Maritime & Coastguard Agency

SS Richard Montgomery: Survey Report 2018

Contents

Abbreviations

CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture
DfT	Department for Transport
EAG	Expert Advisory Group
GPS	Global Positioning System
IHO	International Hydrographic Organization
MBES	Multibeam Echo Sounder
MCA	Maritime and Coastguard Agency
MOD	Ministry of Defence
NEQ	Net Explosive Quantity
PPK	Post-Processed Kinematic
SSRM	SS Richard Montgomery
VORF	Vertical Offshore Reference Frame
VTS	Vessel Traffic Monitoring Service

1 Executive Summary

1.1 Background

1.1.1 The SS Richard Montgomery (SSRM) 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.

1.1.2 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. Around 1,400 tons of explosives remain on board the wreck which is designated under section 2 of the Protection of Wrecks Act 1973.

1.1.3 Surveys of the wreck are undertaken to provide information on its condition, to identify any changes or deterioration and to inform future management of the wreck. This report details the results of the 2018 survey.

1.2 Survey Overview

1.2.1 The survey was commissioned in 2018 but was unfortunately delayed by weather and took place on 20 and 21 January 2019.

1.2.2 The 2018 survey was covered the area identified by the black dotted box in Figure 1.

1.2.3 Comparison with the results of the 2017 survey show that the wreck and the surrounding seabed remained relatively stable between the 2017 and 2019 surveys.

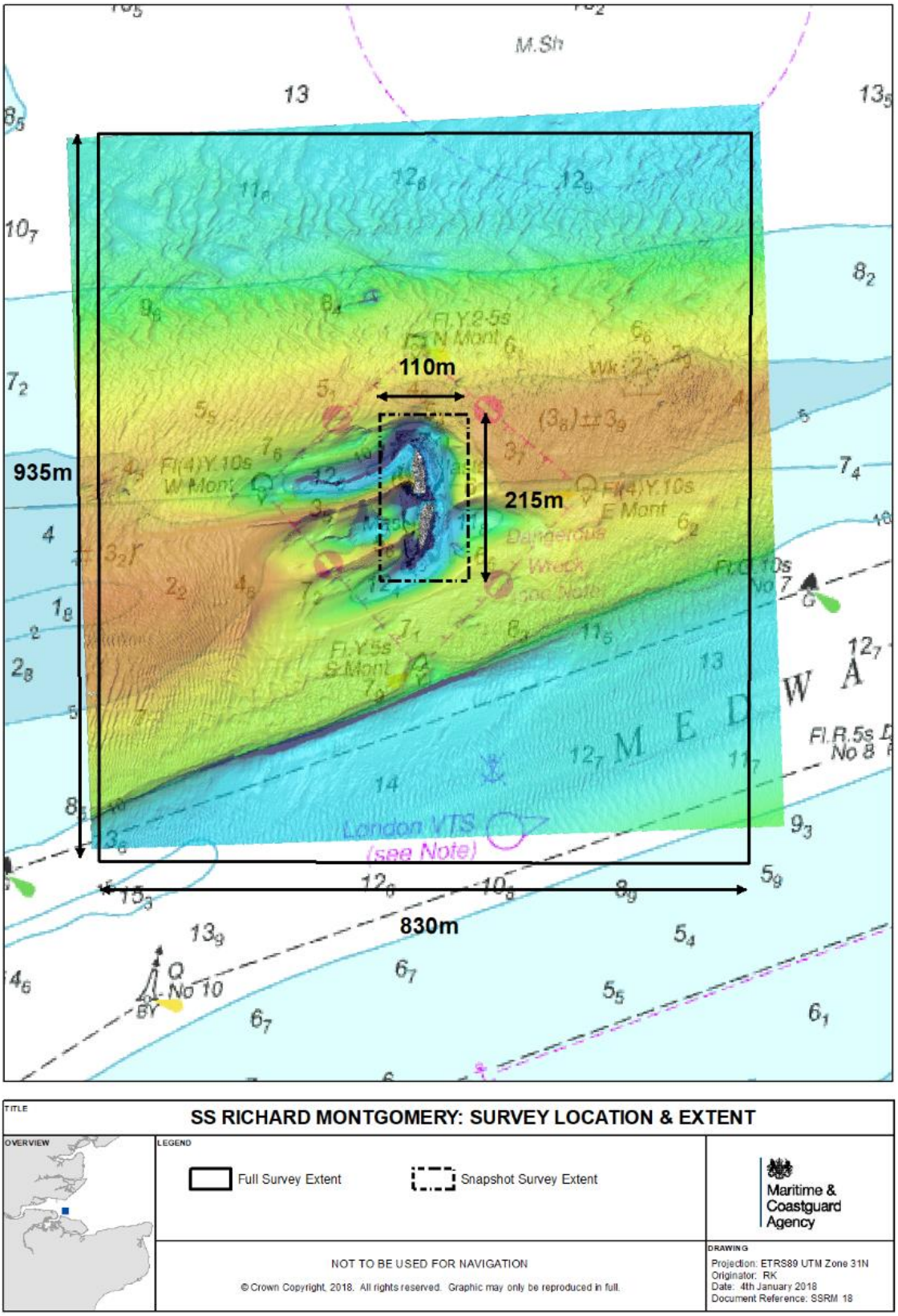

Figure 1 2018 survey location and extent.

1.3 Key Results

1.3.1 As in previous years, the 2018 survey covered the entire wreck and surrounding seabed in detail.

1.3.2 The six Key Areas where more accelerated levels of deterioration have been noted in previous years again received scrutiny. Of these, two showed structural changes since the 2017 survey both of which are in the aft section of the wreck.

1.3.3 In Key Area 5 the deck plate appears to be buckling upwards up to 0.2m on the forward side of the crack on the deck. Key Area 6 is the collapsing bridge deck of the aft section where it has split from the fore section of the wreck. This area shows changes of less than 0.5m to the protruding deck plates.

1.3.4 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, 5 showed some level of change between the 2016 survey and the 2017 survey (all 5 were part of Key Area 5 or 6 as noted above).

1.3.5 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.

1.3.6 In the wider survey area, 72 seabed objects have been noted in previous surveys. Scrutiny of the backscatter data combined with the bathymetry has not identified any further seabed objects in the 2018 survey data.

1.3.7 Surface difference results showed that the seabed area around the wreck has generally remained stable during the period between the 2017 and 2018 surveys. Deposition has occurred on the starboard side of the of the aft section the wreck, with an increase in sediment of up 0.5m.

2 Introduction

2.1 Background

2.1.1 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.

