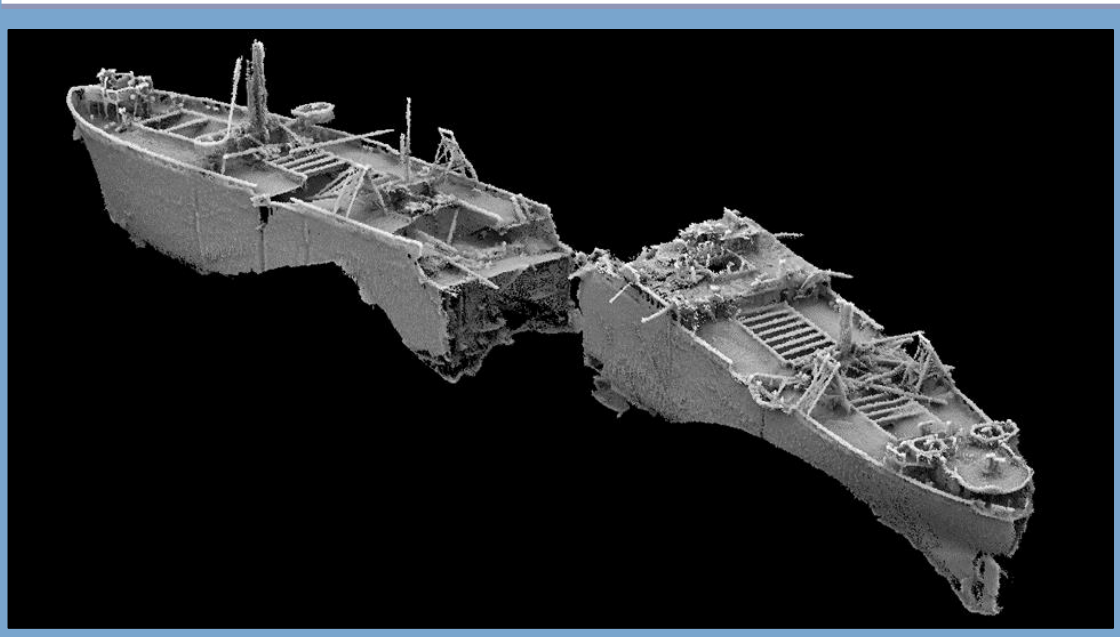
Maritime & Coastguard Agency



SS Richard Montgomery
Survey Report 2017

Maritime and Coastguard Agency
January 2019

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 immediate efforts were made to salvage the cargo, the vessel broke in two, flooded and sank before the salvage operations could be completed. The wreck lies adjacent to the Medway Approach Channel and is approximately 1.5 miles from the town of Sheerness and 5 miles from Southend. 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 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. For the 2017 survey of the wreck, the scope of the work included a multibeam sonar survey of the wreck and the seabed surrounding it and laser scanning of those areas of the wreck which are visible above the water. The collection of both multibeam sonar and laser scanning data have been regular features of the SS Richard Montgomery survey in recent years. As a repeat survey, the multibeam and laser data was acquired in a manner that enabled direct comparison with historical datasets and allows for comparisons with data collected in the future. In addition to this, the 2017 survey included the trialling of a new ultra-high resolution mode on the multibeam sonar unit.

1.3 The survey was commissioned in 2017 and took place in two main phases. The surrounding seabed area and laser scanning surveys took place on the 7th and 8th November 2017 and the survey of the wreck took place on the 19th April 2018.

1.4 In addition to the multibeam and laser scanning surveys, other work undertaken during 2017 includes the formation of an Expert Advisory Group who will provide independent advice to ministers on long-term management options for the wreck and the commissioning of environmental monitoring in the vicinity of the wreck. Part of the 2017 survey included a special focus on the area of seabed identified for the placement of environmental monitoring equipment.

1.5 The results of the 2017 survey work indicate that both the forward and aft sections of the wreck have remained largely stable since 2016. No fundamental changes to the angle of list of either section of the wreck or changes in positions of the masts were observed and surface difference analysis indicates overall stability with structural changes being restricted to discrete regions of the wreck.

1.6 The following are some of the main points from the 2017 survey results:

- As in previous years, the 2017 survey covered the entire wreck and surrounding seabed in detail.

- The six Key Areas where more accelerated levels of deterioration have been noted in previous years again received scrutiny. Of these, three showed structural changes since the 2016 survey. Subsidence of up to 60cm was seen in the collapsed deck plating around Hold 2, the bridge deck area has continued to show

evidence of collapse with some debris falling onto the seabed below and a split in the deck of the aft section of the wreck has subsided by up to 20cm since the 2016 survey.

- Over the whole of the wreck, 96 specific features have been used in successive surveys as comparison points for quantifying change and deterioration. Of these 96 features, 22 showed some level of change between the 2016 survey and the 2017 survey (this includes the changes in the Key Areas noted above).

- Across the wreck, there are small changes that reflect reworking of sediments lying on the deck surfaces and within the hatch openings rather than structural changes.

- In the wider survey area, 66 seabed objects have been noted in previous surveys. Close scrutiny of the backscatter data combined with the bathymetry has increased this to 72 objects noted in the 2017 survey data.

- Surface difference results showed that the seabed area around the wreck has generally remained stable during the period between the 2016 and 2017 surveys. Differences are typically small with an overall slight erosional trend across much of the area. This corresponds to depth changes of -0.2 m to 0.6m.

- During the 2017 survey some data was acquired using a newly available ultra-high resolution mode. This trial had limited benefits but has identified some options for future improvements.

2. Introduction

2.1 The SS Richard Montgomery (SSRM) was a US Liberty Ship of the EC2-S-C1 class, constructed by the St. John's River Shipbuilding Company in Jacksonville, Florida 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. However, on arrival in the Thames Estuary on 20th of August 1944, orders were received to anchor off Great Nore. Unfortunately, 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 engaged to discharge the cargo. However, on the afternoon of the following day, the ship's hull cracked even 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.

2.2 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.

2.3 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 VTS[2].

2.4 Although the wreck is considered to be stable if left undisturbed, the wreck is regularly monitored. Regular 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. Following the formation of an independent Expert Advisory Group (EAG) in 2017, survey results are also provided to the EAG to inform their advice. 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 the purpose of general surveying, multibeam sonar is faster, more cost-effective and provides greater levels of detail, repeatability and reliability than diver surveys. 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] Vessel traffic monitoring service

2.5 As in previous years, the 2017 survey required a multibeam sonar survey of the wreck and the surrounding seabed and laser scanning of the upstanding features of the wreck which are visible above the waterline. The 2017 survey also included the use of a new ultra-high resolution mode on the multibeam unit and a particular focus on an area of seabed identified as the most suitable location for the placing of environmental monitoring equipment.

2.6 This document is the summarised findings of the 2017 SSRM survey work and contains the results of the comparison between the 2017 dataset with datasets from 2016 and 2010. The year-on-year comparisons of survey data are used to help identify and quantify any deterioration of the wreck and, by also using historical datasets from 2010, it provides a longer view of the condition and rate of deterioration of the wreck structure.

2.7 The data analysis covers the entirety of the wreck and, in particular, identifies 96 features on the wreck which have been used in successive surveys as markers for measuring levels of change. Of these, there are six areas which have repeatedly demonstrated levels of accelerated deterioration and are therefore a specific focus of each survey. These six Key Areas are detailed below. This report also includes the results of the surrounding seabed survey. The seabed survey aims to identify changes in the local seafloor topography that may have implications for the wreck's stability or for the neighbouring Medway Approach Channel. It also aims to locate items of debris on the seabed within the survey area, those that may have originated from the wreck and those that are unrelated other than through their geographic proximity.

3. The Survey

3.1 Survey Requirements

3.1.1 For 2017, there were four main requirements of the SSRM survey. These were:

1) a multibeam echo sounder (MBES) survey of the wreck, including use of ultra-high resolution mode
2) an MBES survey of the seabed out to a minimum of 400m distant from the wreck, including the edge of the dredged channel (Medway Approach Channel)
3) laser scanning of those areas of wreck which are visible above the waterline which should also include a photographic record of those featues
4) Detailed survey report containing information on any areas of change, areas of no change and comparisons with a minimum of two previous survey datasets

3.1.2 As in previous years, all data collected (MBES and laser) 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. For 2017, the dataset was compared to the previous year and also the dataset from 2010 in order to provide a view of the immediate changes (if any) from the previous survey and comparisons with 2010 to provide a longer view of the areas of stability and deterioration. Any changes or deterioration since the last survey 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 (the six Key Areas).

3.1.3 The multibeam and laser scanning data were 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.

3.1.4 For the 2017 SSRM survey, a trial was made to see if there were benefits to be gained from using the ultra-high resolution mode that is available on the R2 Sonic 2024 MBES system mounted on the MV Maplin (the results are detailed below).

3.1.5 The 2017 wreck survey took place in two main phases. The surrounding seabed area was surveyed using the Port of London Authority (PLA) survey vessel MV Maplin on the 7th and 8th of November 2017. However, due to availability of personnel, survey vessels and suitable weather, the wreck survey and laser scanning were completed on 19th April 2018 with additional data collected by the PLA survey vessel MV Galloper.

3.2 Survey Area

3.2.1 The survey area is located within the Thames Estuary in an area 1.5 miles from the town of Sheerness on the North Kent coast. The survey site covers a section of the Sheerness Middle Sand bar and parts of the Great Nore and Medway Approach Channel. The boundary of the survey site is defined as an area extending a minimum of 400m from the centre of the wreck and this has been transformed into a square shaped area that allows for practical survey line running.

3.2.2 There is a prohibited area around the wreck which is marked by buoys, however, the survey area extends beyond the buoyed area (see figures 1 & 2 below). The wreck

lies at the centre of this exclusion zone within a deep scour that has been created over the years by the strong tidal currents. To the west and east of the wreck are the shallows of Sheerness Middle Sand with the shoalest region of the survey area being located on the western side. This is 2.04m below Chart Datum (CD). To the north and south of the wreck are the deeper areas of the Great Nore and the Medway Approach Channel. The deepest part of the survey area is the scour that contains the wreck. The maximum depth is 20.60m CD, which is located on the starboard side of the bow.

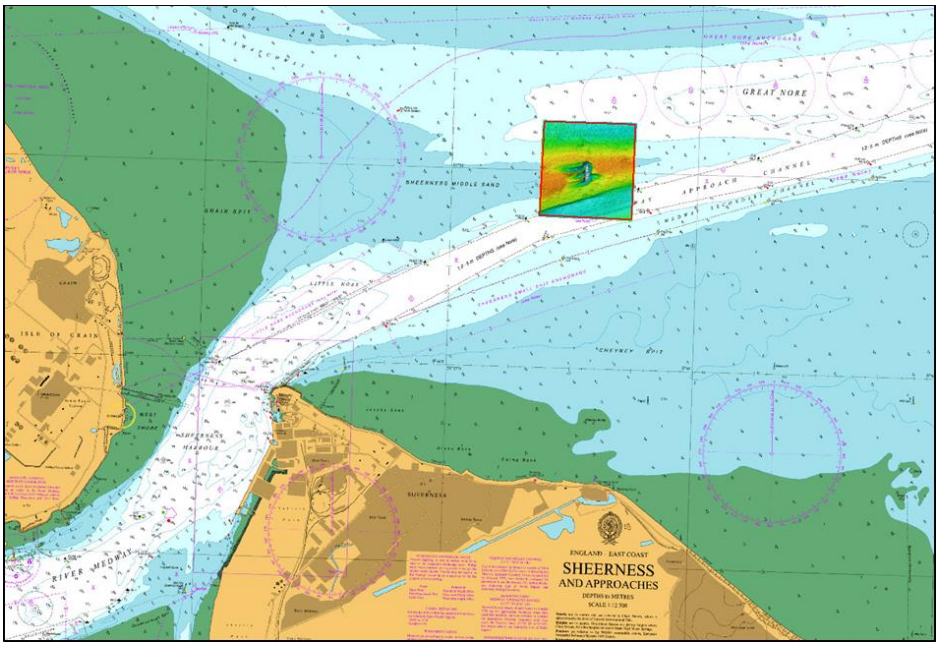


Fig. 1 – Chart showing the survey area with the wreck at the centre.

