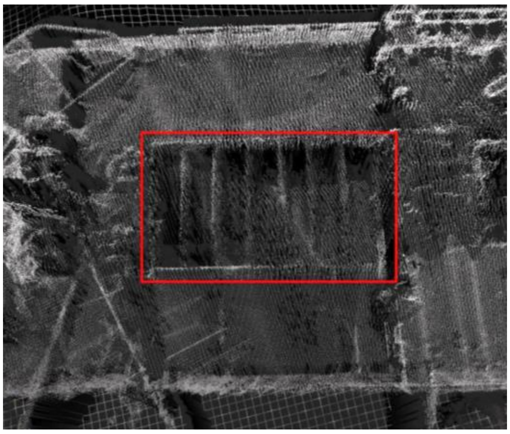
4.4.15 Survey data from the area around the collapsed boat deck did not indicate that any significant shifts in the position of the wreck structure had occurred. When viewing cross-sections through combined datasets in Caris it could be seen that a small amount of subsidence had taken place; up to 0.15m. Surface difference analysis shows that the poorly supported forward end of the aft section of the wreck has subsided by up to 0.30m since the last survey.

2012 2013

Fig 10 & 11 3D point cloud imagery showing the port side of the boat deck on the aft section of the wreck.

4.4.16 Examination of the Hold 4 hatch cover supports in the 2013 dataset shows that the six hatch cover supports are in place and remain in a similar condition to the 2010 and 2012 datasets. The results of the surface difference analysis indicate that there is widespread subsidence of this hatch and the cover supports. This is associated with the subsidence of the deck observed along the port side and the large split in the hull at this section of the wreck. Comparison of the datasets in Caris indicated that the aft-most spar had subsided by 0.5m since the 2012 survey. Also see section 5.9 regarding sediment build-up inside the holds.

2012 2013

Fig. 12 & 13 Hatch Cover Supports over Hold 4 on the aft section of the wreck.

4.4.17 The boiler room casing, boat deck and bridge deck occupy the forward end of the aft section of the wreck. Examination of the 3D point cloud imagery showed evidence of some changes however, as it is not possible for the survey vessel to pass directly over this area of the wreck, it is difficult to clearly identify the structures in the data.

4.4.18 Surface difference analysis indicated a trend of increasing subsidence of the remnants of the bridge deck from the location of the Gunnery Officers' cabin, through the boiler room casing towards the forward-most parts which are overhanging the gap between the halves of the wreck. The forward port side of the boat deck also demonstrated this trend, however elsewhere it appears to have remained static over much of its area. The differences seen in the data are likely to demonstrate both deteriorating structures in this area of the wreck as well as differences in the cleaning of the datasets which has manifested as apparent changes in depth. One area of measurable change is the collapse of a protruding structure which has dropped up to 1.75m at its forward end when compared to the 2012 data.

4.4.19 The boat deck, which would have run around the port, aft and starboard sides of the bridge section, was stated to be missing in some previous surveys. Examination of the point clouds shows that the boat deck is in fact in situ on the starboard side. Data comparisons from the 2010, 2012 and 2013 datasets all show the presence of this deck.

4.4.20 As well as highlighting areas of change and deterioration, the MBES data also assists in building up a better general understanding of the wreck structure. For example, the port and starboard lighting towers were reported as standing at the aft end of the boat deck with the information from previous surveys suggesting that the port tower had collapsed and was lying on the deck by Hold 4. Examination of the dataset and comparison with images from sister vessels, such as the SS Jeremiah O'Brien has provided a better general understanding of the layout of this area. This showed that the structures identified in the 2012 survey report as being the bases of the lighting towers are in fact more likely to be the lower sections of cowled vents coming up through the deck from the forward end of Hold 4 or the engine room. The lighting towers stand next to these vents on the SS Jeremiah O'Brien and this is likely to be the arrangement aboard the SS Richard Montgomery as well.

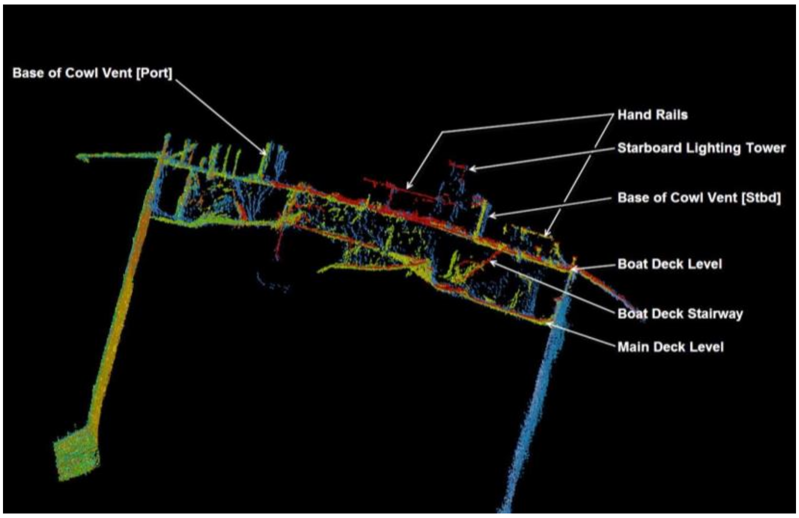


Fig. 14 Cross-section of the aft end of the boat deck with interpretation of the structures present

4.4.21 Across much of the wreck, sediment build-up was noted, in particular inside the holds. This is discussed in section 5 (Seabed Environment).

4.5 Deformation of the Hull (Hogging)

4.5.1 According to contemporary reports, the SS Richard Montgomery showed signs of hogging immediately after going aground in 1944. Successive surveys have noted evidence of deformity in the hull, however, the level of deformity and any increase is difficult to measure.

4.5.2 As in previous surveys, in order to try to measure any changes in the deformation of the hull, a gridded surface of the hull was generated at a resolution of 5cm so as to show the nature of any local deformities. In general terms, small or no change was noted in the 2013 survey data.

4.5.3 On the port side of the forward section the deformation of the hull at measured points had a magnitude of 0.31m and 0.42m in the 2012 dataset. These same points were measured at 0.25m and 0.38m in 2013. Further analysis of the data suggested that the greatest change in the shape of the deformation was nearest to the base of the crack on the port side of Hold 2 which would be consistent with deterioration in this area noted in previous surveys.

4.5.4 Going aft on the port side, measurements of the hull deformity in 2012 gave a magnitude of 0.13m at the measured point and the same point in 2013 gave a measurement of 0.11m. These are small variations and are within what would be expected from deviations of accuracy of positioning in the data.

4.5.5 Assessment of the buckling of the hull plating on the port side forward of Hold 2 suggested that there had been little change in the condition of the hull in the period between the surveys. Buckling of the hull aft of Hold 2 showed small changes of 4-5cm. Surface difference analysis does not show up positional shifts of less than 5cm, so a firm conclusion could not be drawn.

4.5.6 The distortion of the hull plate on the starboard side of Hold 2 did not exhibit any further distortion than was noted in the previous survey. However surface difference analysis of a bulge in the hull also on the starboard side near to Hold 2 suggested that the distortion in the hull plate had shifted towards the bow by approximately 0.8m.

4.6 Masts and Booms

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

4.6.2 During the 2012 survey, it was noted that one of the two stays on the forward mast had broken at deck level but was still attached to the mast. It can be seen in the photographs at figures 15, 16 and 17 below that this broken stay is now completely detached. During the hull thickness assessment, divers noted that the broken stay is now lying on the deck. The second stay remains in place.