2.1.2 On arrival in the Thames Estuary on 20 August 1944, orders were received to anchor off Great Nore. Unfortunately, the water was too shallow for the heavily laden vessel and, as the tide fell, the SSRM dragged its anchor and ran 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 (curved-up in the centre and sagging at the ends) and an explosive-like sound was heard. This sound was the steel hull plates splitting forward of the bridge.

2.1.3 On 23 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 8 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 1,400 tons of munitions net explosive quantity (NEQ) remaining within the forward section of the vessel in Holds 1, 2 and 3.

2.1.4 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 (see Figure 2 below, taken from North approach).

Figure 2 Photograph of the SSRM's three masts above the water – left to right: fore mast, main mast and mizzen mast.

2.2 Management

2.2.1 The SSRM 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 for Transport. The wreck is marked on Admiralty Charts, the prohibited area being delineated by four lit cardinal buoys and twelve red danger buoys. The wreck is also under 24hr surveillance by Medway Vessel Traffic Monitoring Service (VTS).

2.2.2 Although the wreck is thought to be stable if left undisturbed, it is routinely monitored. Regular surveys of the wreck are undertaken to provide information on its condition, to identify any changes or deterioration and to inform future management strategy. The survey results are shared with the independent Expert Advisory Group (EAG) formed in 2017 to advise the DfT on managing the SSRM.

2.2.3 A variety of methods have been used to monitor the wreck. Since 2002, multibeam sonar technology has been the favoured method of survey. Although occasional diving operations are carried out on the wreck (most recently in 2013), 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.

2.3 This Report

2.3.1 This report is a summary of the 2018 SSRM survey findings including a comparison with the 2017 survey dataset. The year-on-year comparisons of survey data are used to help identify and quantify any deterioration of the wreck and it provides a longer view of the condition and rate of deterioration of the wreck structure.

2.3.2 The data analysis covers the entirety of the wreck and 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.

2.3.3 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, including debris that may have originated from the wreck and debris from other sources.

2.3.4 A small additional survey was undertaken to confirm the location of oceanographic monitoring equipment placed on the seabed near the wreck by the Centre for Environment, Fisheries and Aquaculture (Cefas). The results of this survey are also presented in this report.

3 The Survey

3.1 Survey Requirements

3.1.1 The Scope of Work included the following objectives:

a) A Multibeam Echosounder (MBES) survey of the entire wreck.

b) A MBES survey of the seafloor in the immediate vicinity of the wreck.

c) Laser scan survey of the masts and other structures which are visible above the waterline.

d) Process the data and directly compare it to previous survey data (2017) to identify and highlight any areas of structural change or deterioration.

e) Produce a detailed survey report which includes details of any changes noted and comparisons with results from the previous survey.

3.2 Survey Area

The survey area is shown by the dotted black line in Figure 1.

3.3 Survey Operations

3.3.1 The MBES survey of the SSRM wreck took place on 20 January 2019. The laser scanning of the masts and additional multibeam data acquisition was conducted on 21 January 2019.

3.3.2 The multibeam survey and the laser scanning operations were conducted using the EGS Watchful which is a permanently mobilised shallow draft inshore survey vessel operating under the Maritime and Coastguard Agency (MCA) Workboat Code Category 2.

3.4 MBES

3.4.1 The MBES data was collected at high tide using a Kongsberg 2040C Dual Head (dual head, dual swath) MBES, and acquired and processed in Kongsberg SIS (v4.3.2) and QPS QINSy Software (v18.8.1). Multiple passes were run across the wreck, in all practicable directions to ensure complete coverage. 3 and 4 show an overview of the 2018 MBES wreck data.

Figure 3 Overview of Port side of SSRM

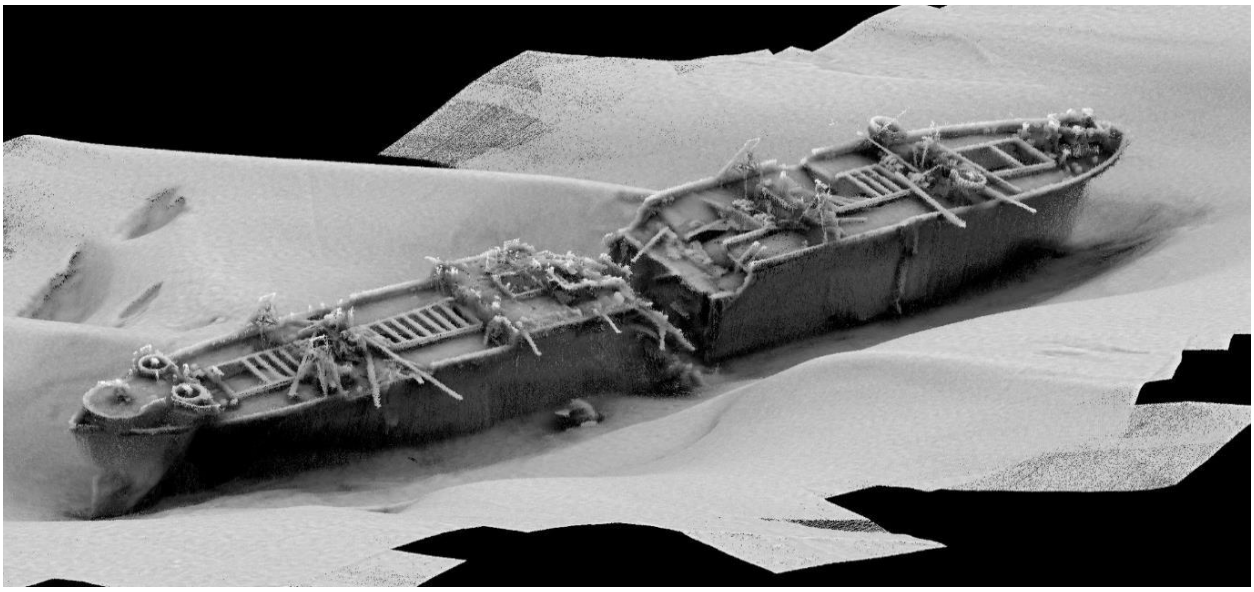

Figure 4 Overview of Starboard side of SSRM.

3.4.2 The MBES data was processed, and position corrected using a post processed kinematic GPS data solution which allowed for a highly accurate and precise dataset.

3.4.3 The data was reduced to chart datum using the same Vertical Offshore Reference Frame (VORF) value of 41.845m as in the previous surveys to allow for a direct comparison. The data was cleaned to remove any outliers and noise within the dataset, and a full density georeferenced point cloud XYZ was exported.

3.4.4 The surrounding seabed data was processed with CUBE methodologies and surface grids were produced all of which adhere to IHO Special Order. These surfaces were used to produce contours, surface difference plots and shaded bathymetric imagery. Figure 4 shows the 2018 MBES of the surrounding seabed.