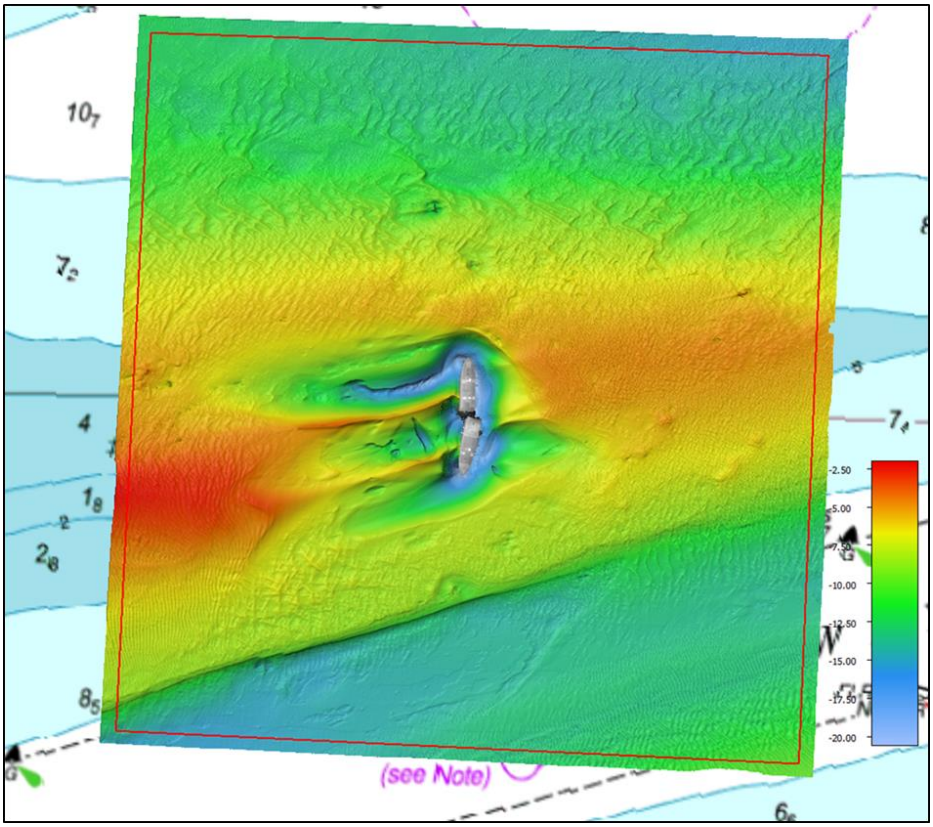


Fig. 2 – Close-up of the survey area showing seabed topography and the wreck at the centre

3.3 MBES and Laser Survey Methodology and Data Processing

3.3.1 The complete survey of the wreck of the SSRM in 2017 has required the acquisition of MBES, laser and photographic data.

3.3.2 The MBES and laser data was acquired using the PLA survey vessels MV Maplin and MV Galloper. MBES data was acquired using the Reson 7125SV MBES system permanently installed on the MV Galloper and the R2 Sonic 2024 MBES unit which is installed on the MV Maplin. Position, attitude and time were controlled using the Applanix POS MV 320 system. The MV Galloper has been used for the SSRM survey in previous years, but the 2017 survey was the first opportunity to use the PLA's newer survey vessel MV Maplin and the R2 Sonic MBES unit.

3.3.3 MBES survey of the wreck was conducted by the MV Galloper during high tide. The MV Galloper is a small survey vessel with a shallow draught and high tide allows for sufficient water depth for safe passage directly over the wreck. This was complemented by the use of the ultra-high resolution mode on the R2 Sonic MBES unit on survey lines adjacent to the wreck. The laser survey of the SSRM was conducted during low tide in order to survey as much of the exposed wreck as possible and to ensure that the laser and MBES data meet. The surrounding seabed area survey was conducted by the MV Maplin and is not reliant on tides in the same way that the wreck survey is. This included a particular focus on the seabed location that had been identified as an appropriate site for the placement of environmental monitoring equipment.

3.3.4 The laser survey data was collected using an Applanix LANDMark Marine Laser System installed on starboard side of the MV Maplin's wheelhouse roof.

3.3.5 Survey lines were run across the entirety of the survey area, adjacent to and directly over the top of the wreck and additional lines were run diagonally between the forward and aft sections of the wreck in order to gain full coverage of the complex structures of the collapsing bridge deck area.

3.3.6 Following the collection of the data, the MBES and laser data was assessed using three key methods, with the photographic data supporting the laser data where appropriate.

3.3.7 From the combined laser and MBES data a point cloud model was generated that enabled 3D visualisation of the entire wreck and its smaller-scale structures. This visualisation was performed in the software CloudCompare which allows the current and historical point cloud data to be qualitatively compared for structural changes. Due to the quality of the visual rendering of the point clouds, much of the report imagery is obtained from this software.

3.3.8 Caris HIPS is used for quantitative comparisons of current and historical data. This software is used to process the raw MBES data and serves as an archive for all the historical MBES data. Cross-sections can be viewed through multiple datasets and accurate measurements of positional differences can be recorded. During the reporting, comparisons were made with the previous survey and a baseline dataset from 2010. This assists in identifying small shifts that occur over longer periods of time and have magnitudes that fall within the positional accuracy of the data, +/- 0.05m.

3.3.9 An overview of changes occurring to the wreck's upper structures is made by performing surface difference analysis. This clearly presents changes occurring across

larger sections of the deck, superstructure and within the hold openings but can also serve to draw the eye to any unexpected changes. The overview of the surface difference results is the first stage in assessing the degradation of the wreck.

3.3.10 In previous survey reports, 96 features on the wreck have been used as markers for year-on-year comparisons. Each of these features was investigated using the three methods described above and information is provided in the sections below on the features showing change and deterioration in the 2017 survey results and features showing no change in the 2017 survey results.

4. Survey Results – The Wreck

4.1 Overview

4.1.1 This section of the report details the output of the survey data acquired from the wreck. It combines the results of all of the survey data and uses various tools to analyse the data and identify areas of change. This includes cross-sections through the data and surface difference analysis.

4.1.2 In particular using surface difference analysis, the results of the survey demonstrate that, in general terms, there has been little change in position of the main body of either the forward or aft sections of the wreck.

4.1.3 The forward section of the wreck shows a further subsidence of the deck plate on the port side of Hold 2 (see below Key Area 2). Aft of the Hold 2 hatch opening is a region that has undergone a local increase and decrease in height. This appears to be the result of a shift in position of a sheet-like piece of debris, the approximate length and width of which suggests that it might be the warning sign which was noted in a previous survey as having become detached from the mast.

4.1.4 Elsewhere across the forward section of the wreck there are small changes that reflect reworking of sediments lying on the deck surfaces and within the hatch openings. In the regions around the masts and A-frames differences are present but these arise from variations in the coverage of the MBES and degree of data cleaning between the two datasets (2017 and 2016)

4.1.5 More substantial changes are seen in the aft section of the wreck. The subsidence of the overhanging remains of the Bridge and Boat Deck region has continued, with the largest change taking place near the starboard side. This section has continued to tilt downwards, pivoting from the area around the boiler room casing (see below Key Area 6).

4.1.6 Surface difference analysis has highlighted the ongoing subsidence of the deck on the port side of the aft mast house. Forward of the split in the deck the collapsing deck plate has subsided by approximately 0.3m since the 2016 survey (see below Key Area 5).

4.1.7 On the starboard side of Hold 4 an increase in height has been noted. This results from the appearance of a linear feature not seen in the 2016 dataset. Inspection of the point clouds and Caris cross-sections indicates that the starboard lighting tower has collapsed and tipped southwards onto the main deck level below.

4.1.8 Over the engine room casing is another feature indicating an increase in height. Comparison of the point clouds from 2010 and 2016 suggests that the south-eastern leg of the upturned gun tub on the boat deck has fallen over the opening of the engine room casing.

4.1.9 The following is a more detailed discussion of the survey results, beginning with the six Key Areas. The six Key Areas are areas of the wreck which, through repeated

surveys, have shown more accelerated deterioration than other parts of the wreck. For this reason, they receive particular attention.

KEY AREA	ID NUMBER	FEATURE	LOCATION
1	ID04	Crack in Hull	Port Side, Forward Section (near Hold 2)
2	ID08	Collapse of Cargo Hold 2 Deck	Port Side, Forward Section
3	ID96	Aperture	Aft end, Forward Section
4	ID22	Split in Hull	Starboard Side, Aft Section (near Aft Mast House)
5	ID24 ID25	Split in Deck Split in Hull	Port Side, Aft Section (near Aft Mast House)
6	ID43 ID45 ID46	Boiler Room Casing, Collapsing Bridge Deck Collapsing Boat Deck	Forward end, Aft Section

Table 1 – The six Key Areas and their corresponding ID numbers

4.2 Key Area 1 – Crack in the hull on the port side of Hold 2

4.2.1 The crack in the hull on the port side of Hold 2 has been evidenced in surveys since at least the 1970s and is likely to have occurred when the vessel went aground in 1944. This crack was well defined in the 2017. Between the 2015 and 2016 surveys the position of the broken section of gunnel over the top of the crack moved and this has created an acoustic shadow around the upper parts of the crack. Added to which, although there are three holes visible in the data, it is not possible to determine whether the soundings are from existing pieces of hull plate or elements of the vessel frame onto which the hull plate, now missing, was originally attached. As a result, the measurements recorded in the 2017 survey suggest that the crack is slightly smaller than was measured in the 2016 but, as outlined above, this is due to acoustic shadows cast by protruding debris rather than actual change.

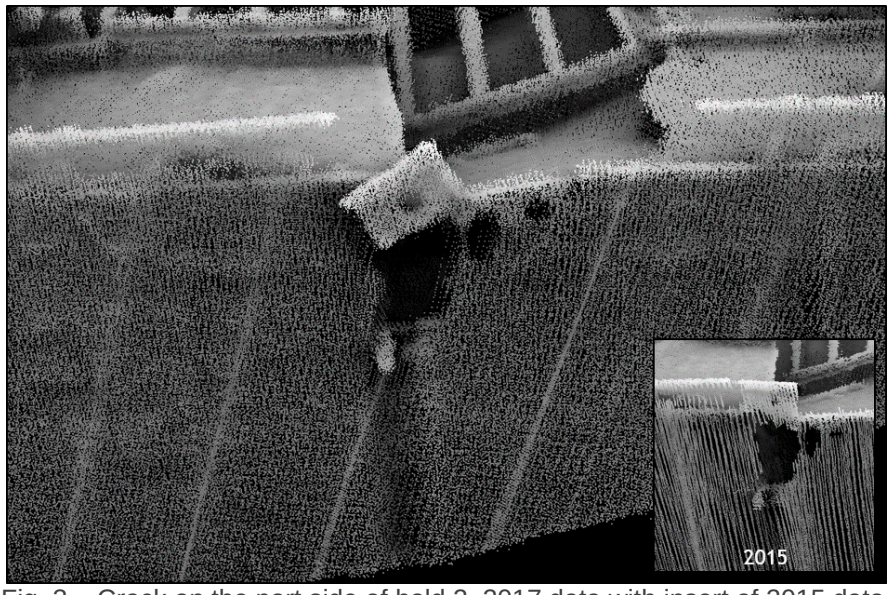


Fig. 3 – Crack on the port side of hold 2, 2017 data with insert of 2015 data.

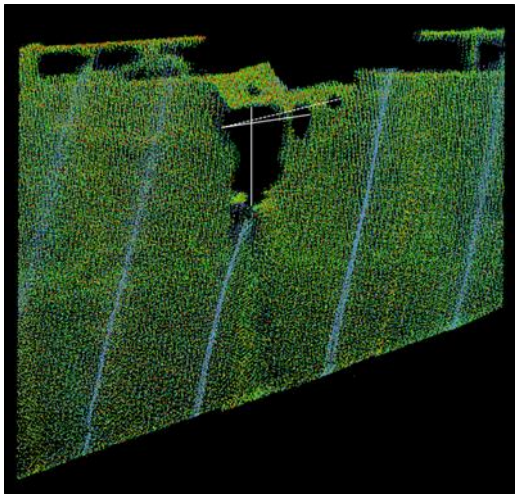


Fig. 4 – 2017 data showing the crack at Hold 2

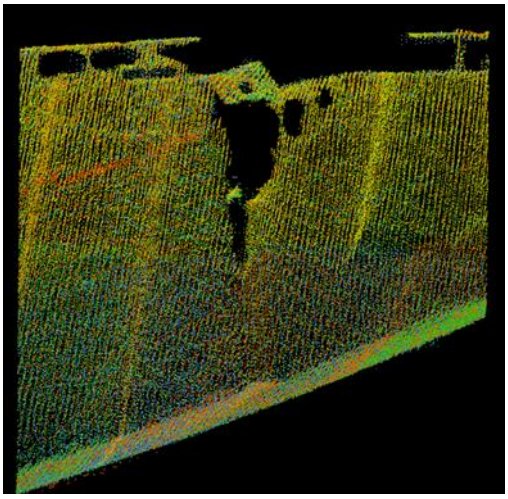


Fig. 5 – 2016 data showing the crack at Hold 2

4.3 Key Area 2 – Collapse of deck plating at Hold 2

4.3.1 The 2017 survey results suggest that the collapsing deck plate on the port side of Hold 2 has continued to collapse since the last survey. The greatest change has occurred at the aft end of the collapsing section of the deck plate and suggests that the forward end of the collapsed section is being supported by the contents of Hold 2.

4.3.2 In previous reports the magnitude of collapse has been measured at the leading edge of the deck plate. However, the focus of change in 2017 has shifted to a point that makes this measurement irrelevant. The surface difference indicates that the collapsing region of the deck has subsided by up to 60cm since the 2016 survey. The data suggests that the collapsed section of deck has broken free from the deck to the aft. In previous surveys this has appeared to be distorted but attached. Measurements taken in cross-sections show that the magnitude of collapse between 2016 and 2017 is 40cm at both locations. In addition, the three aft-most Hold 2 hatch cover supports, which are connected to the collapsing section of deck, also show evidence of collapse from 2016.