Fig 15 2011 – two stays in place


Fig. 16 2012 – one stay broken at deck level

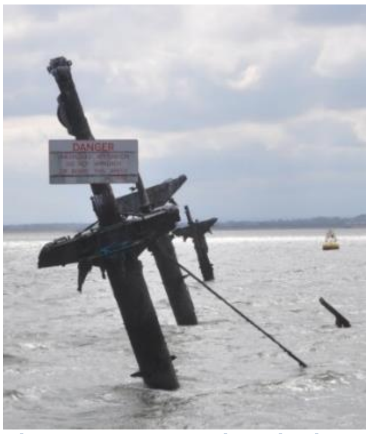


Fig 17 2013 – stay detached completely

4.6.3 The laser data and photographic record also demonstrates that the warning sign on the main mast is no longer in situ. This was in place during both phases of diving operations for the hull thickness assessment in March and September of 2013, but was not in place in January of 2014 when laser scanning took place. Consideration will be given to reinstating the sign.

Fig 18 – 2013, two signs visible during diving operations

Fig 19 – 2014, only one sign in place

4.6.4 Cargo handling booms were attached to each mast. Whilst one of the booms can be seen still attached to the forward mast, most can now been seen in the multibeam sonar data lying across the deck. All of the features identified in the multibeam data as cargo handling booms were assessed and all appeared unchanged from previous surveys.

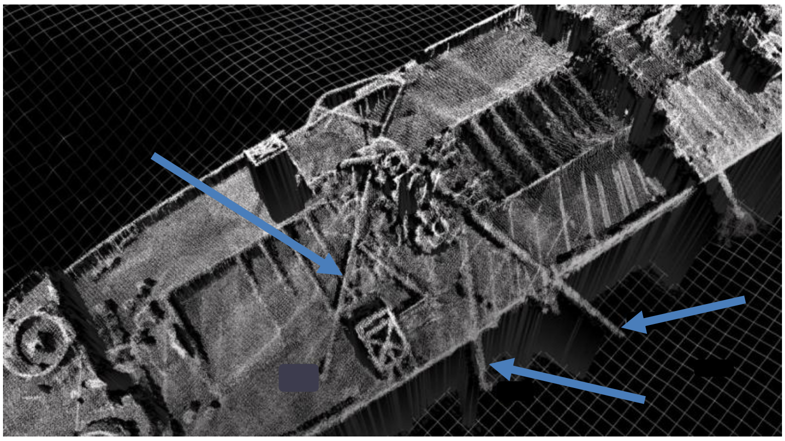


Fig. 20 Mizzen mast cargo handling booms lying across the deck

4.6.5 Mast houses at the base of the fore mast, main mast and mizzen mast were all assessed and no changes or deterioration were noted, although the presence of cowled vents, fallen booms and other structures around the base of the masts make comparisons more difficult. Surface difference analysis of the mast house at the base of the mizzen mast suggested some localised subsidence may be occurring, but closer examination of the data showed that this portion of the wreck had remained static since 2010 and any differences were the result of data cleaning and the insonification of the structures from slightly different angles.

4.6.6 Multibeam data of all three masts showed no signs of deterioration since the last survey. Photographic and laser data demonstrated, as outlined above, that the loose stay on the forward mast is now completely detached. It also showed that a warning sign on the middle mast has become detached since the last survey. The stern mast exhibited no signs of change when compared to previous laser data.

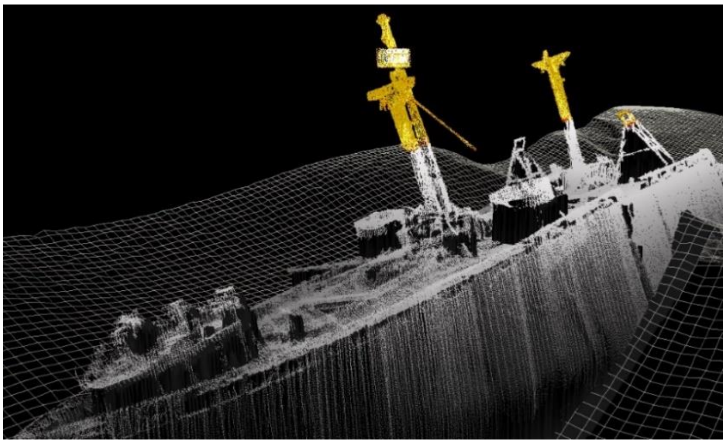


Fig. 21 Laser and multibeam data of the forward section

4.6.7 Once the vertical element mismatch had been compensated for, the two laser survey data sets could be confidently compared and, in general, the data sets show a good correlation between each other in terms of the list and orientation of the masts.

Further information on the condition of the masts can be found in Section 6, Hull Thickness Analysis.

4.7 Areas With No Detectable Change

4.7.1 Across much of the wreck no evidence of deterioration or subsidence could be found when the MBES data from 2010, 2012 and 2013 was compared. The following section of the report identifies some of these areas which showed no evidence of change.

4.7.2 3D imagery and surface difference analysis indicated that there was no change in the position of the remaining the hatch cover support on Hold 1 (a marked increase in the height of sediment in the hold is discussed in section 5).

4.7.3 A hole in the deck on the port side of Hold 2 was present in previous data sets. It measures 0.5m long and 0.3m wide and had not increased in size during the period between surveys.

4.7.4 Comparisons of different datasets for the collapsed area of deck and hatch coaming at Hold 3 show no evidence of change or deterioration. Surface difference analysis shows that some areas of this portion of the wreck may have shifted by very small amounts, typically less than 0.1m. However, this apparent change may have been caused by the degree of accuracy of position, given that consistent change over a wide area indicative of structural subsidence is not present. Cross sectional views of the wreck data in Caris showed that the deck and hatch coaming have remained static since 2010.

4.7.5 On the starboard side of the forward section, three features in close proximity are a hole in the hull plating, a vertical discontinuity of hull plating and a hole along the line of the bilge. The hole in the hull plating was compared with the images from earlier datasets and it does not appear to have increased in size. In fact, a higher density of soundings was achieved in the 2013 survey and assessment of this data suggests that this is actually a section of contorted metal which has caused acoustic shadowing in previous surveys rather than a hole in the hull. The vertical hole along the line of the bilge has been identified in previous data. Comparison with the imagery from 2012 suggests that the hole has not changed shape and a measurement of 4.4m in length was recorded. This area of the wreck is particularly difficult to insonify as the angle of list makes accurate assessments of the state of the hull difficult.

4.7.6 The split in the deck plating on the starboard side of the aft section is approximately 30cm deeper than the deck plating surrounding it. Close comparisons of the historical data sets indicate that there has been no recent subsidence and any suggestions of a deepening trend in the surface difference analysis is a result of different data cleaning processes in this area of debris.

4.7.7 Up to eighteen holes were identified along the port side of the boat deck. These holes have a broadly rectangular shape and are aligned along the beam of the vessel suggesting that they may result from corrosion of the deck plate between supporting spars. The largest of these holes has a length of 2.5m and a width of 0.8m. The 2013 survey data defined these holes with better clarity than in previous datasets. It is therefore difficult to determine whether significant deterioration had occurred. However the imagery from the point clouds appears to be broadly similar and surface difference analysis showed that this part of the boat deck had not shifted since the 2012 survey.

4.7.8 The 2013 dataset clearly showed the presence of the two remaining hatch cover supports at Hold 3. Comparison between the 3D point clouds indicated that there had been no change in their position or deterioration of their condition. Surface difference analysis also suggests that there had been no movement.