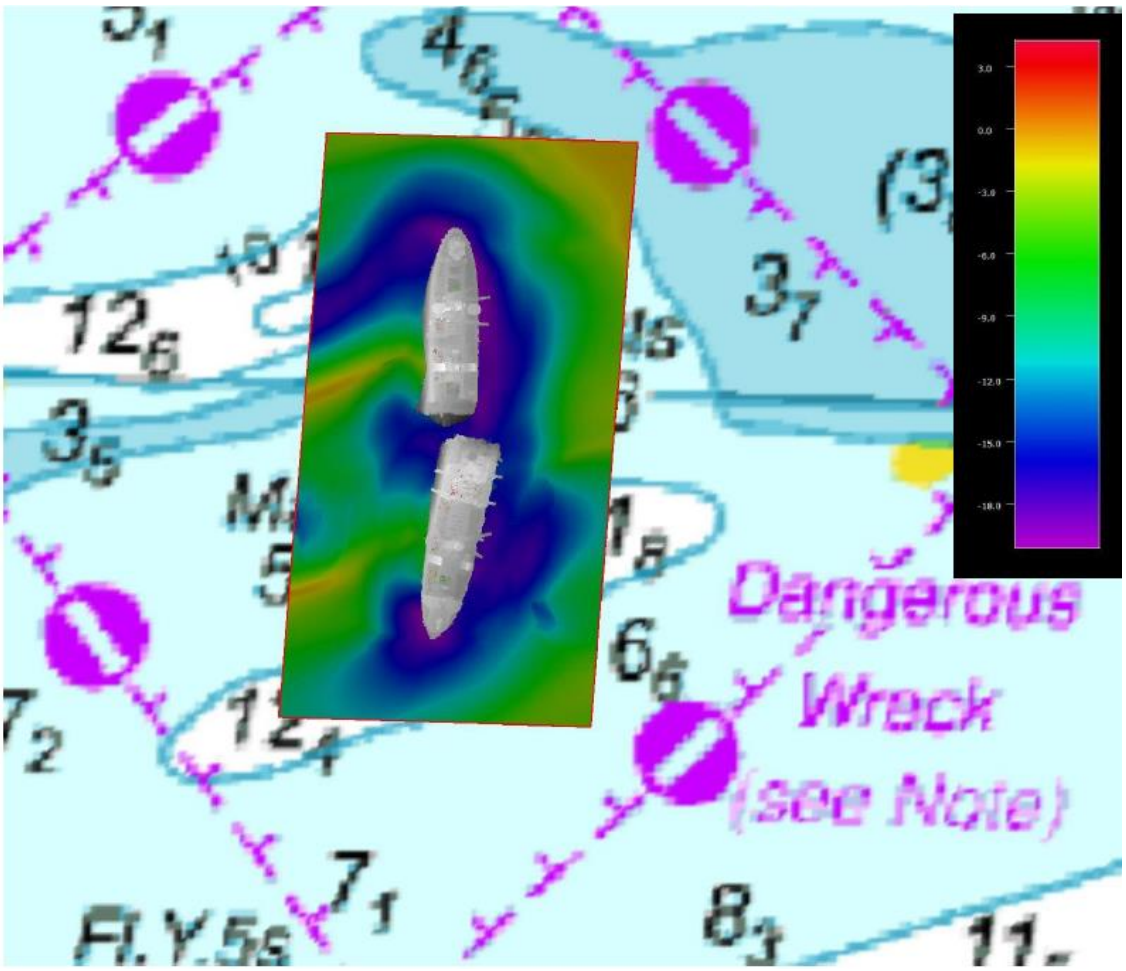

Figure 5 Surrounding seabed MBES survey.

3.4.5 The cleaned point cloud analysis was initially carried out in Cloud Compare where advanced point cloud light shading allows for an effective visual inspection of the wreck data points. Historical datasets can be viewed simultaneously to allow areas of change to be highlighted.

3.4.6 Data profiles have been taken from CARIS subset which allows accurate and spatially comparable data slices to be analysed. In the CARIS HIPS & SIPS software subset vertical and horizontal changes can be quantified and reported.

3.4.7 Throughout this report, all point cloud images have been generated in Cloud Compare. Surface difference plots were generated in QINSy Qimera and all historical profile comparisons have been made in CARIS HIPS & SIPS.

3.5 Laser Scanning

3.5.1 The laser scanning was conducted at low tide using a Carlson Merlin laser scanner, and the data was acquired and processed in V5 Applanix POS MV 320 and QPS QINSy Software (v18.8.1). Multiple lines were run in various directions within the vicinity of the wreck to achieve full coverage and data density around the masts. The laser data was also reduced using a post-processed kinematic (PPK) solution and exported to a separate georeferenced full density point cloud.

3.5.2 Unfortunately, due to the angle of the MBES heads and the height of tide when the MBES data was acquired, a vertical data gap of approximately 1m exists between the Laser and MBES on the main mast structures. 6 shows an overview of the SSRM MBES data combined with the 2018 survey laser scan data.