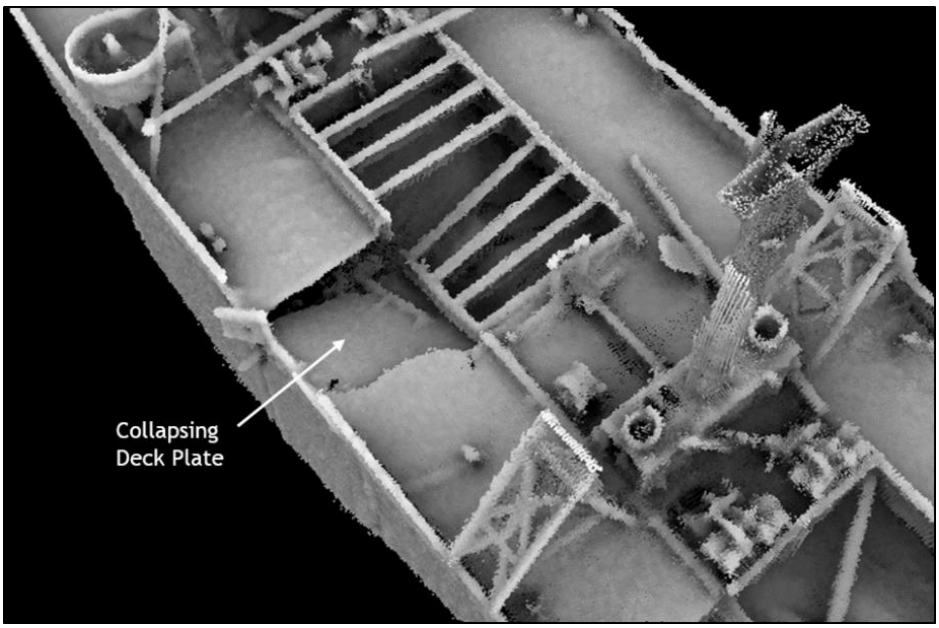


Fig. 6 – 2017 data, collapsed deck plate at Hold 2

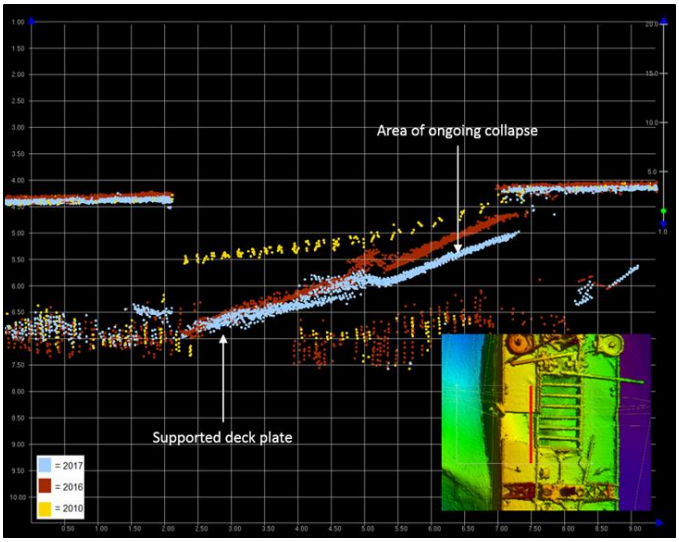


Fig. 7 – Cross section of data showing gradual collapse from 2010

4.4 Key Area 3 – Aperture in the Aft end of the Forward Section

4.4.1 The bulkhead at the aft end of the forward section (at Hold 3) is one of the Key Areas for two reasons. Firstly, the bulkhead is containing the munitions in Hold 3 and, secondly, there are apertures in the bulkhead, one in particular which is identified as one of the Key Areas of focus. It has been well-defined in the 2017 survey data and measurements taken of the aperture and compared with the previous survey and with survey data from 2010 show that there has been no change in the dimensions. Figure 9 below shows the 2017 data (in blue) overlaid with survey data from 2016 (red) and 2010 (yellow).

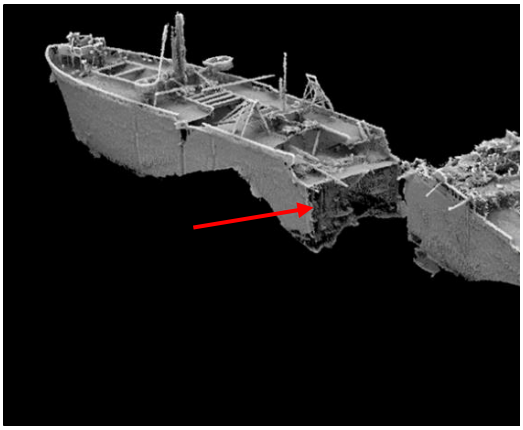


Fig. 8 bulkhead, aft end of Hold 3

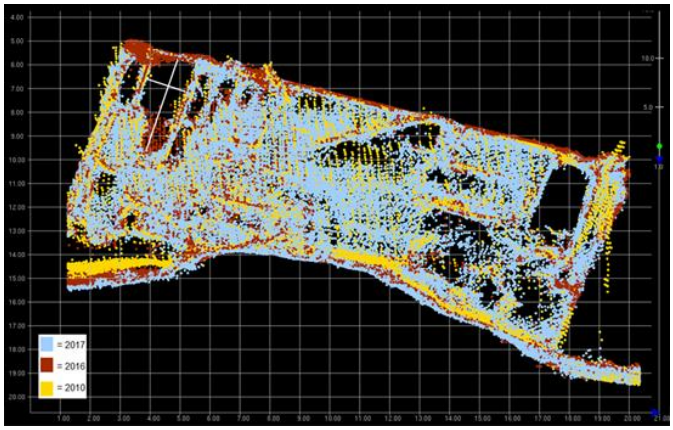


Fig. 9 Surface difference using 2017, 2016 & 2010 data

4.5 Key Area 4 & 5 – Split in the Starboard Side of the Aft Mast House

4.5.1 Located on the starboard side of the aft mast house is a split in the hull (Key Area 4), which is mirrored by a split in the deck and hull on the port side of the mast house (Key Area 5). On the starboard side, this split disrupts the line of the hull, as can be seen in Figure 10 below. Measurements in the 2017 data show up to 0.3m of disruption near the gunnel. However, comparisons with the 2016 dataset show that this split has remained stable and there is a close alignment between the two sets of point cloud data. This is also confirmed by the results of surface difference analysis in this area of the wreck.

4.5.2 Key Area 5 is a split in the deck and hull plating at this same area of the wreck on the port side. These features are clearly visible in the 2017 dataset and surface difference results highlight the ongoing subsidence of the deck plating. Measurements taken in Caris indicate that up to 0.3m of movement has occurred since the 2016 survey. However, cross-sections taken through the data to examine the split in the hull show that the split reaches from deck level to near the seabed but that it is not demonstrating any change since the 2016 survey.

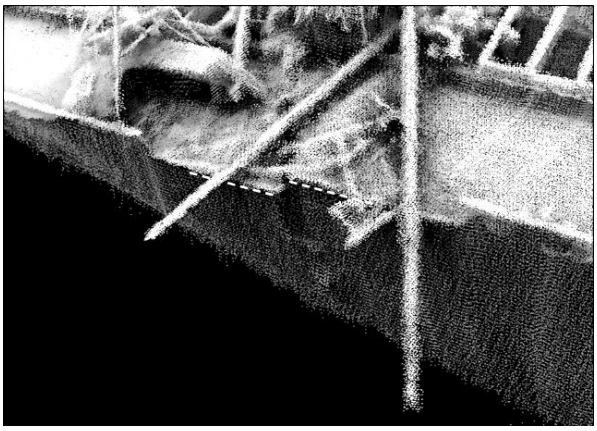


Fig. 10 Key Area 4 showing discontinuity of deck

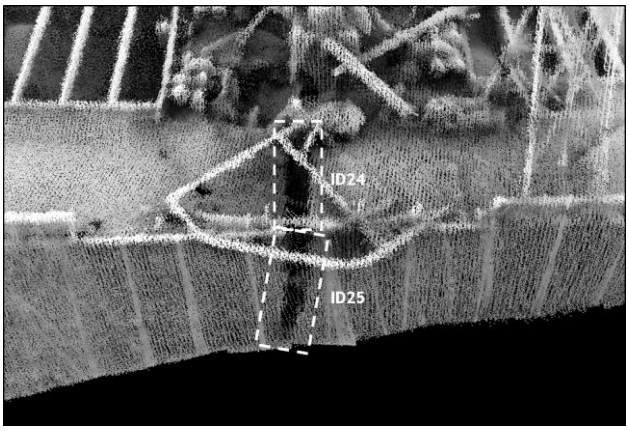


Fig. 11 Key Area 5 showing crack in deck and hull

4.6 Key Area 6 – Collapsing Bridge Deck Area

4.6.1 This feature was added to the Key Area list in the 2015 survey report after a collapse of the overhanging bridge deck was noted. The subsidence of the bridge deck has continued since the 2016 survey with the inclined sections tilting more steeply into the gap between the two sections of the wreck. The collapse is most notable towards the starboard side and it appears that part of the leading edge has detached and fallen to the seabed. This is most clearly shown by an increase in size of the mound of debris directly beneath this side of the wreck. Inspection of the point cloud data shows that there are changes to the extent of the inclined section of wreck.

4.6.2 The changes and deterioration of the remains of the ship's superstructure in this area of the wreck include the region on the starboard side of the boiler room casing which has collapsed by approximately 1.5m at the aft end and has become detached and dropped to the seabed (6m) at the forward edge. Although the greatest changes are focussed on the starboard side, there is also evidence of collapse along the full width of the overhanging bridge deck. Cross-sections taken through the data at this part of the wreck shows subsidence across the area of between 20cm to 30cm. The cross-sections and surface difference analysis show that the wreck aft of the boiler room casing has remained stable with the above noted changes occurring in the poorly supported/overhanging structures.

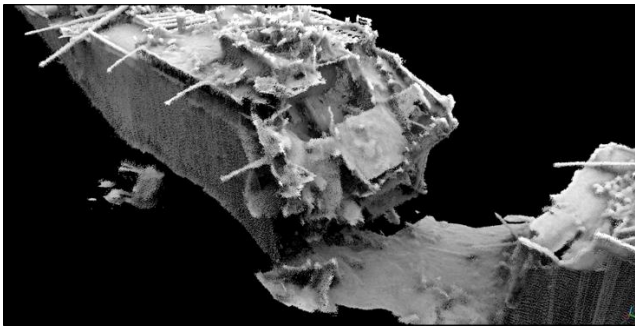


Fig. 12 Collapsing superstructure 2017

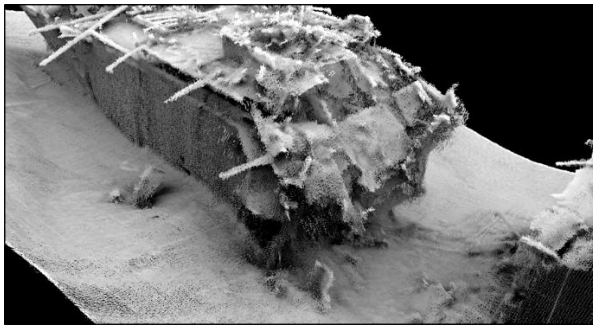


Fig. 13 Collapsing superstructure 2016

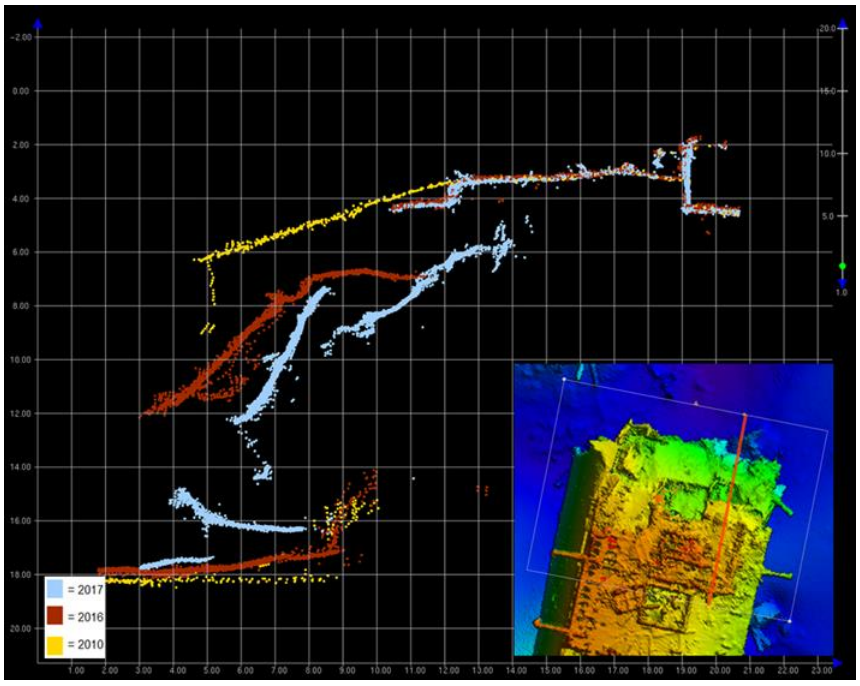


Fig. 14 Shows a cross-section through the combined 2017, 2016 and 2010 datasets demonstrating the largest area of collapse over this seven-year period.