4.7.9 Assessment of the data around the engine room skylight and engine room casing (previously identified as the boiler room casing) shows that there has been little deterioration when compared to the 2010 and 2012 datasets. It is apparent that the skylight, which would have been in place above the engine room casing, has completely collapsed. Surface difference analysis and comparison with historical datasets have shown that this section of the wreck has not subsided. The rim of the casing and the surrounding deck has been placed consistently in the same position in recent surveys.

4.7.10 The forward gun tub and gun have been well defined in the 2013 dataset. No evidence of collapse or deterioration was apparent. The stern gun and gun tub have also been well defined in the data. Comparison with the 3D point cloud imagery indicated that there has been no deterioration of this feature. All other gun tubs were assessed and compared to previous survey data and all data suggests little or no deterioration has occurred.

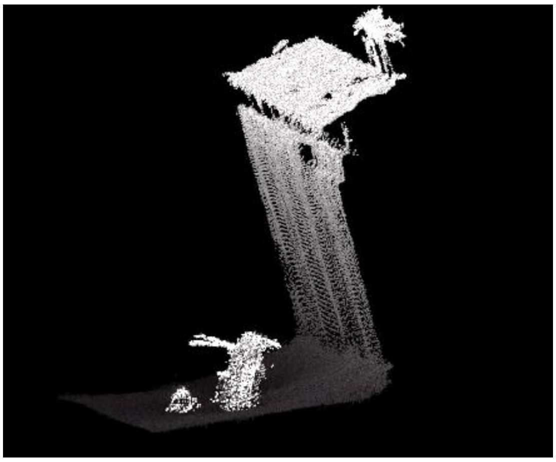


Fig. 22 20mm gun tub lying on seabed on stbd side of the stern section

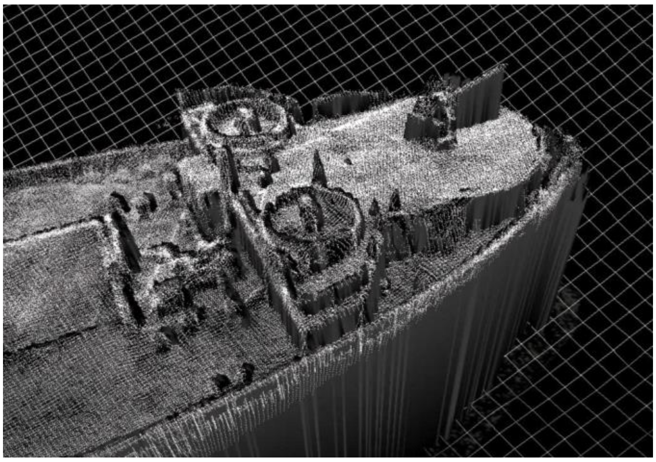


Fig. 23 Stern gun and gun tubs

4.7.11 The Gunnery Officers' Cabin, located on the boat deck between the boiler and engine room casings, shows no signs of deterioration when compared to imagery from the datasets acquired in 2010 and 2012. Surface difference analysis showed that the top of the cabin has remained static but the edges appear to have moved. This is probably due to differences in data cleaning of the soundings overhanging the boat deck.

4.7.12 Although not identified in previous surveys, the bilge keel was observed on the port side of the aft section of the wreck. This is the only area where the bilge keel is exposed and the feature may have been subjected to sediment coverage on the starboard side. Comparison between the point cloud imagery suggested that there has been no deterioration since the 2012 survey.

4.7.13 The A-frame structures of the life raft racks were assessed in the survey data and appear to be in the same condition as in previous years' datasets. No evidence of deterioration was observed.

4.7.14 The propeller and rudder were well defined in the 2013 dataset and compare very well with the data from previous surveys. There is no evidence for deterioration of this feature over the past year.

4.8 Condition of the Munitions Cargo

4.8.1 The multibeam sonar and laser scanning surveying 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 on the wreck where previous survey data may have shown indications of the cargo. Whilst the 2013 survey included all of these areas and data collected showed some indication of cargo material inside the holds, it can be difficult to interpret this data with any certainty.

4.8.2 Small holes in the deck plating on the port side of Hold 1 allow for penetration of the hull by the sonar beams. However the information returned is not sufficient to draw any conclusions of the contents of the hold.

4.8.3 The large crack in the port side hull at Hold 2 and the collapsed deck plating above it allow for the acquisition of sonar data from inside the hold. The data collected in 2013 very closely resembles that from 2012. This suggested that there has been little has change during the period between surveys as.

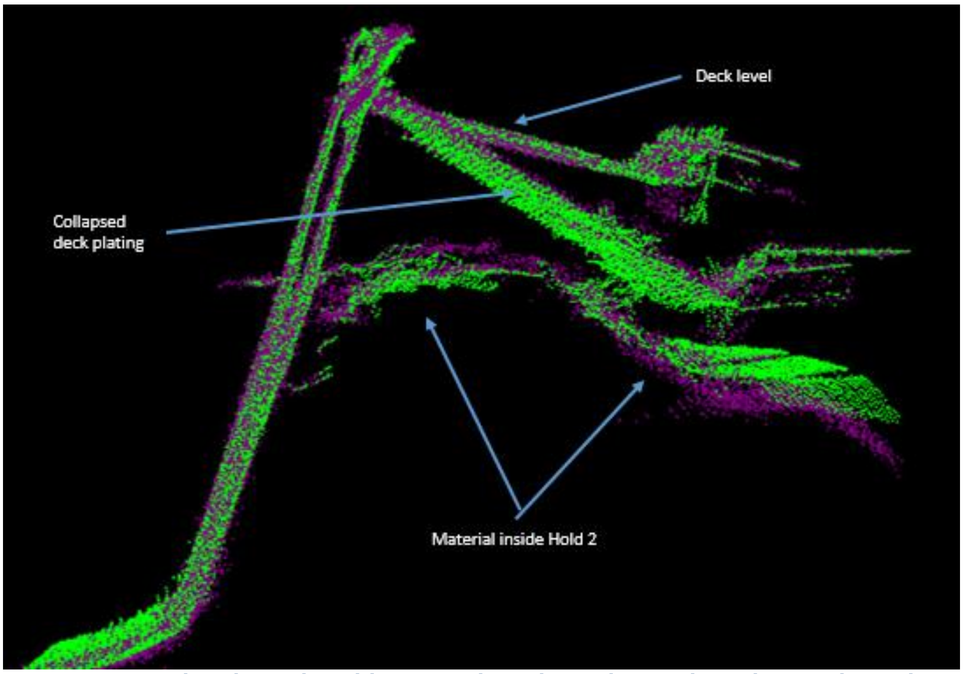


Fig. 24 A cross-section through Hold 2. 2012 data shown in purple and 2013 shown in green.

4.8.4 Comparison between point cloud imagery taken of the fractured, aft end of the forward section shows debris strewn across the exposed deck and overhanging the edges. This tangle of wreckage was caused when the ship broke into two sections in 1944 and is likely to contain cargo material. This area appears to remain in the same condition as shown by the 2010 and 2012 datasets and can be seen in figure 23 below.