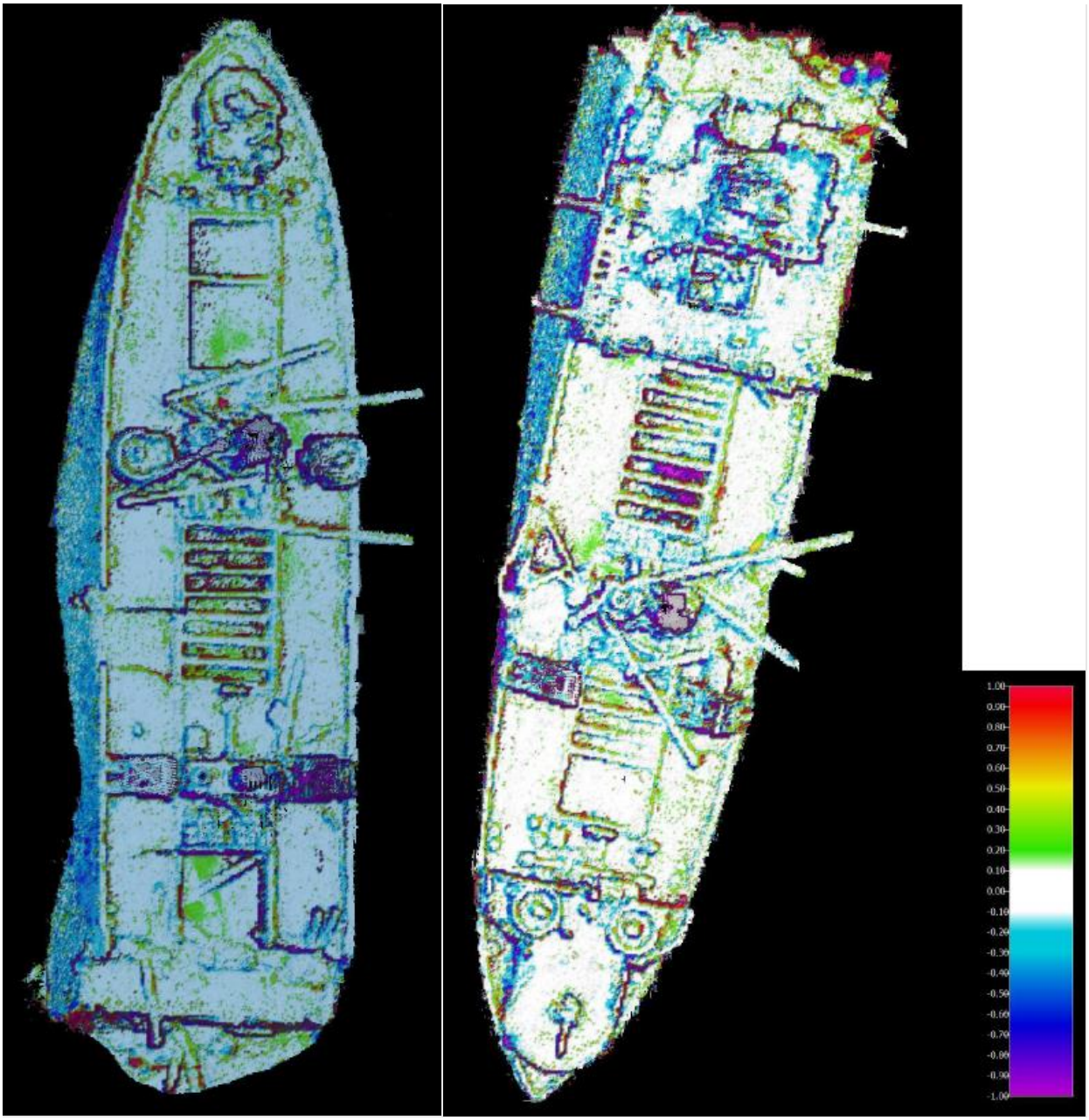

Figure 6 Surface difference between 2017-2018 survey data on forward (left) and aft (right) sections.

3.5.3 In addition to laser scan data, photographs were taken to add to the available information on the condition of the exposed masts. Figure 2 shows the masts above the water.

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

4.1.3 There has also been little change in the individual features of the wreck. There are only two areas that show changes, both in the aft section of the wreck.

4.1.4 In Key Area 5, the deck plate appears to be buckling upwards up to 0.2m on the forward side of the crack on the deck (see Key Area 5 below).

4.1.5 Key Area 6 is the collapsing bridge deck of the aft section where it has split from the fore section of the wreck. This area shows changes of less than 0.5m to the protruding deck plates (see Key Area 6 below).

4.1.6 The following is a more detailed discussion of the survey results beginning with wreck profiles and surface difference analysis.

4.2 Wreck Profiles and Surface Difference

4.2.1 Wreck Profiles

4.2.2 Profiles of the hull were reviewed to monitor for any wreck movements or listing which may have occurred since the previous surveys. The locations of these profiles are shown in yellow in Figure 7.

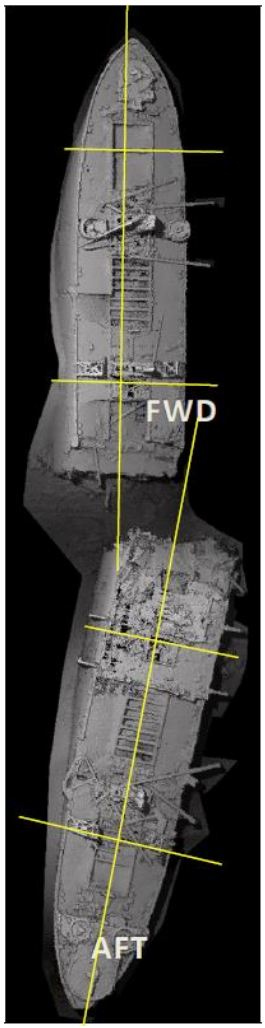

Figure 7 Location of profiles examined.

4.2.3 The data shows good correlation between previous datasets with no change observed in the various profiles of the wreck. This suggests that the SSRM has remained stable in all planes of attitude and position, and any minor changes are attributed to small scale feature changes only.

4.2.4 Surface Difference

4.2.5 Surface differencing provides a useful tool in quickly assessing the general deterioration of the wreck. The accuracy of final processed datasets has been considered and the scale is graduated to reflect this by discounting any values less than 0.10m. Any areas highlighted to have undergone change have been investigated further by looking at profiles of the areas affected.

4.2.6 Surface differencing between the 2017 and 2018 datasets has highlighted that most areas have not changed since the previous survey.

4.2.7 Small changes can be seen in the collapsing bridge deck at the forward end of the aft section of the vessel (feature ID43, ID45 and ID46) and at the accommodation block/bridge wing area (Figure 8). This area experienced significant changes prior to the 2015 survey and has again shown change, albeit of a smaller magnitude. The changes seen here are in the region of 0.5m difference due to the subsidence of deck plating at the NE edge of the bridge deck.