4.7 Other Areas of the Wreck Showing Change in the 2017 Survey

4.7.1 Across both the forward and aft sections of the wreck, 96 identification areas are used as markers to help identify and quantify changes and deterioration. These numbered points on the wreck have been used as part of the survey reporting for more than ten years. Below is a table outlining the numbered identification (ID) areas which have demonstrated some level of change since the 2016 survey (not including those changes in the Key Areas which are already outlined above).

4.7.2 Break in Gunnel, Port Side, Hold 2 – ID07

The displaced section of gunnel on the port side of Hold 2 has tilted slightly, the maximum amount of change being c.15cm. It is possible that this is a small positional misalignment of the data rather than an actual change.

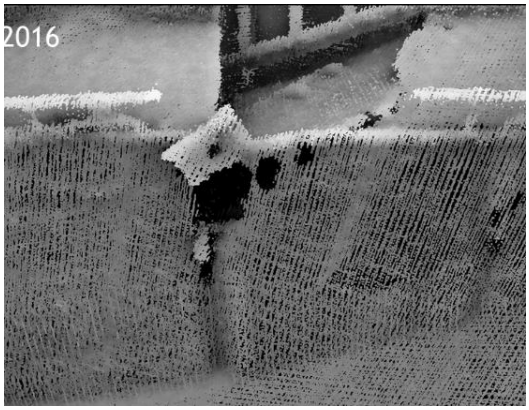


Fig. 15 Gunnel at port side Hold 2, 2016

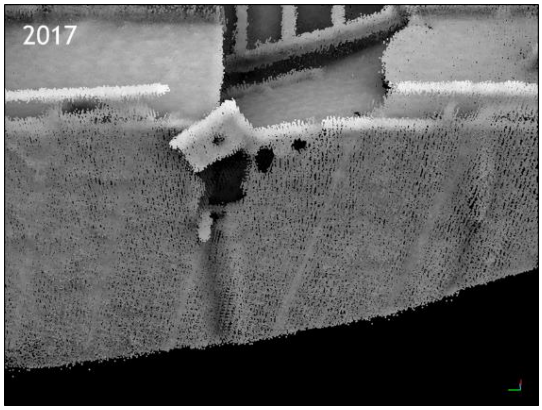


Fig. 16 Gunnel at port side Hold 2, 2017

4.7.3 Holes in the Deck Plating, Port Side, Hold 2 – ID13

These four holes are in the collapsed deck plating at ID08. One hole is now so deep in the hold space that it could not be seen in the data. Of the other three holes, one shows some expansion since 2016, c.20cm.

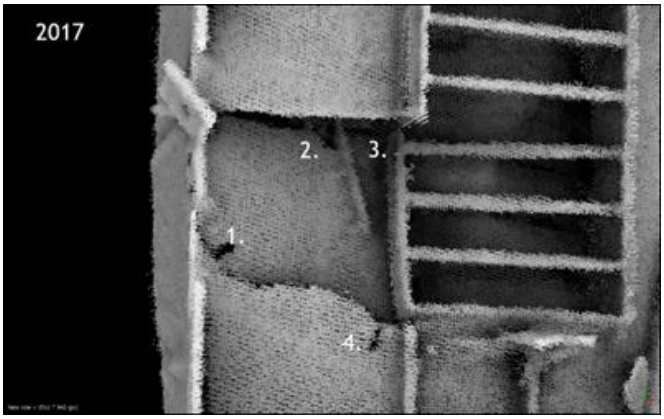


Fig.17 ID13, holes in deck plating at Hold 2

4.7.4 Holes in the Deck Plating, Port Side, Hold 1 – ID14

The 2017 data was compared to previous survey datasets and the results of this showed that a small hole towards the northern end of this cluster of holes may have opened up since the last survey.

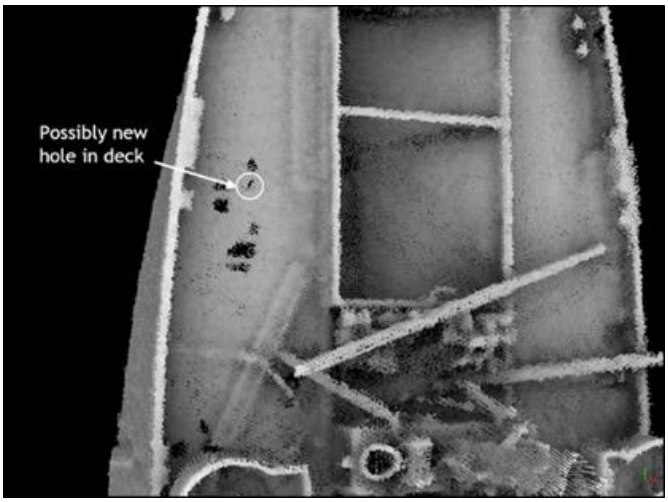


Fig. 18 ID14, holes in deck, port side, Hold 1

4.7.5 Collapse of Deck and Hatch Coaming, Port Side, Hold 3 – ID15

Both Surface difference analysis and cross-sections through the data were used to assess this area of the wreck. The results of this suggest that up to 15cm of subsidence has occurred since 2016. The image below shows a cross-section through the data from 2017 (blue), 2016 (red) and 2010 (yellow).

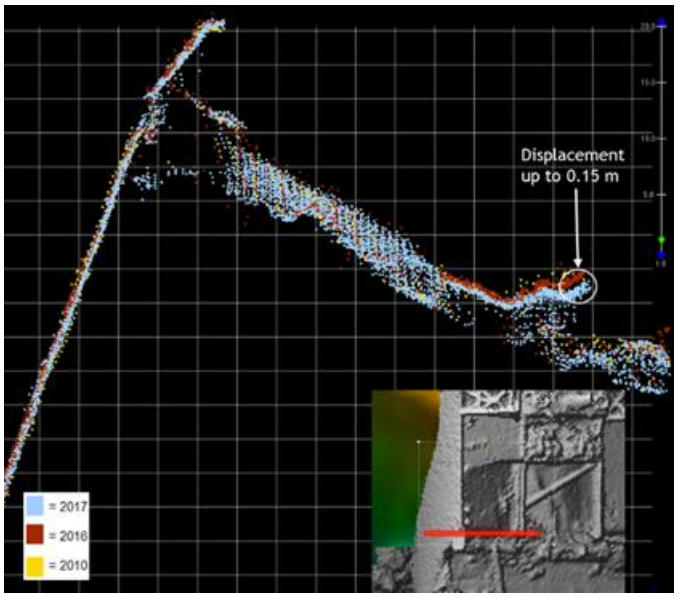


Fig. 19 Cross-section through three datasets on the port side of Hold 3

4.7.6 Collapsed Boat Deck, Port Side, Aft Section – ID28

This is part of the central superstructure along with the bridge deck (Key Area 6) and is a complex area of features and structures. Surface difference analysis at this area of the wreck shows an overall trend of subsidence with some localised uplift resulting from horizontal translocations of smaller features. Cross-sections through the data show the degree of subsidence is small, with measurements indicating up to 20cm of collapse. The image below shows a cross-section through data from 2017, 2016 and 2010 which demonstrates this gradual subsidence.

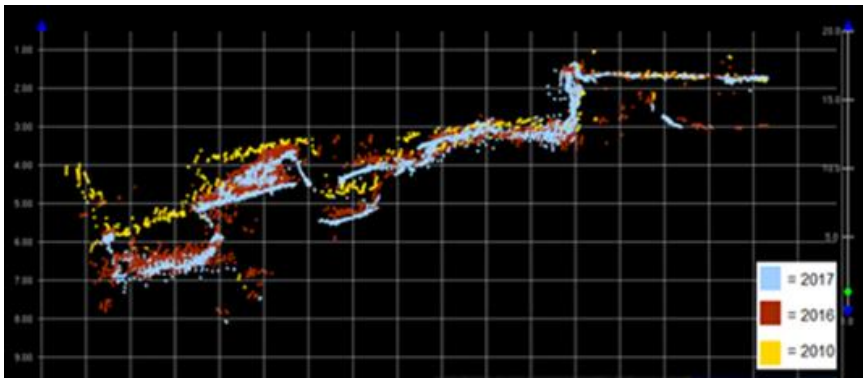


Fig. 20 Collapsed Boat Deck, showing cross-section through three datasets.

4.7.7 Collapse of Lower Hold Covers, Hold 2, Hold 3 and Hold 4 – ID31, ID32, ID33

The lower hold covers are not visible on the wreck due to the accumulations of sediment within the holds. However, these areas display year-on-year change due to the strong tidal currents moving and depositing sediments within the holds. In Hold 2, the sediment level has largely remained the stable with a depth increase of 20-30cm on the eastern side of the hold opening. In Hold 3, localised changes in the sediment surface in the

northwest corner have occurred. There is a depth increase of up to 40cm, but this may in part relate to noise in the previous survey rather than an actual change. In Hold 4, the deposition of sediment has changed since the last survey and this change is focussed at the southern end of the hold where the sediment depth has increased by up to 1.2m since 2016.

4.7.8 Hold 2 Hatch Cover Supports – ID39

All six hatch cover supports are present at Hold 2, the forward three remain stable and comparisons with the 2010 survey data show that they have not moved since at least the 2010 survey. The aft three supports have continued to subside along with the deck plating around them. The main subsidence here is towards the aft end of the hatch and specifically the aft hatch coaming. The aft cover support has subsided by approximately 30cm and the aft part of the hatch coaming has subsided by approximately 40cm. See Fig. 6 for an image of this area of the wreck.

4.7.9 20mm Gun Tub, Port Side, Central Superstructure – ID57

The SSRM was well armed, with bow and stern guns and a number of 20mm guns on circular platforms (gun tubs) along the length of the hull on both the port and starboard side. ID57 is a gun tub on the port side of the superstructure/bridge deck area. This feature has remained generally stable, but the easternmost leg has fallen from its 2016 position and can now be seen lying at a more acute angle across the deck area.

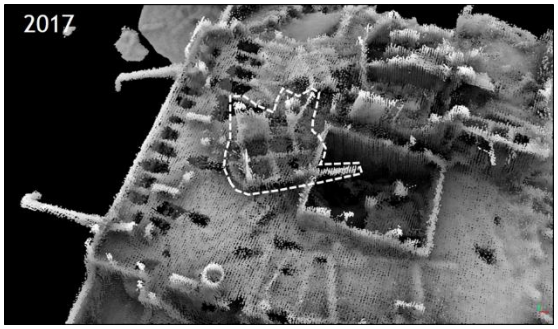


Fig. 21 Gun tub on port side of central superstructure - 2017

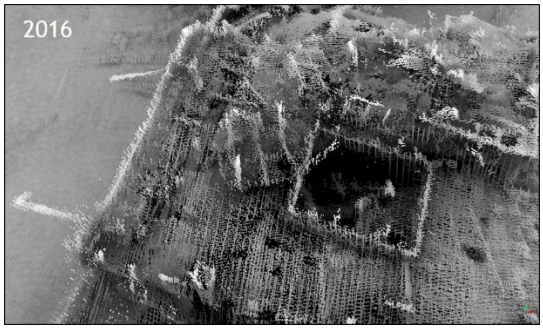


Fig. 22 Gun tub on port side of central superstructure - 2016

4.7.10 Fore Mast and Mast House, Forward Section, Aft of Hold 1 – ID60

Whilst the main structure of the fore mast and mast house has remained stable since the previous survey, it was noticed in the laser and photographic element of the survey that a small piece of triangular metal frame that protruded from the mast has fallen away since the 2016 survey.

Fig. 23 Fore mast, showing small section of missing frame

4.7.11 Forefoot (bow) – ID78

The level of seabed support at the foot of the bow is regularly assessed in the survey data. In the 2017 data there is an increase in dept of up to 0.2m since 2016, although this increased depth is very similar to the seabed depth in 2010 (noting that the historical dataset has a sparsity of date in this difficult to ensonify area of the wreck). The forefoot is still supported by the seabed and the maximum depth on the starboard side of the forefoot is 20.4m.

4.7.12 Lifeboat Davit, Starboard Side, Aft Section – ID79

The 2017 dataset shows that the lifeboat davit at ID79 on the starboard side of the aft section of the wreck has subsided by 0.1m since the 2016 survey. Measurements of the depth of the distal end of the davit show that, in the years between the 2010 and 2017 surveys, it has moved from a depth of 7.5m in 2010 to 10.4m.