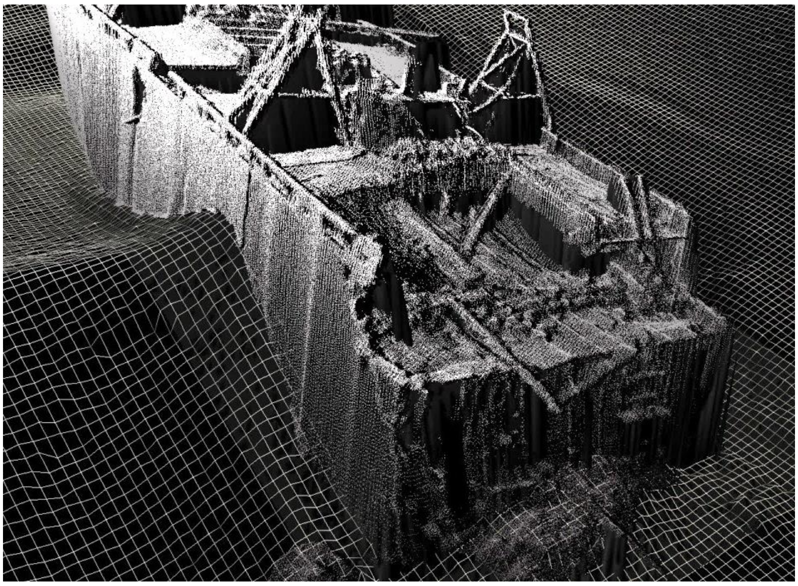


Fig. 25 2013 – Point cloud data showing Hold 3, aft end of the forward section

4.8.5 At the aft end of Hold 3 is a bulkhead which is containing the cargo in lower Hold 3. There are apertures in the bulkhead, through which it may be possible to visualise the munitions cargo. This bulkhead was well defined in the 2013 data and the aperture could be clearly observed. Some penetration of the aperture with sonar beams was achieved however, due to the limitations of the system and the structure of the wreck it was not possible to identify the contents of Hold 3. Image below shows a cross-section through the data at Hold 3 including the outline of what may be cargo material.

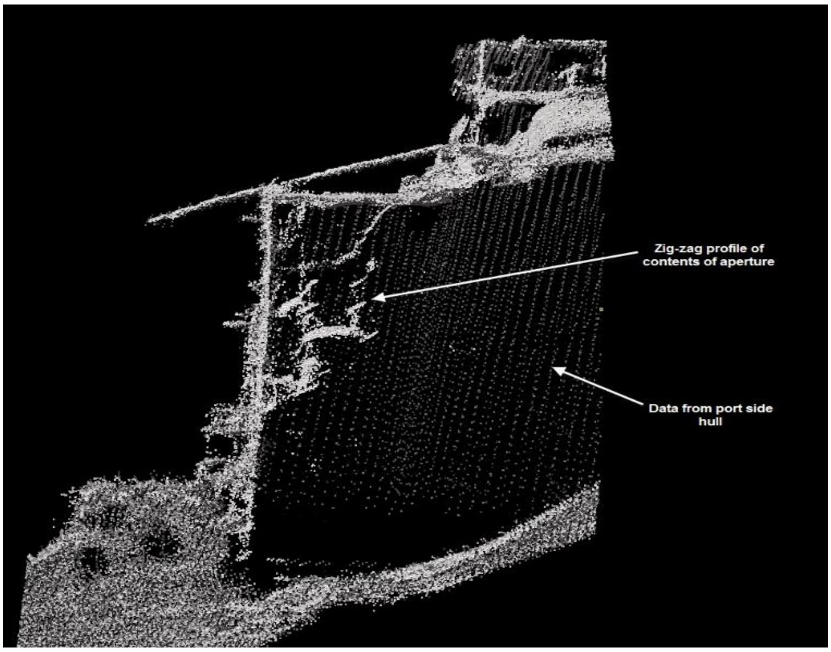


Fig. 26 Cross-section through the aft end of the forward section with contents of Hold 3 shown in profile.

4.9 Vessel List and Orientation

4.9.1 The wreck remains in two distinct sections, as can be seen from the image below, despite the presence of a number of significant structural cracks. The two sections are referred to as the bow or forward section and stern or aft section in this report.

Fig. 27 Plan view of the wreck of the SS Richard Montgomery

4.9.2 Both sections of the wreck list to starboard (east) and the two sections are located at the positions given in the table below. The positions given are located approximately in the centre of each of the sections of the wreck.

Section	X	Y
Bow (Forward)	346139.5	5704071.2
Stern (Aft)	346140.4	5704001.2

4.9.3 Comparison between the alignments of the dataset from the 2013 survey and the 2010 and 2012 surveys indicated that there has been no change in the angle of list or orientation of either section of the wreck. Surface difference analysis over the entire wreck showed that subsidence was affecting localised structures on the wreck but no evidence of a large-scale shift, which would indicate a change in list angle, was observed in either the bow or stern sections.

5. SEABED ENVIRONMENT AROUND THE WRECK

5.1 The multibeam sonar survey includes full coverage of the seabed out to a distance of 400m from the wreck. This aims to identify any large-scale sediment reworking and to locate any objects which may have become exposed or covered by the shifting material.

5.2 The seabed around the wreck was split into three areas, area A being the dredged shipping channel to the south, area B the scour patterns caused by the wreck and area C is the seabed in the immediate vicinity of the wreck. The areas are shown in the figure below.

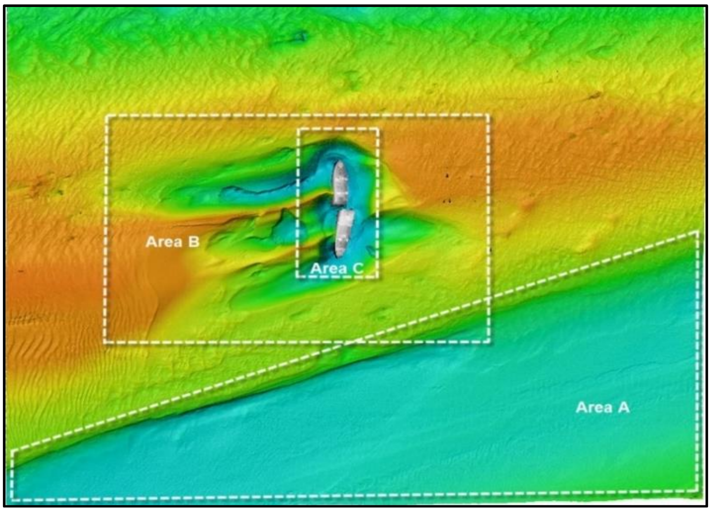


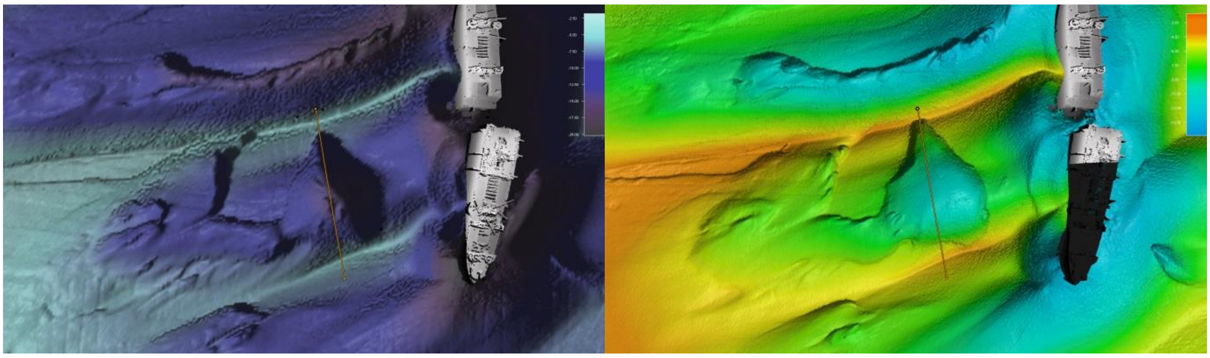
Fig. 28 The three areas of the seabed that will be examined in greater detail.