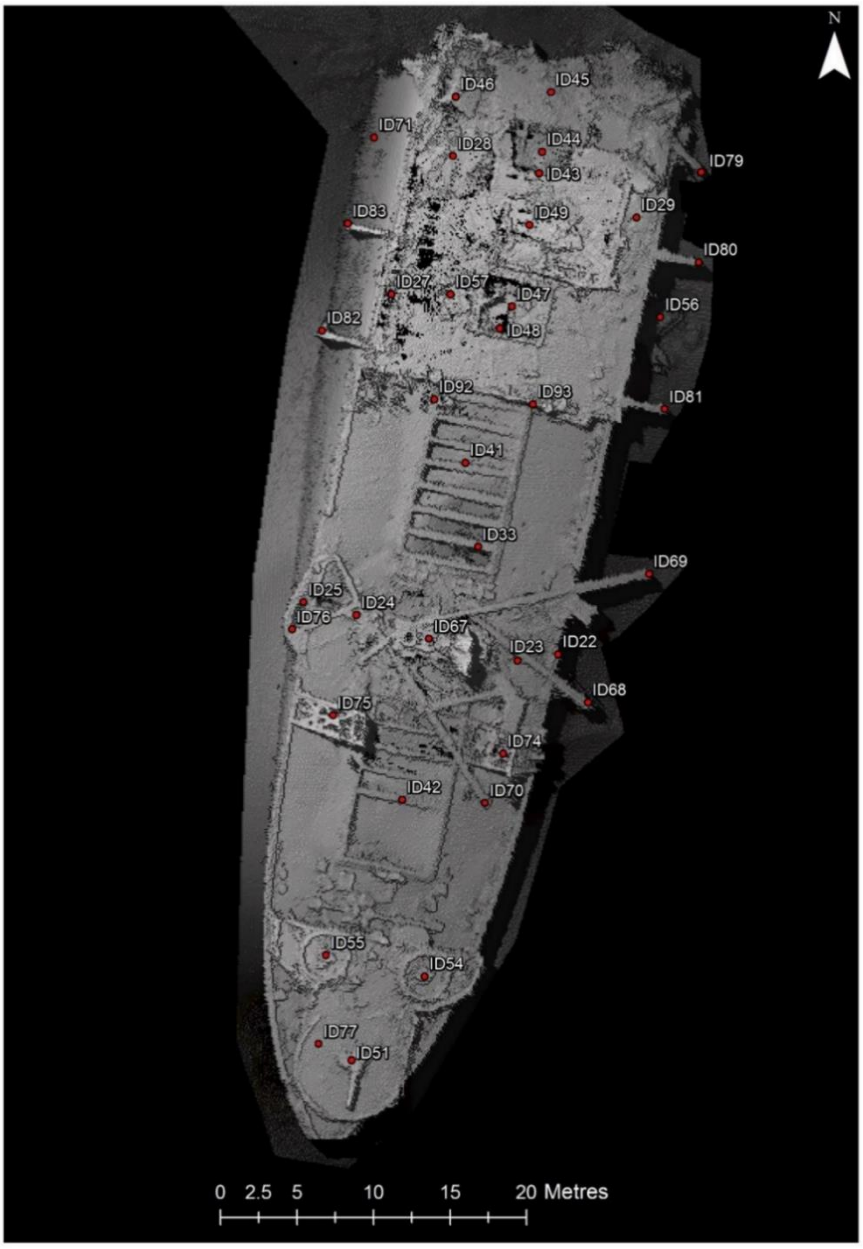

Figure 8 ID features on rear section.

4.2.8 The deck plate on the port side of hold 2 (feature ID08) has remained stable (Figure 9). Interrogation of the data using the CARIS profile shows no changes on this section of collapsed deck.

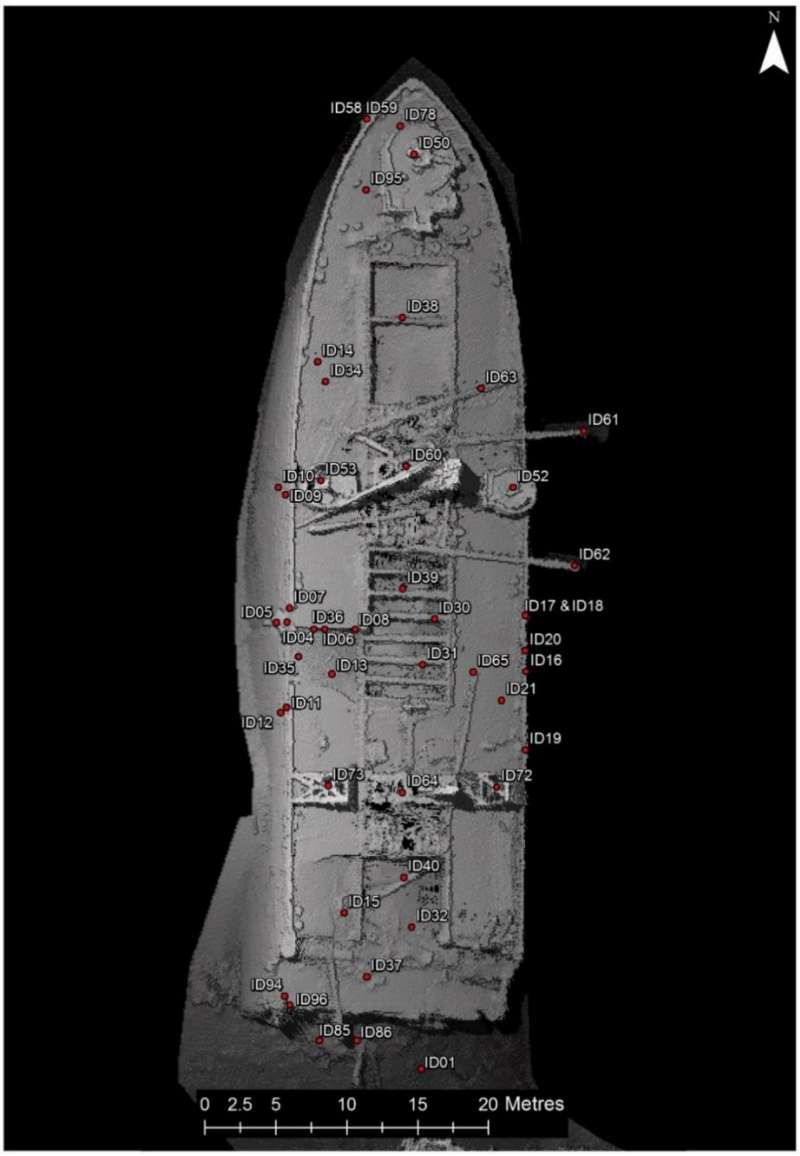

Figure 9 ID features on forward section.

4.2.9 Smaller changes of less than 0.10m elsewhere along the deck are thought to be the product of accretion or erosion of sediments, which most likely occur on a cyclical pattern during tidal phases. Marine growth on the hull structure may also account for minor changes.

4.2.10 Vertical Hull Section Surface Difference

4.2.11 Surface difference analysis of the vertical hull sections is a new technique which has not been used on this wreck before. It provides an effective and quick way of monitoring for any hull deformities and subtle buckling or bulging.

4.2.12 No new deformities have been found and the differences shown are most likely due to comparison of differing data densities and marine growth. The red areas approximately mid-way along both the forward and rear hulls are the cracks. The differences here result from the fact that the inside of the hull is being surveyed rather than a change in the hull plates around the cracks (Figures 10-13).