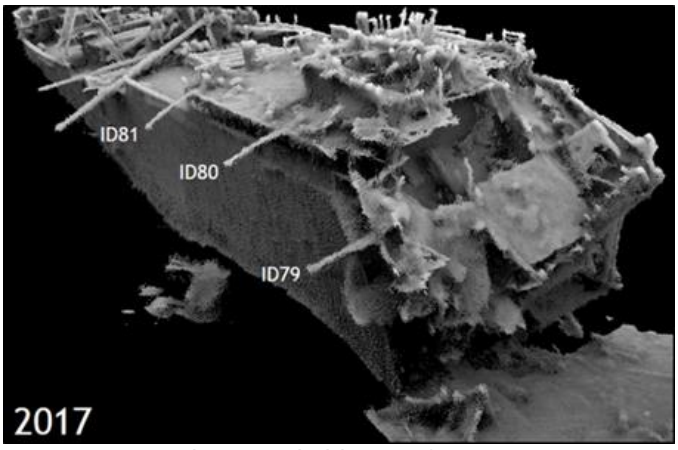


Fig. 24 Subsidence of ID79.

4.7.13 Debris on the Seabed Between the Two Sections of the Wreck – ID85

When it sank in 1944, the SSRM broke into two sections. This created a debris field between the two sections of the wreck, in particular, at the foot of the bulkhead at the aft end of Hold 3. The debris has generally remained stable since 2016. The main exception to this is at the foot of the stern section of the wreck on the starboard side below the overhanging Bridge/Boat deck area. Here it can be seen in the data that sections of debris have fallen to the seabed at this location creating a new pile of debris 3.0m higher than in 2016. Another exception is the eastern linear feature extending from the midships region of the forward section of the wreck which appears to have tilted down by up to 0.15m at the tip since 2016.

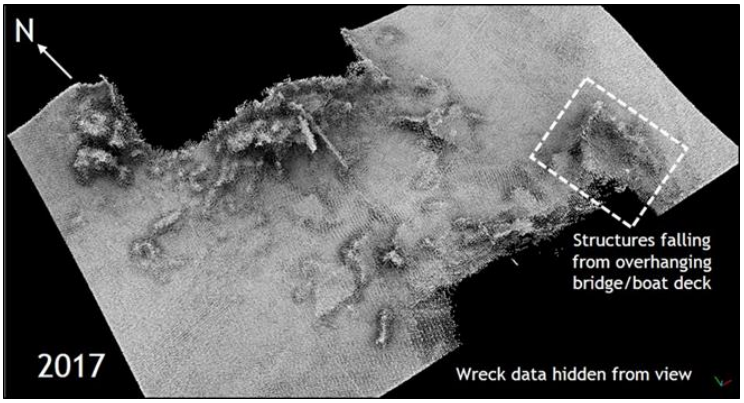


Fig. 25 Debris field from the 2017 survey data

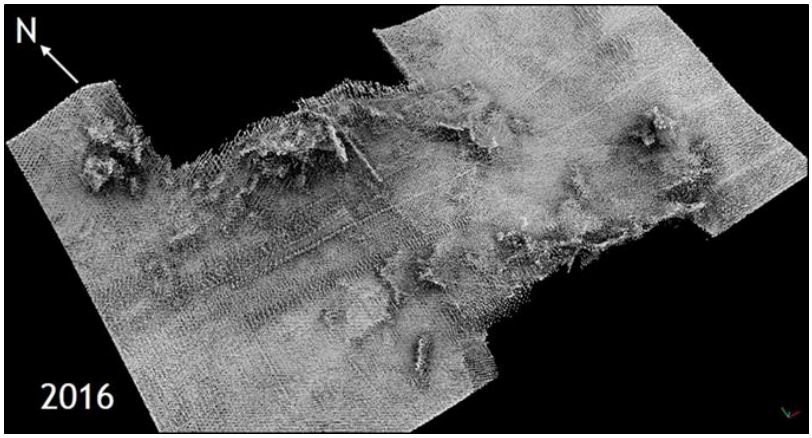


Fig. 26 Debris field from the 2016 survey data

4.7.14 Towing Cable – ID89

ID89 is a feature on the seabed within the survey area. In the 2017 data it has been identified as possibly a towing cable related to the salvage operation. It is a curving linear feature which shows in the 2017 data to have a definite angular structure, suggesting that it is not just part of the sedimentary structure but a piece of debris.

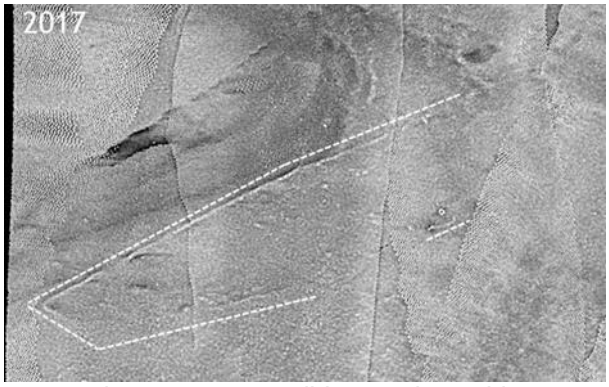


Fig. 27 ID89, possibly a towing cable

4.7.15 Starboard Lighting Tower, Aft of Central Superstructure – ID93

Analysis of the surface difference results from the 2017 survey data shows that there has been a structural change on the starboard side of the wreck at the aft end of the central superstructure. Close inspection of the 2016 and 2017 data shows that the structure identified as the starboard lighting tower has collapsed towards the south and now lies over the Hold 4 deck at the foot of the stairs to the boat deck level. Improvements in the density of soundings over the aft end of the central superstructure area reveals some of the fine detail of the complex structures strewn across the deck.

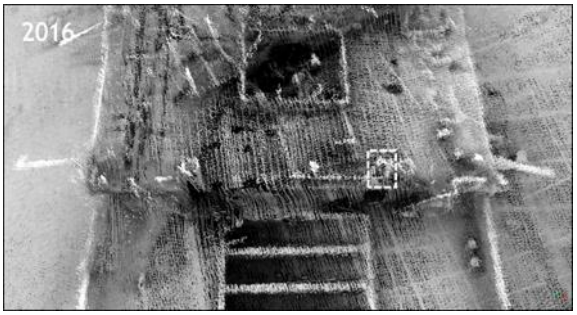


Fig. 28 Starboard lighting tower in 2016 data

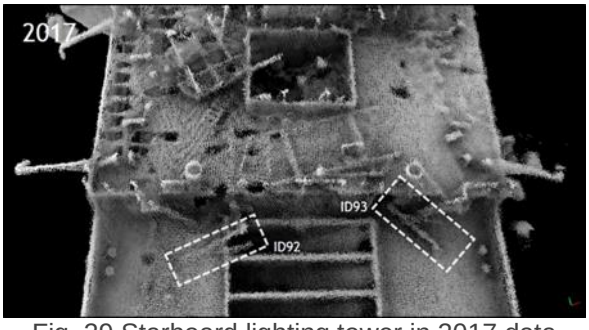


Fig. 29 Starboard lighting tower in 2017 data

4.8 Areas of the Wreck Showing No Change

4.8.1 Across much of the wreck, no changes were identified in the 2017 survey data when compared with data from 2010 and 2016. The following table lists all of those ID features for which no changes could be identified in the 2017 survey data.

FEATURE ID	FEATURE	LOCATION
ID01	Separation of hull in two sections	-
ID02	Forward section	-
ID03	Aft section	-
ID04	Major Hole and Split in Hull Plating (Crack in Hull)	Port Side, Hold 2
ID05	Severe Buckling of Hull Plating	Port Side, Hold 2
ID09	Severe Buckling of Hull Plating	Port Side, Fore Mast House
ID09	Buckling of Hull Plating	Port Side, Fore Mast House
ID11	Hole in Hull Plating	Port Side, Hold 2
ID12	Buckling of Hull Plating	Port Side, Hold 2
ID16	Horizontal Crease in Hull Plating	Starboard Side, Hold 2
ID17	Hole in Hull Plating	Starboard Side, Hold 2
ID18	Severe Vertical Discontinuity of Hull Plating	Starboard Side, Hold 2
ID19	Severe Horizontal Buckling of Hull	Starboard Side, Hold 2
ID20	Large Hole in Hull Plating	Starboard Side, Hold 2
ID21	Bend in Deck Plating	Starboard Side, Hold 2
ID22	Vertical Split in Hull Plating	Starboard Side, Aft Mast House
ID23	Split in Deck Plating	Starboard Side, Aft Mast House
ID25	Severe Split in Hull Plating	Starboard Side, Aft Mast House
ID26	Holes in Bulwarks	All over wreck
ID27	Holes in Boat Deck	Port Side, Aft Section
ID29	Boat Deck Missing Above Walkway	Starboard Side, Aft Section
ID30	Hole in Lower Hold Cover	Hold 2
ID34	Indications of Tween Deck Cargo	Port Side, Hold 1
ID35	Indications of Tween Deck Cargo	Port Side, Hold 2
ID36	Indications of Tween Deck Cargo	Port Side, Hold 2
ID37	Indications of Tween Deck Cargo	Aft End of Forward Section
ID38	Hold 1 Hatch Cover Support	Hold 1
ID40	Hold 3 Hatch Cover Supports	Hold 3
ID41	Hold 4 Hatch Cover Supports	Hold 4
ID42	Hold 5 Hatch Cover Supports	Hold 5
ID44	Smoke Stack	Central Superstructure
ID47	Engine Room Skylight	Central Superstructure
ID48	Engine Room Casing	Central Superstructure
ID49	Gunnery Officers Cabin	Central Superstructure
ID50	Forward Gun and Gun Tub	Bow
ID51	Stern Gun and Gun Tub	Stern Superstructure
ID52	20 mm Gun Tub	Starboard Side, Fore-Mast House
ID53	20 mm Gun Tub	Port Side, Fore-Mast House
ID54	20 mm Gun Tub	Starboard Side, Stern Superstructure
ID55	20 mm Gun Tub	Port Side, Stern Superstructure
ID56	20 mm Gun Tub	On seabed on Starboard Side of Central Superstructure
ID59	Port Anchor	Port Bow
ID61	Fore-Mast Cargo Handling Boom	Fore Mast
ID62	Fore-Mast Cargo Handling Boom	Fore Mast
ID63	Fore-Mast Cargo Handling Boom	Fore Mast
-	Fore-Mast Cargo Handling Boom	Fore Mast
ID64	Main Mast and Mast House	Midships, Forward Section
ID65	Main Mast Cargo Handling Boom	Midships, Forward Section
ID66	Main Mast Cargo Handling Boom	Midships, Forward Section
ID67	Mizzen Mast and Mast House	Midships, Aft Section
ID68	Mizzen Mast Cargo Handling Boom	Midships, Aft Section
ID69	Mizzen Mast Cargo Handling Boom	Midships, Aft Section
ID70	Mizzen Mast Cargo Handling Boom	Midships, Aft Section
ID71	Bilge Keel	Port Side, Fore and Aft of Gap between Sections

FEATURE ID	FEATURE	LOCATION
ID72	Large Life Raft Rack	Starboard Side, Forward Section
ID73	Large Life Raft Rack	Port Side, Forward Section
ID74	Large Life Raft Rack	Starboard Side, Aft Section
ID75	Large Life Raft Rack	Port Side, Aft Section
ID76	Anti-Torpedo Net Cage	Port Side, Aft Section
ID77	Propeller and Rudder	Stern
ID80	Lifeboat Davit	Starboard Side, Aft Section
ID81	Lifeboat Davit	Starboard Side, Aft Section
ID82	Lifeboat Davit	Port Side, Aft Section
ID83	Lifeboat Davit	Port Side, Aft Section
ID84	Lifeboat Davit	Missing
ID86	Vertical Boiler and Debris	Gap between Forward and Aft Sections
ID87	Heavy Wreck Debris (also ST17)	40m east of Hold 1
ID88	Charted Wreck (also ST18)	346479.83 E, 5704193.43 N
ID92	Portside Lighting Tower	Aft of Central Superstructure
ID94	Hold 3 Contents (through aperture ID96)	Port side, Aft End of Forward Section
ID95	Bow Section	Bow
ID96	Aperture in aft end of Forward Section	Port side, Aft End of Forward Section

Table 2. ID features exhibiting no change since the 2016 survey

4.9 Areas of no change – angle of list

4.9.1 The wreck remains in two distinct sections and cross-sections were taken through the data for both the forward and aft sections of the wreck. These cross-sections were compared to datasets from 2016 and 2010 in order to check for any changes in the angle of list. The results of this showed that the two sections of the wreck had not experienced any large-scale shift in position or change in the angle of list. This analysis did show some smaller-scale changes, for example, the mobile sediments around Hold 2 have accumulated since the 2016 survey and, on the aft section of the wreck, the overhanging bridge and boat decks can be seen tipping at increasing angles towards the seabed (see section 4.6 above for images).