5.3 Analysis in the area of the dredged channel showed that sediment deposition had occurred in the central section over the entire length which is inside the survey area. Typically, approximately 0.3m of additional material has been deposited but an isolated maximum increase in height of 1.0m was observed. This corresponded to the infill of a scour pit which was present in the channel during the 2012 survey. The northern edge of the channel has seen significant sediment erosion with typically 0.8m of material lost along its length. The maximum amount of erosion identified was a section in which 1.4m of sediment lost. This is most likely to have resulted from instability and collapse of the channel wall over the last year. Close examination of the DTM indicated that there were no pieces of debris from the wreck in this area and that the channel is sufficiently far from the wreck that it does not affect local sediment deposition or removal.

5.4 With regard to the scour patterns around the wreck, overall, the large-scale features persist although their shapes have been subject to change from deposition within deeper areas and erosion at the fringes.

5.5 The central scour pit closely resembled the pattern seen in the 2012 survey. The results of surface difference analysis showed that the eastern scour pit has seen sediment deposits of 1.76m in the centre, probably due to the slumping of sediment peaks on the sand wave to the north. The narrow scoured channel and western pit have seen less significant sediment deposition in their deeper sections and some progression of the northern and eastward limits has also occurred.

5.6 Although there has been no change in the height of the sand wave crests which form the north and south limits of the scour pit, there has been a great deal of sediment accumulation within the pit itself.



2012 2013

Fig. 29 & 30 Close up views of the scour pit between the sand waves to the west of the wreck

5.7 The sediment immediately around the wreck has shown less variation between surveys. Some repositioning of the sand wave slopes has occurred on the western side of the wreck and one on the south eastern side with increases of depth of up to 1.6m. Some slight sediment accumulation is evident along the sides of the wreck which is typically of the order of 0.1m to 0.2m. Around the bow of the wreck some subtle changes in the structure of the gentle ridges at the base of the scour here are evident and are caused by the focussed flow of the tidal currents around the vessel. It is likely that there has been little change to the sediments that underlie the wreck and it may now sit on top of the exposed London clay bedrock. This is further indicated by the lack of change in the wreck's angle of list or any wreck-wide subsidence and was also confirmed by diver observations as part of the hull thickness analysis.

5.8 The results from the 2013 seabed survey show that the positions of the depth contours remain consistent with previous surveys' datasets. Around the wreck site the contours have shifted slightly and broadly show that the shallow areas have been subjected to erosion with material deposited within the scour pits around the wreck. This sediment reworking trend is reflected across the survey site as a whole with the tops of the sand banks becoming deeper and sediment becoming deposited in the Medway Approach Channel to the south of the wreck site. This is likely to have been caused by increased current velocities in the estuary during the seasonal storms and tidal surges during the autumn and winter of 2013.

5.9 Survey data focussed on the hull structure also showed evidence of sedimentation since the 2012 survey. Data from all of the holds demonstrated sediment build-up inside the hold since the previous survey. In Hold 1 there was marked increase in height along the port side at the aft end of the Hold 1 hatch. This surface has risen by 0.80m when compared to 2012. In Hold 2 the greatest difference in depth was located near the aft end and showed an increase in height of up to 2.1m. Holds 4 and 5 also showed some increase and in Hold 3 both upward and downward movement was noted in close proximity. This probably represents fluctuations in mobile sediment. As with sediment movement around the wreck, this is assumed to have been caused by sediment build-up during the autumn storms and tidal surges which preceded the 2013 survey.

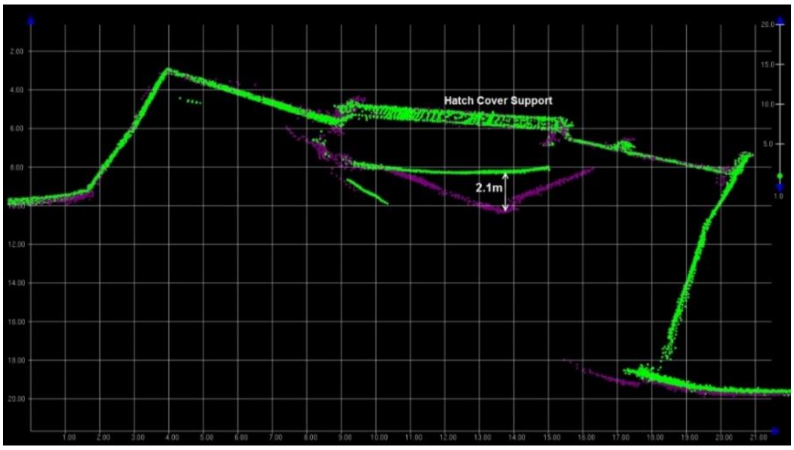


Fig. 31 Cross section through the combined datasets of 2012 (green) and 2013 (purple) of Hold 2 showing the difference in surface positions between 2012 and 2013.

5.10 Seabed targets within the survey area were again relocated and examined.

6. HULL THICKNESS ASSESSMENT

6.1 The Requirement

6.1.1 Dive surveys of the SS Richard Montgomery have not been carried out frequently. This is in part due to the challenging diving conditions in the Thames Estuary and in part because the process of corrosion is slow with detectable changes taking time to become apparent. However, in addition to the MBES and laser scanning survey, divers were employed on the wreck during 2013 to carry out an ultrasonic hull thickness assessment.

6.1.2 Hull thickness assessments have taken place at approximately 10 yearly intervals, the last being in 2003. The 2013 hull thickness assessment was undertaken by divers from the Ministry of Defence Salvage and Marine Operations team (S&MO). As with the rest of the survey work in 2013, bad weather was a factor in the acquisition of this data. The work was initially begun in March 2013 but only half of the readings could be collected. The work was completed in September 2013.

6.1.3 In order to add value to this diving survey, a number of secondary objectives were identified and carried out by the S&MO dive team. These were the deployment of current meters to record the strength of the current that the wreck is subjected to; the deployment of a multi-parameter water sonde to measure the chemical and physical properties of the water in the vicinity of the wreck; inspection of the wreck using Blueview and Didson imaging sonars; and a side scan sonar survey of the area surrounding the wreck.

6.2 Hull Thickness Assessment Methodology

6.2.1 The hull thickness assessment followed the methodology used during the previous dive survey of 2003 in order to generate a comparable set of results. The methodology involved taking thickness readings at eight datums spaced at 7 metre intervals from the forward end of Hold 1 to the break in the hull at Hold 3. At each datum, measurements were taken on the deck, 1 metre down the ship's side and 1 metre above the seabed.

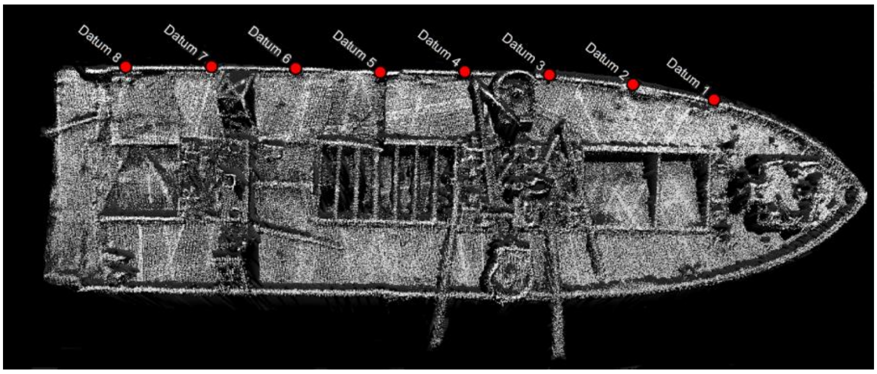


Fig. 32 Hull thickness datum locations

6.2.2 At each measurement location a small area of hull was cleaned of marine growth and concretion, a series of measurements were taken and then averaged to provide a reading. The assessment was of the external shell plating of the wreck only and no work was undertaken on the internal structure or the munitions contained within the wreck. Measurements were taken on the port side only due to the angle of list and the presence of overhanging debris making the risk of diver entanglement too great on the starboard side of the wreck.