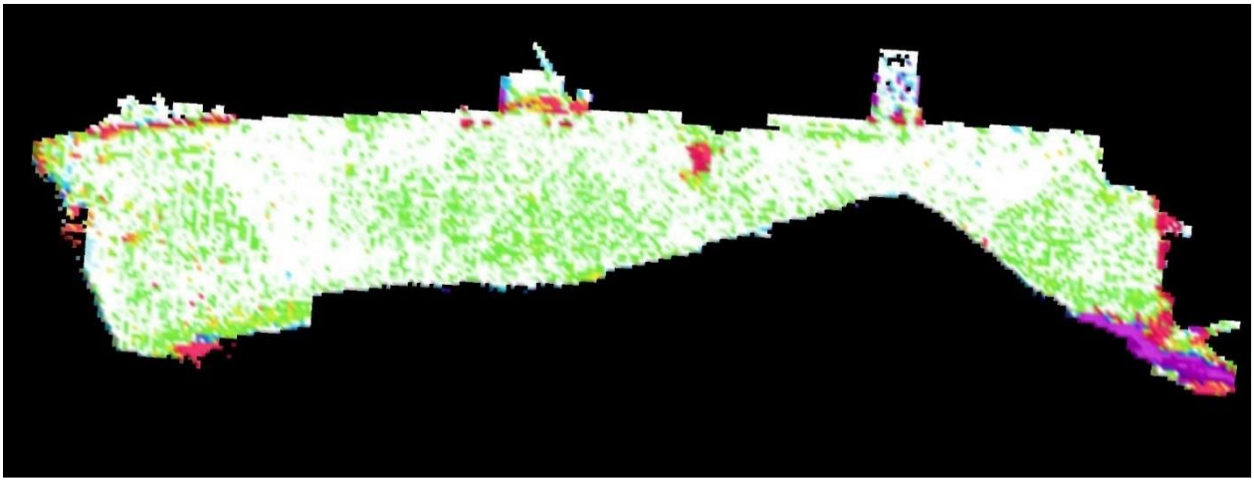

Figure 10 Port forward hull surface difference plot between 2017 and 2018 surveys.

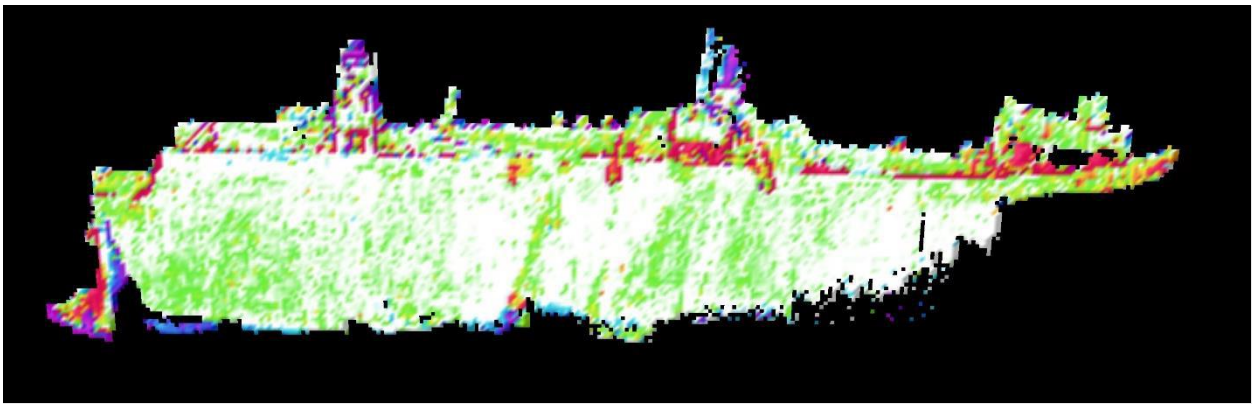

Figure 11 Starboard forward hull surface difference plot between 2017 and 2018 surveys.

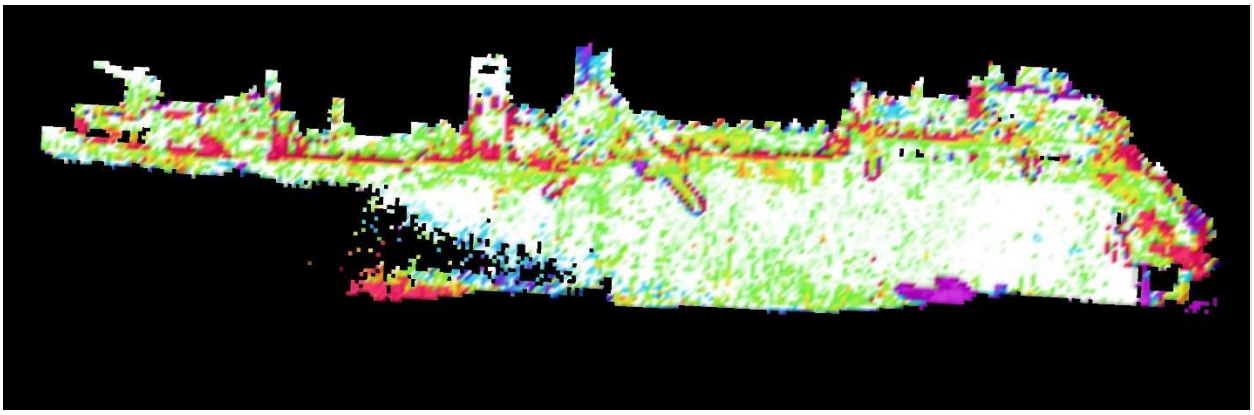

Figure 12 Starboard aft hull surface difference plot between 2017 and 2018 surveys.

Figure 13 Starboard forward hull surface difference plot between 2017 and 2018 surveys.

4.3 Key Areas and Features

4.3.1 Over the whole of the wreck, 96 specific features have been used in successive surveys as comparison points for quantifying change and deterioration. The location of these features is given in Figures 8 and 9.

4.3.2 In addition to the 96 features there are six Key Areas that have been highlighted in previous surveys as areas of significant structural change which are monitored each survey. The location of these is shown in Figure 14.