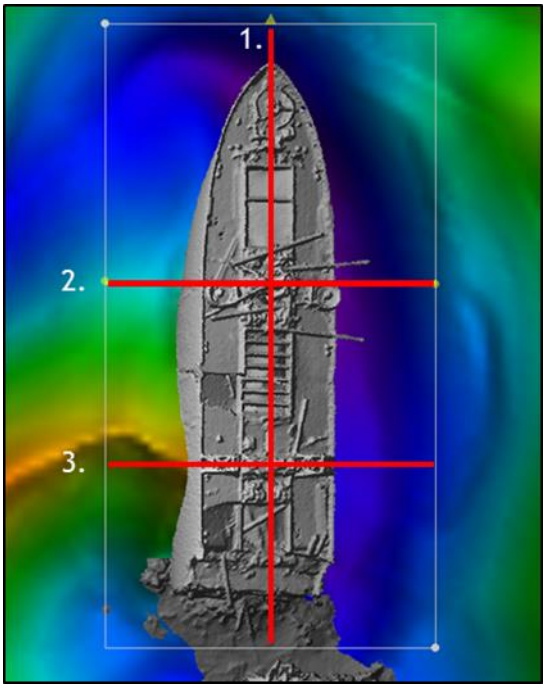


Fig. 30 Location of cross-sectional views on the forward section of the wreck

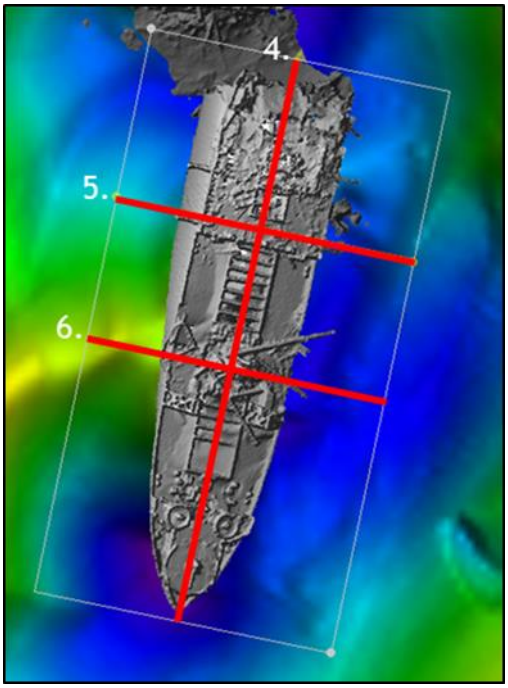


Fig. 31 Location of cross-sectional views on the aft section of the wreck

4.10 Areas of no change – buckling and creasing of hull plating

4.10.1 Across the wreck, evidence of disruptions, buckling and creasing in the hull plating have been noted in successive surveys for many years. There are a number of ID features which relate to this and in previous surveys it has been difficult to use to the survey data to accurately determine how, if at all, these areas or creasing or bulging have changed.

4.10.2 Data from the 2017 survey shows that these areas have generally remained stable. For example, the features described as severe disruptions of the vessel's structure on the starboard side of Hold 2 and a horizontal crease in the hull plating have been assessed alongside data from 2016 and 2010 and the results indicate that they have remained stable since 2010. Similarly, buckling along the port side of the hull on the forward section of the wreck has not shown any evidence of change since the previous survey. In other areas, such as the area around the turn of the bilge, the angle of list makes a full ensonification of the area difficult, so caution is required when interpreting the data in order to avoid identifying holes in the hull which are in fact acoustic shadows. Direct comparisons of areas that were well ensonified in both the 2017 and 2016 surveys indicate that these positions have not changed.

4.10.3 Coverage over the boat deck is improved in the 2017 dataset and this has led to better definition of the holes in the boat deck and the structures between them. This shows the port side boat deck plate is perforated with an abundance of holes. In parts, the collapsed deck plate is visible within the wreck. Switching between overlaid point clouds shows that the 2017 data defines pre-existing holes in the deck that are also visible in the 2010 survey, suggesting that there has been no change since 2010, but that the holes are much clearer to see in the higher definition of the 2017 dataset.

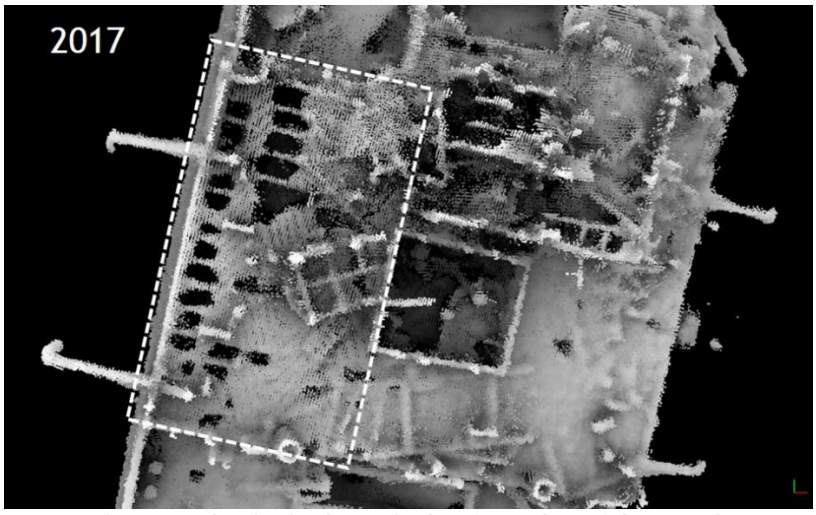


Fig. 32 Holes in the boat deck, aft section of the wreck

4.11 Indications of ‘Tween Deck Cargo

4.11.1 Although the focus of the multibeam survey is the structure of the hull rather than the cargo, at a number of points in the wreck it has been possible in previous surveys to visualise material inside the holds. In some cases this may represent cargo and in others it may represent sediment build-up. For the 2017 there was good coverage of the contents of Hold 2 as far as they are visible through the crack in the hull on the port side and the collapsing deck plating. Taking cross-sections through the data and comparing

them with previous datasets, similarities in the positions of the ensonified contents suggest that no movement has taken place since the previous survey. Some improvement in the density of the data was achieved and this translates as better definition of the features. Structures with rounded forms are present within the hold, possibly representing the munitions cargo.

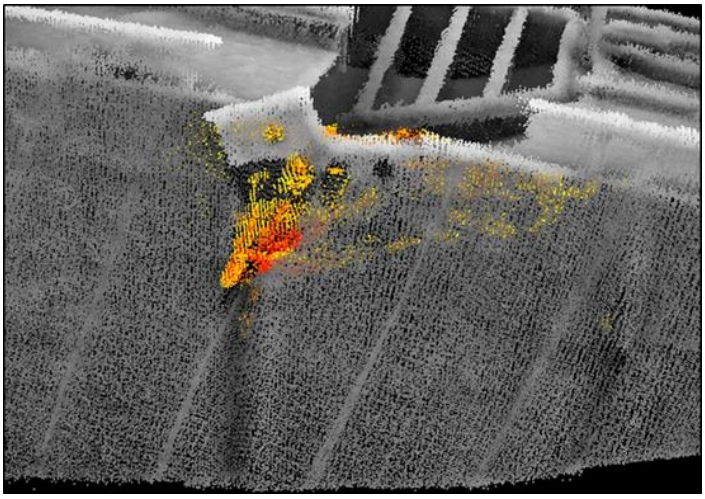


Fig. 33 Yellow/red data showing data points inside of the hull visualised thorugh the holes in the hull and collapsing deck plating.

4.11.2 The ‘tween deck cargo from Hold 3 is clearly visible scattered across the aft end of the forward section and at the base of the wreck within the debris in the gap between the two sections of the wreck. Comparisons of point cloud imagery and cross-sections in the data indicate that there has been no movement of this debris. The surface difference results also show that there is no significant change.

4.11.3 Cargo material is also visible through the hole in the bulkhead at the aft end of Hold 3. This can be seen in the image below. Cross-sections taken in Caris to observe the hold contents show that the comparison of the shoalest data is not possible with the 2016 dataset due to a lack of density at similar shoal depths. Although generally sparse, the 2010 dataset shows soundings at the same levels as the 2017 dataset and this suggests that there has been little or no change in the positions of the contents of this hold since at least 2010.

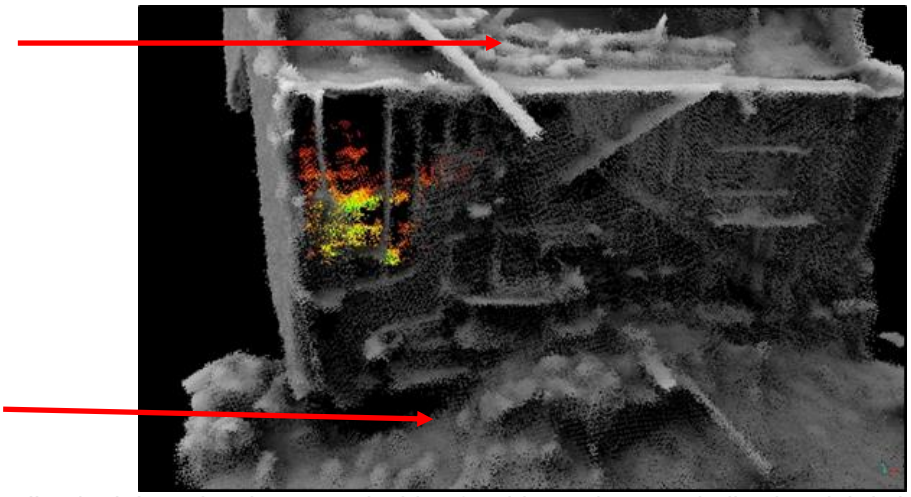


Fig. 34 Yellow/red data showing cargo inside of Hold 3 and arrows indicating debris in the remains of the ‘tween deck and debris pile.

4.12 Laser Survey Results

4.12.1 Laser scanning is used to survey the features of the wreck which are visible above the waterline such as the masts and remain booms and sections of lifeboat davits. The laser element of the 2017 survey was performed using an Applanix LANDMark Marine Laser System. Laser data was acquired just after the low tide with coverage comparing well with previous surveys. The resulting high-density point cloud was combined with that generated from the MBES data to produce the complete model for the 2017 report. Comparison with the historical laser datasets showed that the 2017 data was well aligned and of similarly high quality. Photographs of the masts and other features exposed at the low tide were taken to supplement the laser point cloud.

4.12.2 The multibeam data, laser data and photographs all demonstrate that, aside from the loss of a small section of frame (see above), the forward, main and mizzen masts have all remained stable since the last survey.

Fig. 35 Photograph of features visible above the waterline.

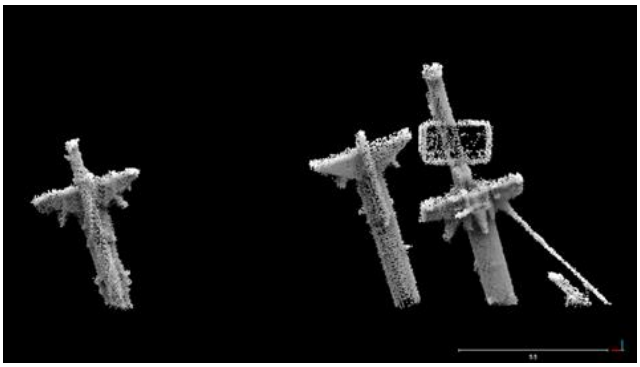


Fig. 36 Laser scanning data of features visible above the waterline.

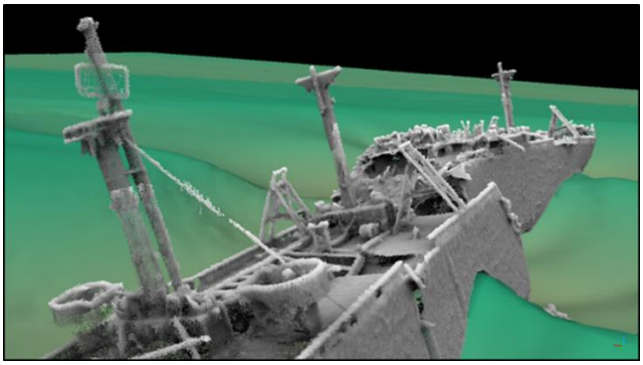


Fig. 37 Combined MBES and laser data looking from the bow towards the stern

5. Survey Results – The Seabed

5.1 The SSRM survey area extends beyond the wreck itself to cover the surrounding seabed out to a minimum 400m from the wreck and the edge of the dredged channel to the south of the wreck. Figure 38 below shows the results of this seabed survey. The data collected is used identify where changes to the seabed topography around the wreck have occurred. This is achieved by performing surface difference analysis against historical datasets and by comparing contours created from these surfaces.