Fig. 33 Cleaned area of hull showing roughness of surface

6.2.3 Datum 1 at the forward end of Hold 1 was positioned using Ultra Short Base Line (USBL) tracking of the diver overlaid in real time on the multibeam survey data in Hypack survey software. The G-clamp from the previous diving survey in 2003 was relocated and a magnet was used on the ship's side next to the Datum 1 G-clamp. This was attached by a 7 m distance line to a second magnet. The second magnet was positioned at Datum 2. The pair of magnets was then stepped back to the subsequent datums using the 7 m distance line checked with USBL to ensure correct positioning.

6.2.4 A weighted guide rope was attached to the datum being surveyed. This rope was marked with the position below deck edge to take the measurement and hung vertically down to the seabed.

6.2.5 During the 2003 survey, the divers cleaned areas of the hull to enable thickness readings to be taken. Due to concerns about this process causing increased localised corrosion, the cleaned areas were painted following the reading being taken. This means that the painted areas are no longer representative of the hull. Therefore, each survey point was moved slightly deeper below the deck edge. The shell expansion plans for this type of Liberty ship shows that in this area of the hull a constant plate thickness was used, so thickness readings would remain comparable with the 2003 results.

6.2.6 Once clean steel had been exposed, the thickness readings were taken using a Cygnus wristed mounted thickness gauge with the reading being displayed and recorded on the surface via a repeater.

6.2.7 In water visibility in the Thames Estuary is poor and for the first phase of thickness readings in March 2014 divers reported visibility to be 20 to 30cm. Phase two in September 2014 had slightly better conditions with visibility reaching a maximum of 0.5m on the upper parts of the wreck, though generally decreasing on the lower parts of the hull.

6.3 Results – Condition of the Hull

6.3.1 Aside from the thickness readings, the divers were able to provide additional information on the condition of the hull which is difficult to ascertain through multibeam sonar surveys alone.

6.3.2 The divers found that, as expected, the hull was covered in a layer of hard concretion that could only be removed by chipping away at it with scraper or diver's knife. No measurements of concretion thickness were taken but the divers estimated it to be approximately 10mm thick and the covering appeared to be uniform at all locations and depths.

6.3.3 Small amounts of marine growth were found on the concretion but this was limited in thickness and extent. On the shallower sections of the wreck the marine growth included bryozoans, tube worms, barnacles and sponges and a limited amount of seaweed. In the deeper sections of the wreck, there was no seaweed and generally less growth and what growth there was consisted mainly of bryozoans and sponges (mainly mermaid's glove).

6.3.4 On the deck of the wreck, the divers reported a layer of sediment that increased in thickness in areas protected from the current such as the deck edge. The maximum reported thickness of this layer was approximately 20cm. However, there was localised build up in excess of 1m in small areas protected from the current. Areas of the deck that were not sheltered from the current did not have a significant sediment build up.

6.3.5 For the eight datum points, the deepest reading was taken by the diver standing on the seabed allowing the diver to report on the seabed conditions. At Datums 1 and 2 the diver reported a hard seabed, most likely London clay, with no sediment layer on top of the hard base material and the diver did not sink into this base material whilst taking the readings. At Datum 3 a solid seabed with a thin layer of sediment was reported. Between Datums 4 to 8 soft sediment was reported, getting progressively softer towards the shallowest part of the sediment plume at Datum 7. Divers reported quickly sinking in to the sediment whilst taking the readings. The 0.5t mooring line sinker weight positioned close to Datum 7 was inspected by a diver and was found to have formed a crater of over 1m in depth during the 3 days that it was deployed.

6.3.6 Whilst the multibeam sonar data is able to identify and measure cracks, holes and deformities in the hull structure, a diving survey is able to add a slightly different dimension to this data. On inspecting the cracks, holes and deformities in the hull, divers were able to confirm that:

6.3.7 At datum 2 directly below the deck edge the diver confirmed a series of holes of circa 30 cm diameter running parallel to the deck edge.

6.3.8 At Datum 3 there is a small hole in shell plating below the deck edge where the plate appears to have corroded away.

6.3.9 Between datums 5 and 6 the deck is collapsed (as can be seen in the multibeam imagery). At the limits of the collapse the beams that support the deck are visible.

6.3.10 The crack at Hold 2 which has been identified in the multibeam data for a number of years was verified by divers. The crack extends from the top of the bulwark vertically down through the deck edge where it opens to a hole in the shell plating just below the deck edge (again, as can be seen in the multibeam imagery). The hole is approximately 0.5 m wide by 1 m deep. This is smaller than the multibeam survey suggests, however the plating directly below the hole is heavily inset which may have caused shadowing in the multibeam data. The inset plating extends all the way to the seabed and the diver reported that the deformation disappeared into the sediment.

6.3.11 At seabed level at datum 6 the diver located an area of deformation in the hull, above which is a hole 0.1 m wide by 0.75 m deep that narrows to form a crack extending to 2m below the deck edge. The plating forward of the crack is folded back on itself in a tight radius to form an S shaped deformation. In this area the diver reported that the whole side of the ship was bowed outwards and was no longer a flat side as found on the rest of the wreck.

6.3.12 At datum 7 the existence of a hole in the gunwale, 2m wide by 0.5m deep was confirmed. The deck area at datum 8 is largely collapsed as is clear from the multibeam data and there is a hole in the shell plating 0.5 m wide by 0.5m deep just below the deck edge. Just aft of the area of deck collapse is a set of mooring bollards, the bollards and the deck aft of them is intact until the break of the hull.

Fig. 34 Diver inspecting the wreck

6.4 Hull Thickness Measurements

6.4.1 The results of the ultrasonic hull thickness readings are given in the table below. Where possible, multiple readings were taken and averaged for each survey point. The results shown below are the averaged results.

Datum	1	2	3	4	5	6	7	8
On Deck (mm)	9.8	7.6	12.5	2.6	8.2	15.6	15.8	9.0
1 m below deck edge (mm)	9.3	hull perforated	15.0	13.5	6.2	10.8	16.1	12.2
1 m above seabed (mm)	10.2	16.8	13.1	11.9	7.4	6.5	11.3	15.2

Table 3. Average hull thickness readings 2013

6.4.2 The readings when compared to the 2003 results show a loss of steel in most areas, but the amount of loss is not uniform and in some areas there is a localised high level of loss. The measurements averaged across all survey points show a loss of 2.3 mm of steel since 2003 and the rate of corrosion found in this study corresponds with, and explains, the deterioration seen in the multibeam sonar data between 2003 and 2013.