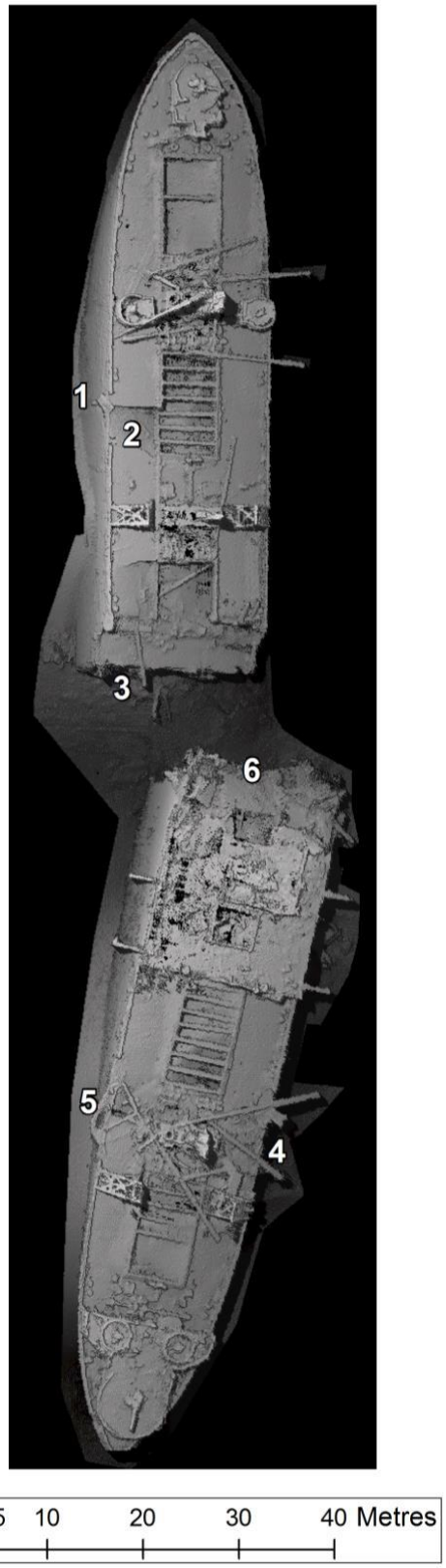

Figure 14 Six Key Areas of SSRM significant for structural change.

4.3.3 Key Area 1 – Crack in hull (ID04)

4.3.4 Feature ID04, crack in the hull, is located on the port side of the forward section of the wreck adjacent to hold 2. In comparison to the point cloud datasets from 2018 and 2017, no changes have occurred in this location (Figures 15-17).

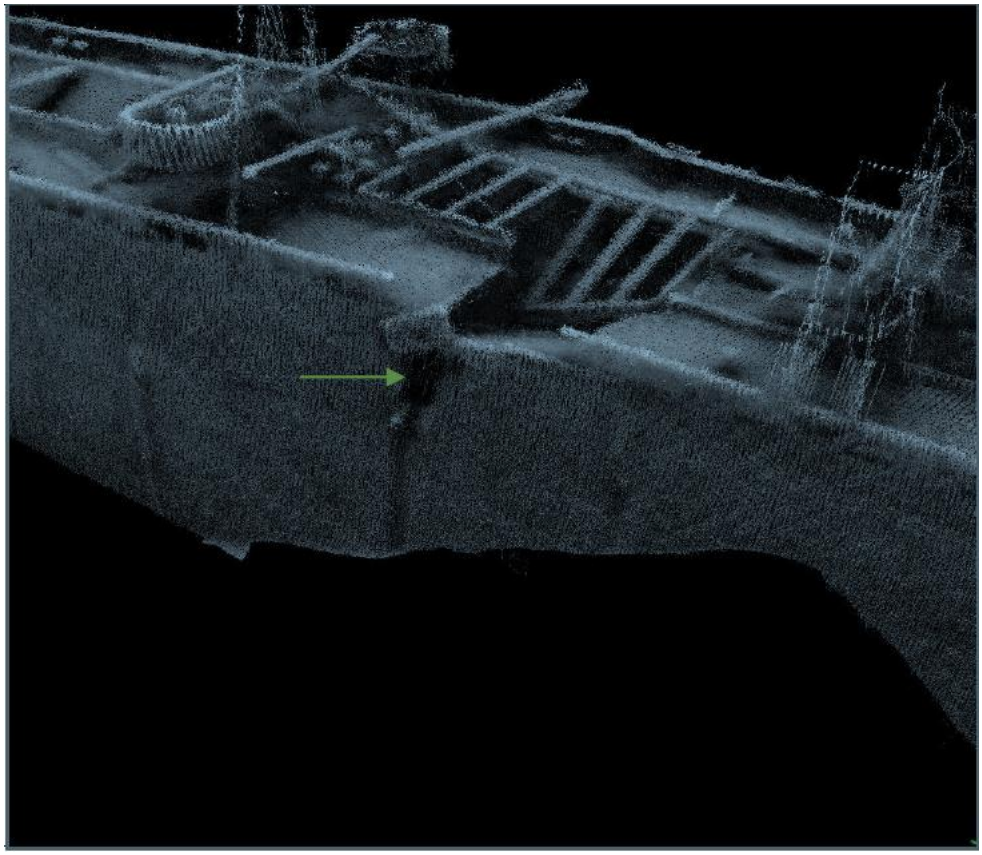

Figure 15 Crack in hull ID04 in 2017 survey data.

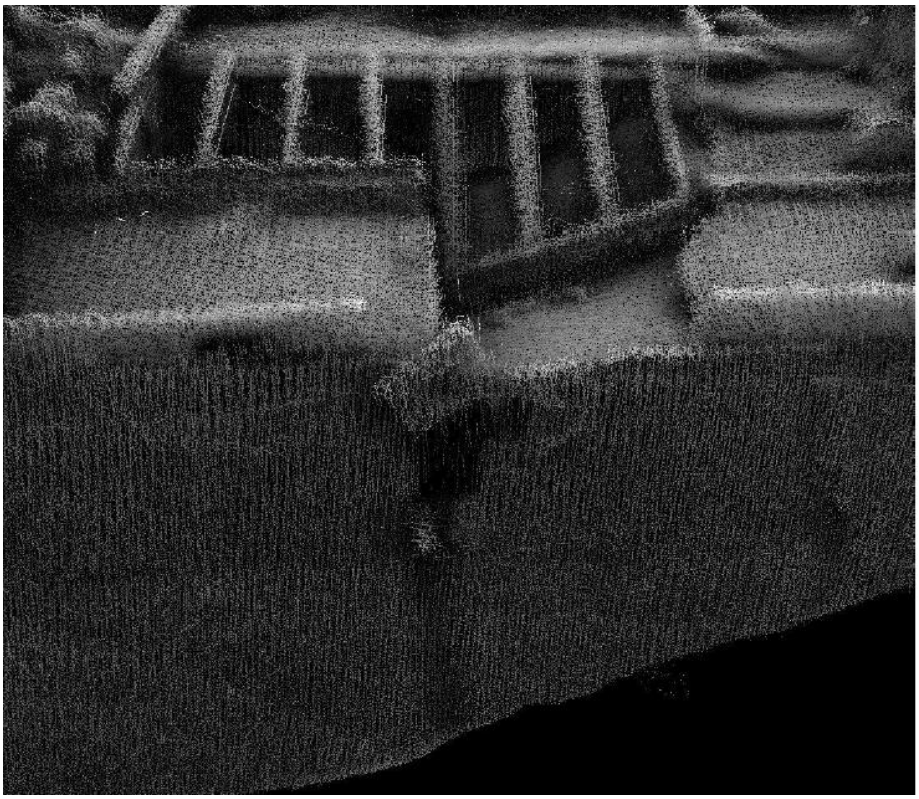

Figure 16 Crack in hull (ID04) in 2018 survey data.