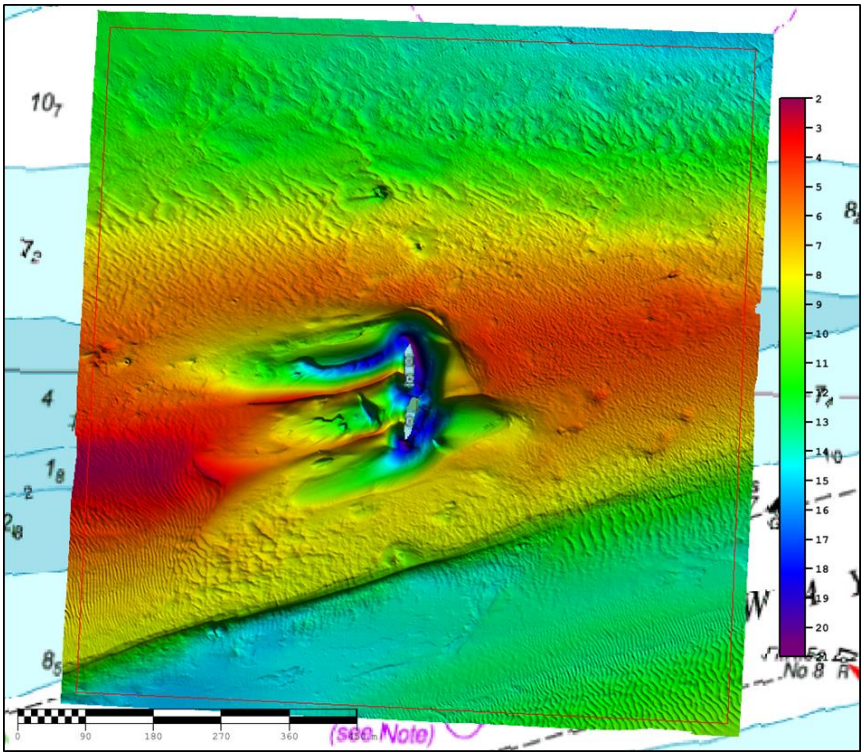


Fig. 38 The full survey area

5.2 In addition to providing information about sediment migration, the seabed survey is used to locate and identify features within the seabed area around the wreck. The survey aims to relocate objects previously identifed on the seabed and report on any changes to these, and also to identify any new objects which might have appeared since the last survey.

5.3 For the 2017 survey, the seabed survey work took place in two phases due to issues with weather and availability of vessels and personnel. This means that there are some minor misalignments within the two datasets due to sediment re-working in the period between the two phases. However, overall, the seabed survey has provided thorough coverage.

5.4 The seabed survey demonstrated that water depths around the wreck site varied from 2.04m to 20.60m with the shoalest point of the seabed located on Sheerness Middle Sand to the western side of the wreck and the maximum depth located in the scour near the foot of the bow.

5.5 Seabed Comparison

5.5.1 In order to compare differences in the seabed across the surveys, the seabed survey area has been divided into three sections. Area A is the dredged channel to south of the wreck, Area B is the scour patterns around the wreck and Area C is the seabed adjacent to the wreck. Surface difference analysis was used to compare the depths across the 2017 and 2016 datasets. This applies a colour scale to highlight any changes. The surface difference results show that the seabed has generally remained stable during the period since the 2016 survey. The differences are typically small with the data indicating an overall slight errosional trend across much of the area. This corresponds to depth changes of between 20cm-60cm. In some isolated areas, larger changes were seen, for example the scour around the buoy sinkers and around the smaller wrecks within the survey area. The features show both errosion and deposition in close proximity which is indicative of a shift in the walls of the scours rather than a significant overall deepening or infilling.

5.6 Area A – Dredged Channel

5.6.1 Surface difference analysis was used to identify any changes in the area of the Medway Approach Channel. Within the channel, there has been a widespread erosional trend with depth changes typically between -0.2m and -0.6m. The greatest difference is in the far southeast corner with a change of -0.8m. Towards the western end of the survey area a maximum depth change of -1.6m was seen in the survey data. This depth change relates to a scour that has developed on the northern side of a smooth protrusion of the seabed. The scour does not appear to have formed around a piece of debris.

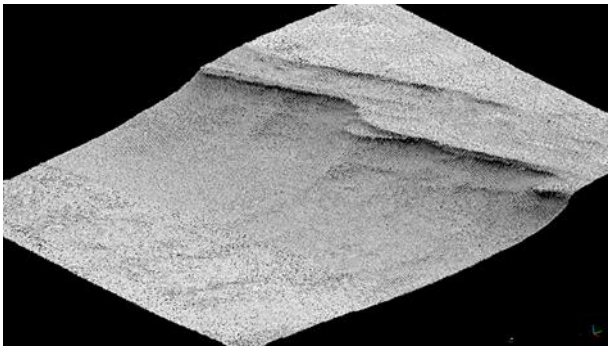


Fig. 39 Seabed results 2016

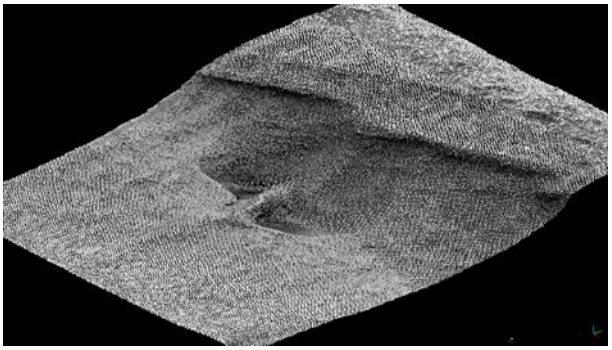


Fig. 40 The same area of seabed in 2017

5.7 Area B – Scour Patterns

5.7.1 Over its years on the seabed, the wreck has caused the formation of a deep scoured areas in particular to the west of the wreck. Surface difference results indicate that the scours have remained stable since the 2016 survey. Some reworking of the steep walls has occurred and the shifts in their positions generates large vertical differences in the colour map but these may relate to small horizontal changes of steep slopes.

5.7.2 The southwestern scour shows the least change between the datasets. Small increases in depth, up to 0.3m, across the region nearest the wreck and some infilling of the small scoured pocket on the northern flank (-0.2m to +0.2m) have occurred. The smaller southeastern scour shows some pronounced changes. These relate to the marked increase in depth of a smaller scour feature on its southern slope. The maximum

depth increase here is -1.9m. Adjacent to this is a change of +1.1m, which suggests that the scour is shifting position rather than increasing in depth overall.

5.7.3 The long, northwestern scour has increased in depth along its southern slope by between -0.2m and -0.6m. This relates to a slight southward shift in the position of the apex of the ridge separating the northern and central scours on the western side of the wreck. This shift is small; between 1.0m and 2.0m. The deep channel at the base of this scour shows some larger changes in depth caused by repositioning of the steep northern wall and a small expansion of the "bowl" at the western end of this channel.

5.7.4 The central scour on the western side of the wreck shows the largest differences from the 2016 survey. At the eastern end of this scour is a depression with a pronounced groove on its eastern edge. The development of this groove feature is shown as a region of deposition (maximum +1.0m) and region of erosion (maximum -3.1m). On the western edge of this depression are two bowls and both of these show evidence of expansion.

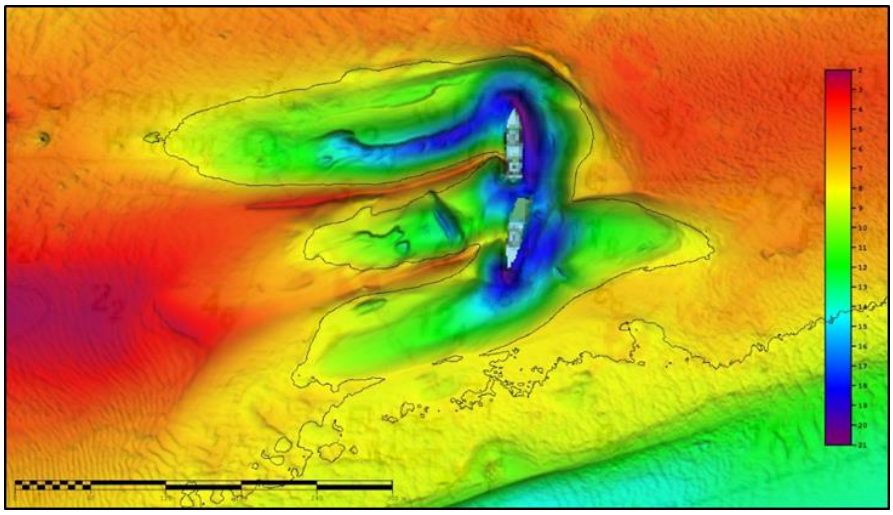


Fig. 41 Overview of the scoured area around the wreck, the black line is the 8m contour which is used here to highlight the form of the scours

5.8 Area C – Wreck Site

5.8.1 Comparisons of the surfaces in the immediate vicinity of the wreck showed some differences between the 2016 and 2017 survey. On the eastern side of the wreck the slopes show a general trend of deposition. This is typically between 0.3m and 0.8m. Towards the north east of the wreck there are two bands where deposition has occurred. The outer band has a maximum increase in sediment height of 1.39m and nearer the wreck this is 1.19m. On the western side of the wreck the changes observed are more complex with areas of deposition and erosion in close proximity. The areas of change will be discussed from north to south beginning at the bow.

5.8.2 Beneath the bow there has been some localised erosion with a maximum change of -1.72m. The southern slope of the northern scour shows a general erosional trend with changes typically around -0.5m and a maximum change in height of -0.94m. Adjacent to the aft end of the forward section the seabed on the northern slope of the central scour shows evidence of deposition. The maximum amount of deposition in this area is 1.58m. On the western side of the aft section of the wreck there are regions of both erosion and deposition. Alongside the boat deck and Hold 4 there is an area of erosion with a change of -1.06m. Within this region the surface difference results show very large changes (as

much as -6.96m), however these are related to differences in coverage and presentation of survey results in the 2016 and 2017 datasets. In the 2016 survey some of the data from the hull of the wreck has been included in the seabed survey whereas this is excluded from the 2017 dataset.

5.8.3 Alongside Hold 5 there is a region of apparent deposition with evidence of large changes up, to 2.98m. For the 2016 survey, data was gathered in two phases. Viewing cross-sections through the data in this area shows that the second there is much better alignment between the 2017 survey and the second of the two 2016 phases of survey. The results of the Cefas environmental study may shed more light on the sediment regime around the wreck and bring more clarity to the observations seen in the wreck monitoring surveys.

5.9 Contour Assessment

5.9.1 Contours were generated from the 2017 dataset and compared with those from 2016 and 2010 in Fledermaus. The 2010 set of contours is used as a baseline dataset against which longer term trends could be identified. Seabed contours for the 2010, 2016 and 2017 surveys were generated at 5m intervals. The contours between the 2016 and 2017 surveys show a close alignment across the survey area with only minor differences compared to the 2010 baseline dataset. This suggests that the scour bedforms are in equilibrium with the tidal regime in the Thames Estuary.

5.9.2 Seabed contours from the 2017 and 2016 surveys generated at 2m intervals in the area of the scours around the wreck demonstrate a close alignment between the contours from the two datasets. This is especially true on the eastern side of the wreck. To the west the differences in the positions of the contours are most varied around the pear-shaped scour within the central scour. However, as the surface difference results indicate, the survey site has remained generally stable since the last survey. Along the slope of the Medway Approach Channel the 10m and 12m contours from 2017 and 2016 are very closely aligned which indicates little change between the two surveys.

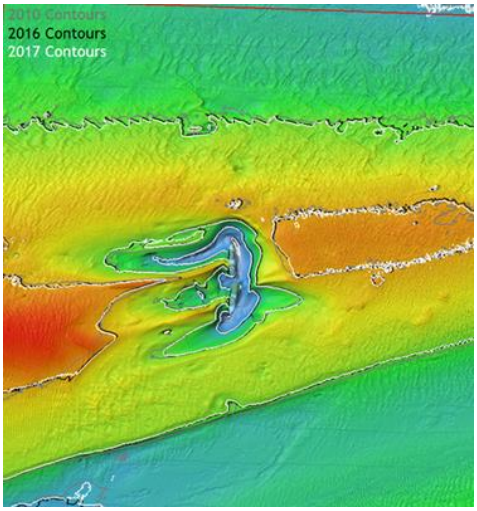


Fig. 42 Comparisons of seabed contours between the 2017, 2016 and 2010 surveys. Contours generated at 5m intervals. White = 2017, black = 2016 and grey = 2010.

5.10 Seabed Targets

5.10.1 Aside from the SS Richard Montgomery, there are various other objects on the seabed within the survey area, including another wreck thought to be a Thames barge. Each seabed object is relocated and assessed in each survey and any newly

located objects are reported on. In 2016 this list contained 66 objects and the number has increased to 72 in the 2017 report. This increase is due to close scrutiny of the backscatter data combined with the bathymetry. Below is an image showing the location of these targets within the survey area. It can be seen that the majority are not directly adjacent to the wreck and the approximately diamond shape that they make around the wreck is due to many of the targets being part of current or previous sinkers and chains for the buoys around the wreck. The one object that is on the seabed close to the wreck may represent one of the two current meters that were lost in 2013.