6.4.3 When comparing measurements from the 2013 data, it can be noted that some of the survey points are thicker than those taken in 2003. This is not an error in the measurements but is a reflection of the difficulties of taking consistent, comparable ultrasonic thickness readings on the hull of a corroded wreck. Pitting and crevice corrosion mean that within a small area, the thickness readings can vary by several millimetres. For this reason, multiple thickness readings were taken at each location and averaged to produce a reading for the location. This average of multiple readings minimises the effect of the roughness of the hull surface on the results, giving an accurate indication of the overall condition and corrosion loss from the wreck.

6.4.4 The average loss of total thickness since 1944 is in the region of 4.7mm. This is based on the original thickness figures taken from a generic set of Liberty ships plans rather than plans specifically of the SSRM. The survey showed that hull thickness has reduced by 2.3 mm since 2003 leaving an average of circa 11 mm of steel remaining.

6.4.5 Whilst the thickness readings provide a guide to the quantity of steel remaining, it was noted by the divers that the quality of the material remaining is very low in some areas. During cleaning of the hull with a scraper, the divers on several occasions punctured through the shell plating. This was despite thickness readings of up to 8 mm in the plating close by and thickness readings of up to 16.8 mm at other locations. This localised loss of steel reflects what has been recorded in the multibeam sonar pictures where no change has been observed in some areas whilst others are deteriorating at an increasing rate.

6.4.6 The thickness readings are of the shell plate only. The shell plate forms an important part of the structure of the vessel but it is supported by the frames, longitudinals and bulkheads of the internal structure. The conditions experienced by the internal structure of the wreck are different from those of the shell plating. The loss of steel due to corrosion of the internal structure is unlikely to be the same as the loss of the shell plate as the holds are largely filled with sediment which will lower the oxygen available and therefore the corrosion rate in the lower parts of the hold.

6.4.7 As noted above, a number of holes in the shell plate were noted by the divers, mostly in the region of the deck edge. The perforation of the hull by the divers when preparing the surface for thickness readings suggests that the number of holes is likely to increase in the near future.

6.4.8 The sediment levels within the holds mean that the upper part of the shell plate is most likely to be exposed on both sides. This means that there is no sediment to protect the upper part of the internal structure by lowering oxygen levels resulting in both sides of the shell plating corroding at similar rates. This higher rate of corrosion would explain the increased frequency of perforation of the shell plate in the deck edge area.

6.4.9 The deformation of the hull in the area of Datum 6 which forms the shell plating of the aft end of Hold 2 was also noted in the 2003 survey. The 2003 survey described it as a crack in this area and a "fold in plate into the burial". The 2013 survey suggests that the severity and extent of the deformation has increased considerably. When the deformation is combined with the high corrosion loss of steel at datums 5 and 6, it suggests that this area is deteriorating more rapidly than others.

6.4.10 The outwards bowing of the hull in the Hold 2 area has been noted in successive multibeam sonar surveys. This type of deformation is difficult to measure in multibeam data, and surface difference calculations that have been used to try to quantify the difference year on year. During the hull thickness assessment, divers noted the deformation of the hull in this area. When compared to diver observations in 2003, this deformation appears to have increased significantly in the intervening 10 years. The gradual collapse of the decking and the deformation of the shell plate around Hold 2 would suggest that this area of the hull is likely to be the first to suffer from structural collapse, particularly given that other sections of the wreck showed no deformation of the hull. This confirms previous surveys which have focussed on the area around Hold 2 due to its apparently more advanced deterioration.

6.4.11 It should be noted that a reading from the deck area was removed for clarity as the deck has collapsed in this area since 2003 causing a misleading comparison of results. Data was from an area of the hull which has perforated since 2003 and inclusion of this data causes the average loss figures to be misleading. Also, data removed as there is no data from 2003. The 2013 readings were achieved by moving forward of the datum to record the thickness of the closest shell plating steel at this depth; this increased the amount of data on the wreck but is not comparable with 2003 data.

6.5 Mast Thickness Readings

6.5.1 Aside from the thickness readings taken on the hull, the dive team also assessed the condition of the masts and took thickness readings. The mast thickness was also gauged using a Cygnus handheld gauge, calibrated against a test piece prior to use. Readings were taken at three locations: around the intertidal zone (taken from a boat); 1.5 m above; and 0.5 m above the deck house (taken by diver). The focus of this diving survey was the bow section of the wreck as this is the section known to contain munitions. Therefore, only the two masts on the bow section were assessed.

6.5.2 The average results are shown in the table below.

[9]

Mid mast Location	**Average**	**Maximum**	**Minimum**
Intertidal (3 to 5 m above deck house)	25.3 mm	25.4 mm	25.1 mm
1.5 m above deckhouse	23.2 mm	23.3 mm	22.9 mm
0.5 m above deckhouse	22.8 mm	22.9 mm	22.7 mm
Foremast Location	**Average**	**Maximum**	**Minimum**
Intertidal (3 to 5 m above deck house)	29.3 mm	29.4 mm	29.2 mm

Table 4 – Thickness readings of SSRM masts

6.5.3 No diver readings were taken on the foremast due to poor weather preventing diving but it is expected that the readings would follow the same profile as the Mid mast; a slight reduction in steel thickness in the lower sections.

6.5.4 The masts on the forward section of the wreck appear to be in good condition when visually inspected from the surface. The corrosion on the masts appears to be uniform in the intertidal area and whilst there is some pitting, this appears limited in depth and extent.

Fig. 35 Taking surface mast thickness readings

6.5.5 The masts appear to lack any perforation therefore it is likely that the water exchange within the tube of the mast is very limited. This will reduce the dissolved oxygen content in the water contained within the mast, therefore reducing the internal rate of corrosion.

6.5.6 The mid mast has no stays supporting it whereas the foremast has a single stay. During the 2011 multibeam survey, it was noted that one of the two stays on the foremast had parted at deck level since the 2010 survey. It is likely that the one remaining stay has very little remaining strength. The mid mast (and stern mast) has lacked stays for many years and this suggests that the lack of stays is not of concern if the supporting structure has sufficient strength to support the mast.

6.5.7 The masts are made from a helical seam pipe stepped on the deck above the bulkhead separating the holds below. The masts do not penetrate the deck being welded to a heavy plate inset into the deck, this plate is very limited in extent and is octagonal in shape. Surrounding the lower section of the mast is a deck house fabricated from light steel plate.

6.5.8 The masts remain supported by the welds at the base and a limited amount of support from the deck houses. Given the poor state of the deck recorded during the dive survey, the structural strength of the deck has undoubtedly been considerably reduced since the vessel was fabricated.

6.5.9 The plans show the mast supported by the transverse bulkhead and a longitudinal centre line girder beneath the deck. This structure in its original, as built state provided considerable strength however the dive survey has shown that the deck is in poor condition and the vessel has lost a considerable amount of steel. Steel will also have been lost from the structure supporting the masts.

6.5.10 As the masts are subject to wave, wind and tidal forces and exert considerable leverage on the deck, further detailed analysis of the masts should be considered.

6.6 Water Sonde Results

6.6.1 A Hydrolabs DS5X multi-parameter sonde was deployed for the duration of the survey work in order to monitor water temperature, conductivity, salinity, pH, turbidity, dissolved oxygen and oxygen reducing potential.

6.6.2 Readings were taken at 15 minute intervals with the sonde deployed at a depth of 4m to record the conditions being experienced by the deck level of the wreck. Readings were taken during both phases of the dive survey in March and September 2013.

The average results for the deployed period are shown in the tables below.