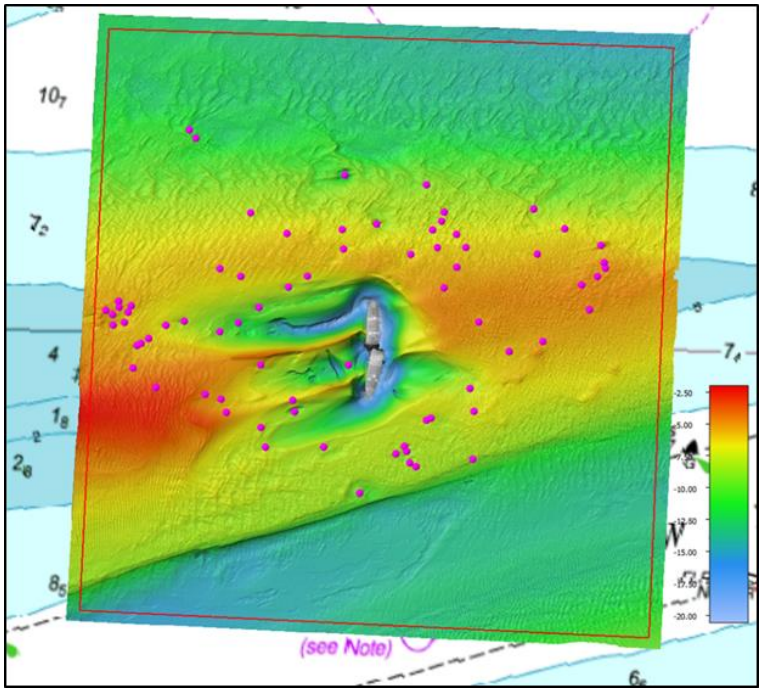


Fig. 43 Seabed targets

5.11 Cefas Equipment Site

5.11.1 DfT have commissioned Cefas to carry out some environmental monitoring around the wreck. This monitoring would require the placement of scientific equipment on the seabed just outside of the prohibited area. Ahead of the placement of this equipment, the survey contractor was asked to pay particular attention to the proposed seabed location for the equipment. The measured depth at this location at the time of the survey is 6.08m below Chart Datum. The seabed is gently sloping towards the south and the proposed location is a transition region between a bank with gentle ripples and the smooth flanks of the northern scour. The angle of slope was computed across the surface. This showed that at the proposed deployment position the angle of slope is 3°. A slope angle of 15° is located 25m to the southeast of the selected position and this increases to near 20° 40m along the same bearing.

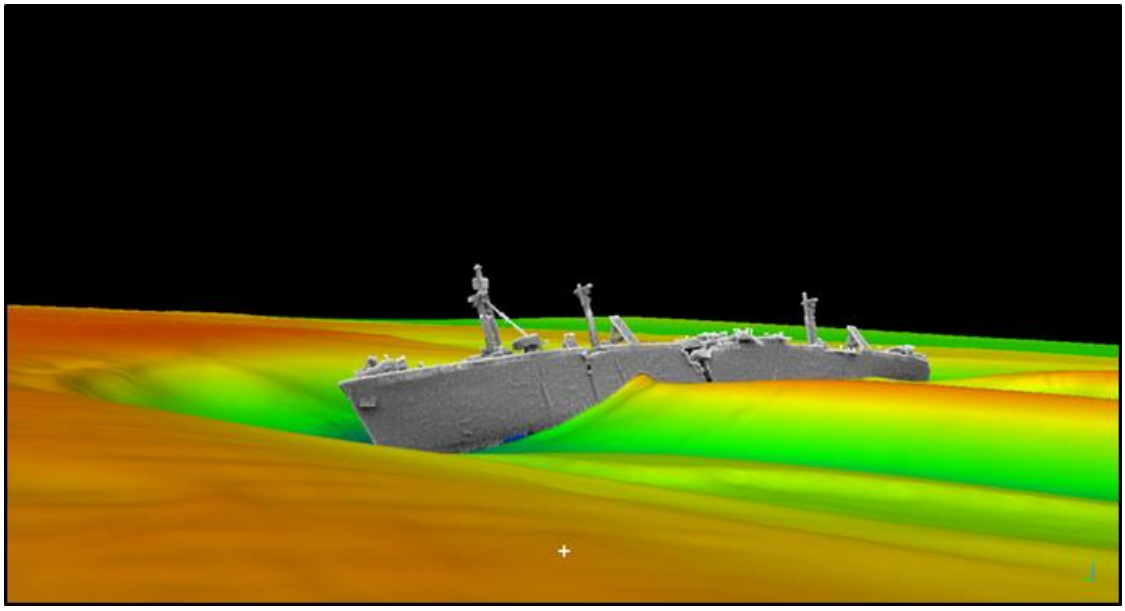


Fig. 44 View of the wreck from the proposed position for the Cefas equipment

6. Ultra-High Resolution Bathymetry Trial

6.1 During the 2017 survey of the SSRM an attempt was made to acquire data using a newly available ultra-high resolution mode which is enabled on the R2 Sonic 2024 MBES system fitted to the survey boat. Previous SSRM datasets have been acquired using a MBES system that has a maximum operating frequency of 400 kHz and this has yielded excellent results over the wreck and seabed. The R2 Sonic 2024 is capable of operating at 700 kHz and at this frequency the beam angles are reduced to 0.3° x 0.6° from 0.45° x 0.9° at 400 kHz. This results in a smaller beam footprint on the target. In a survey like the SSRM this could potentially improve the ability of the sonar to define small-scale structures on the wreck and allow more accurate measurements of features such as the crack in the hull.

6.2 Using the ultra-high resolution mode, survey lines were run in close proximity to the port and starboard sides of the wreck using a tilted sonar head to improve coverage of the wreck's upper structures. Unfortunately, during the trial it became clear that other onboard vessel systems were generating interference that severely impacted on the usefulness of this data. All vessel systems that could safely be disabled were, but unfortunately the interference could not be eliminated.

6.3 A qualitative evaluation of the ultra-high resolution dataset suggests that edges of features are well defined and it would be possible to create a point cloud model of sufficient quality to perform a comparative analysis of the wreck. The data from the R2 Sonic has a very close beam spacing and, in the benign conditions experienced during the survey, generated data with very high density ideal for capturing the features of the wreck.

6.4 Although this initial trial wasn't completely successful, the collection of ultra-high resolution data has the potential to improve the clarity of the point cloud model. If it is trialled again in the future, it is recommended that it is from a different vessel, possibly a smaller one that is capable of surveying directly over the wreck and that this ultra-high resolution surveying takes place on a different day to the normal wreck survey as the period of slack water is too short to have two survey vessels trying to survey the wreck at the same time.

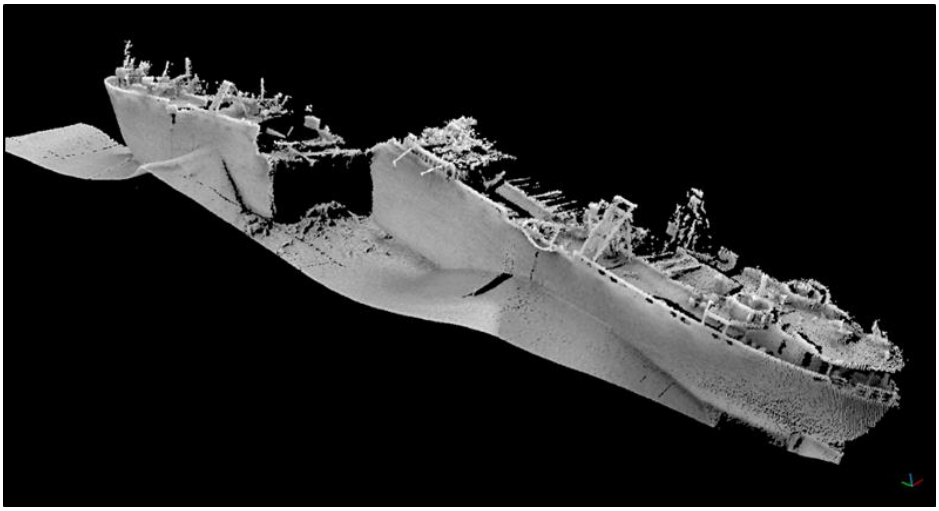


Fig. 45 Point Cloud showing the coverage using the 700kHz mode

7. Conclusions

7.1 The 2017 survey of the SS Richard Montgomery took place in two phases with the surrounding seabed and laser surveys being undertaken on the 7th and 8th November 2017 and the wreck MBES survey taking place sometime later, on the 19th April 2018. Bathymetry data was acquired using vessels owned and operated by the PLA and equipped with a Reson 7125 MBES on the MV Galloper (used for surveying the wreck and seabed immediately adjacent to it) and an R2 Sonic 2024 MBES on the MV Maplin (used for surveying the surrounding seabed and ultra-high resolution trials on the wreck). Laser data was acquired using a stand-alone Applanix LANDMark Marine system mounted on the wheelhouse roof of the MV Maplin. The data from these three sources was combined to make a high-density point cloud model of the exposed and submerged parts of the wreck for visualisation and comparison with historical datasets from 2010 and 2016.

7.2 The results of this survey work have yielded a high-density point cloud model of the wreck, including a good level of definition of some previously poorly ensonified regions of the wreck, providing a good basis for comparative analysis. This analysis, based on 3D visualisations of the point cloud, cross-sections through multiple historic datasets and surface difference analysis, has shown the progress of degradation of the wreck.

7.3 From investigations of the six Key Areas, it was found that structural changes had occurred in three. At Key Area 2 the collapsing deck plate had changed the manner of its movement. In previous reports the displacement had been greatest along the forward edge of the collapsing plate. In this survey this forward edge appears to now be supported by the contents of Hold 2 and the maximum displacement is now at the aft end, with up to 0.6m of subsidence recorded. At Key Area 5, the deck has shown further subsidence since 2016 with up to 0.2m of displacement observed although the associated split in the hull plating shows no evidence of increasing in size. The collapsing bridge deck area at Key Area 6 shows the greatest degree of change with the magnitude of collapse being greatest on the starboard side where a section of debris that was previously overhanging has now become detached and lies on the seabed below. The level of subsidence on the port side of the bridge deck area was much smaller in magnitude, with changes in the region of 20-30cm.

7.4 The remaining Key Areas showed no evidence of degradation from the previous surveys.

7.5 Fourteen other ID features were identified as having undergone some degree of structural deterioration since the 2016 survey. Of these, four are worthy of note either because of their level of change or because they are associated with a neighbouring Key Area. These are:

- The collapsing boat deck on the port side of the Key Area 6 region of the wreck which has subsided by up to 0.2m.
- The Hold 2 hatch cover supports which show up to 0.3m of subsidence and are associated with the collapsing deck plate of Key Area 2. The hatch coaming closest to the collapsing deck plate shows displacement up to 0.4m.

- The forward-most lifeboat davit on the starboard side of the stern section of the wreck, has subsided by 0.10m compared to 2016. This movement is associated with the collapse of Key Area 6.
- The debris on the seabed between the forward and aft sections of the wreck was added to after a section of the overhanging bridge/boat deck (Key Area 6) detached from the wreck and is now lying on the seabed below.

7.5 The remaining changes (which are outlined in section 4.7 above) correspond to structural differences in smaller features that are indicative of an ongoing picture of slow but continued deterioration but in themselves are likely to bear little consequence to the overall structural integrity of the wreck, such as a new hole in the deck plating near to Hold 1 and changes in the sediment surfaces of Holds 2, 3 and 4 which are regularly seen in the survey results.

7.6 Interpretation of the ID features that display no identifiable changes indicates that, in general, the forward and aft sections of the wreck have remained largely stable since the 2016 survey and some areas have not displayed any change since the 2010 survey. No fundamental changes to the angle of list of either section of the wreck or changes in positions of the masts were observed. Additionally, no changes were identified in the crack in the hull on the port side of Hold 2 (ID04) or any of the large bulges, creases and discontinuities present in the hull on the port and starboard sides of the forward section of the wreck. Surface difference analysis of the data also indicates this overall stability, with structural changes being restricted to discrete regions of the wreck.

7.7 As part of the 2017 survey a trial of the ultra-high resolution mode of the R2 Sonic 2024 MBES system took place. This yielded some positive results, although, the quality of the point cloud generated from the 400 kHz Reson 7125 MBES is very high, so the observed differences are marginal. The assessment of the ultra-high resolution data indicates that the coverage and density of soundings were very good and the 40° mechanical tilt of the MBES system resulted in the wreck's upper structures being well ensonified. Although, some interference from one of the survey vessel's operating systems reduced the usefulness of this additional data. Should this ultra-high resolution mode be tried again in the future, it would be beneficial to run the two stages of the wreck survey on consecutive days to prevent competition for slack water time impinging the quality of the main over-the-wreck survey (assuming the use of the same two survey vessels), or utilising a survey vessel with the ultra-high resolution mode and small enough to conduct the over-wreck survey. For optimum results, it would be advisable to run a number of survey lines down the port and starboard sides of the wreck (and over the wreck if using a suitable survey vessel) and acquiring data using the full range of settings available on the MBES. The most suitable data can then be incorporated into the final point cloud.

7.8 It would also be possible to conduct an additional ultra-high resolution wreck survey during the laser survey operations at the low tide slack water period, with the potential benefit of positioning the MBES unit lower in the water and gaining a different perspective on the hull features (alongside the wreck only, not over the top of the wreck at low water).

7.9 The area identified for the placement of environmental monitoring equipment was fully surveyed (it is within the normal survey area). This equipment is expected to be placed on the seabed for at least a 12-month period. Results are not expected until the end of 2019.