Parameter	**Average**	**Minimum**	**Maximum**
Temperature (C)	4.37	4.13	4.60
Conductivity (mS/cm)	43.24	39.3	47.10
Salinity (ppt)	27.89	27.92	30.67
pH	8.15	8.15	8.17
Turbidity (NTU)	22.1	7.9	70.8
Dissolved Oxygen (%)	94.18	92.3	96.2
ORP (mV)	359	356	367
Depth (m)	4.20	1.80	4.83

Table 5 Water data – March 2013

Water data	**Average**	**Minimum**	**Maximum**
Temperature (C)	17.53	16.91	18.27
Conductivity (mS/cm)	51.2	49.7	53.4
Salinity (ppt)	33.69	32.60	35.35
pH	8.30	8.27	8.36
Turbidity (NTU)	13.67	4.3	42.9
Dissolved Oxygen (%)	91.4	89.4	94.2
ORP (mV)	386	372	403
Depth (m)	4.29	4.82	3.33

Table 6 Water data – September 2013

6.7 Sonar Survey

6.7.1 As outlined above, in order to obtain the most value from the diving survey, various equipment was trialled. This included a Sound Metrics Didson Sonar, a Blueview sonar and also side scan sonar, which hasn't been undertaken on the wreck for many years as the preferred method of multibeam has been used.

6.7.2 The Didson sonar system is a diver-held imagining sonar that operates at a very high frequency (1.8 MHz) to produce high definition images over a short range. S&MO has not previously used a Didson unit for wreck imagery work, so this was a trial of the system.

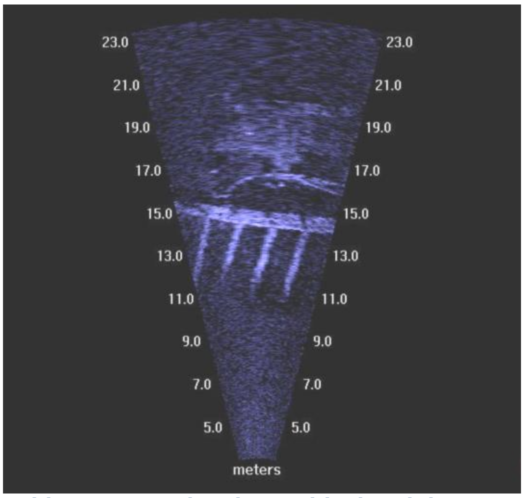


Fig. 36 Image from Didson sonar showing Hold 4 hatch beams and debris on deck

6.7.3 The short available weather window for diving operations unfortunately did not allow the wreck to be extensively imaged using the Didson unit.

6.7.4 It was seen from the Didson footage that there is more debris on the decks than can be seen on the Multibeam footage. The debris mainly appears to be the stays and parts of the rigging from the masts; the majority is in proximity to the deck houses and all of it lies on the side decks of the wreck.

6.7.5 Although only a short timeframe was available to trial the unit, the deployment did prove that the system could be used to provide additional data to supplement that of a vessel mounted multibeam unit. This is particularly likely to be the case within the holds and the various apertures where the sonar can be deployed to "look" directly without diver penetration of the wreck. The further use of a Didson unit can be considered when any future diving operations take place on the wreck.

6.7.6 The side scan sonar unit used for this survey was a Cmax CM2 high frequency system. The survey was carried out with the sonar being towed from the stern of the Miner III on a winch system. The large scour pit to the west of the wreck made detailed imagery difficult to achieve as the altitude of the fish could not be kept constant above the seabed, reducing quality of coverage.

6.7.7 The purpose of the side scan survey was to identify small features in the vicinity of the wreck that may have been missed by a multibeam system.

6.7.8 The seabed within the prohibited area was surveyed. The side scan showed the seabed within the scour pit area to be smooth and, with the exception of the debris that lies between the bow and stern sections, no sonar targets of note were detected.

6.7.9 In the area of the break between the bow and stern sections of the wreck, there are a number of sonar targets that appear to be parts of ships structure. These can also be noted in successive multibeam survey datasets.

6.7.10 Beyond the scour pit, the sinker weights that moor the buoys were clearly visible and the chains connecting them to the buoys have marked out thrash zones several metres from the buoys as would be expected.

6.7.11 The sea bed is generally smooth with low sand waves; the sand waves are more defined to the west of the wreck on Sheerness Middle Sand.

6.7.12 There are a small number of sonar targets in the vicinity of the wreck out of the scour pit. None of the targets identified are considered likely to be from the wreck of the SSRM and appear to be natural features, old mooring items from marking the wreck or unconnected debris.

6.7.13 There were no targets identified to suggest munitions are present on the seabed in the area surveyed. However, the experience of the divers suggests that any heavy items will quickly be submerged into the sediment and may not be detectable by side scan sonar. For this reason, the side scan survey is not to be considered as a reliable indicator of the presence or otherwise of unexploded ordinance.

6.7.14 Also trialled on the wreck during the diving work was a Blueview P900-130 imaging sonar. Blueview operates at 900 kHz which is a lower frequency than the Didson sonar unit, but it provides a much wider field of view. The Blueview operated correctly and provided some imagery of the wreck but as it was vessel mounted rather than diver held, it did not provide any additional detail that had not previously been seen on the multibeam surveys.

6.8 Current Meters

6.8.1 Two current meters were deployed close to the wreck during the first phase of the diving work in March 2013. The intention was to leave them in place for at least 4 months before recovery. An attempt was made to recover the meters during the September dive survey but the current meters could not be relocated. No indication of them could be found on either Blueview or side scan survey and divers were unable to locate them despite their deployment positions being accurately known. It is likely that due to the very soft mud and strong currents around the wreck, the anchors failed to hold them in position.

7. RECOMMENDATIONS & CONCLUSIONS

7.1.1 The following recommendations are made as a result of the diving survey:

- The plans of the SSRM may still exist and, if so, they are likely to be held America within the National Archive at College Park, Maryland. It is recommended that the plans are obtained so that analysis of corrosion loss can be made against the actual SSRM plans rather than generic Liberty Ship plans.
- The shell plating of the port side of Hold 2 is carefully examined following multibeam surveys for signs further deformation and a diving survey of any significant observed change to the area should be considered.
- The 2012 naval architecture review could be updated to include the information from this survey, with particular attention being paid to the masts and the structure supporting them.
- A second attempt is made to take current meter readings at the wreck site.
- The survey showed that hull thickness has reduced by 2.3 mm since 2003 leaving an average of circa 11 mm of steel remaining.
- The condition of the steel is not uniform with some areas of the hull being in poorer condition than others and some areas where divers perforated the hull whilst cleaning it for thickness readings. However, in other locations thicknesses of up to 16.8 mm were recorded. This localised loss of steel reflects what has been recorded in the multibeam sonar data where no change has been observed in some areas whilst others are collapsing at an increasing rate.
- The dive survey confirms that the cracks observed by the regular multibeam surveys and the 2003 dive survey continue to propagate.
- Considerable deformation of the hull in the region of No. 2 Hold was observed including some deformation that had not previously been noted by multibeam surveys. The condition of the hull in this area is poor compared with the other areas of the hull and this suggests that the area around Hold 2 is likely to be the first to suffer any significant structural collapse. It is recommended that this section of the wreck is given particular monitoring attention.
- The masts were surveyed and thickness readings taken. The readings showed the masts to be in good condition with readings between 25 and 29 mm. This combination of the thickness of the masts and the poor condition of deck and hull plating should be examined further to ascertain the strength of the structure supporting the masts.
- The dive survey shows the wreck is continuing to degrade and in the region of Hold 2, the structure is deformed, cracked and corroded. It is considered that this area is the most likely to be the first area of the wreck to suffer structural collapse. The likely predicted time for collapse is outside the scope of this survey.