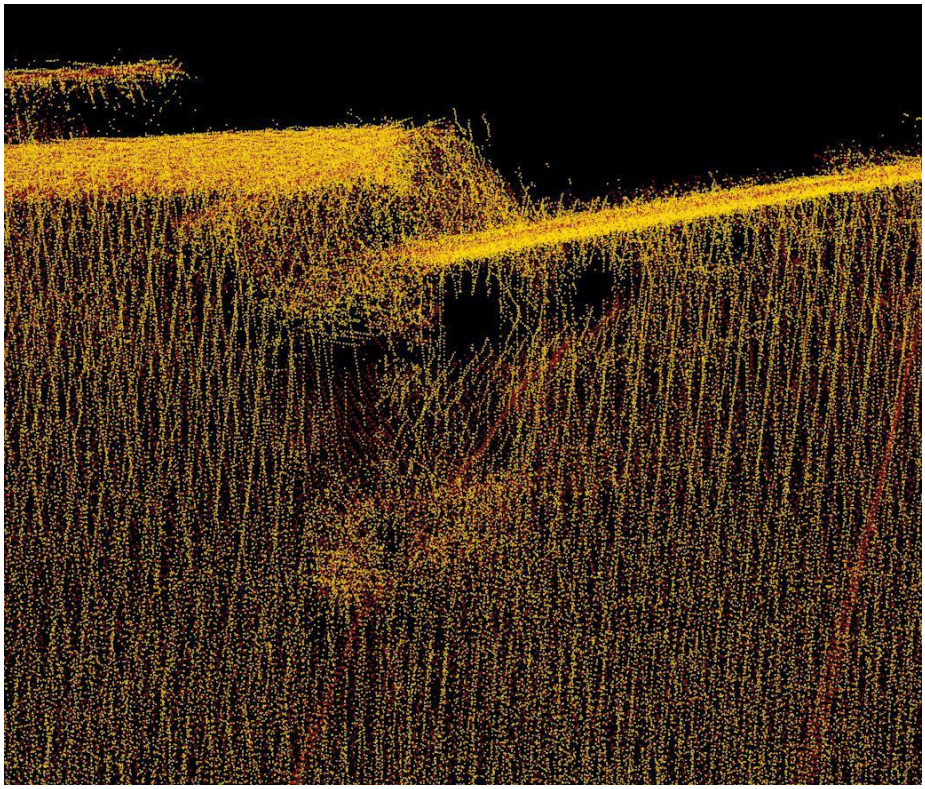

Figure 17 Crack in hull (ID04) 2018 survey data yellow, 2017 survey data red.

4.3.5 Key Area 2 – Collapse of hold deck 2 (ID08).

4.3.6 The collapsed hold deck 2 is situated on the port side of hold 2 and consists of an area of deck that has undergone subsidence. This area is part of the key areas as it has shown change over the previous surveys. No change has been observed between the 2017 and 2018 surveys (Figures 18 and 19).

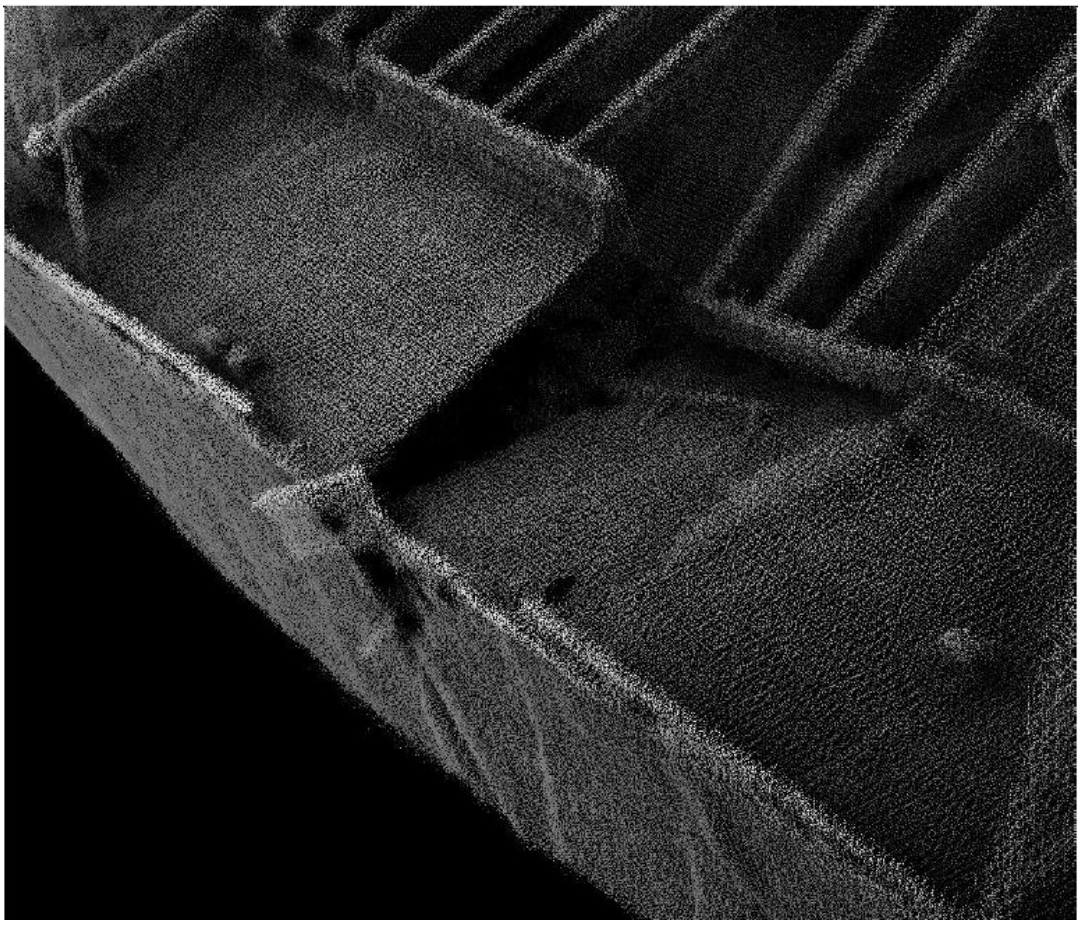

Figure 18 2017 survey collapse of hold deck 2.

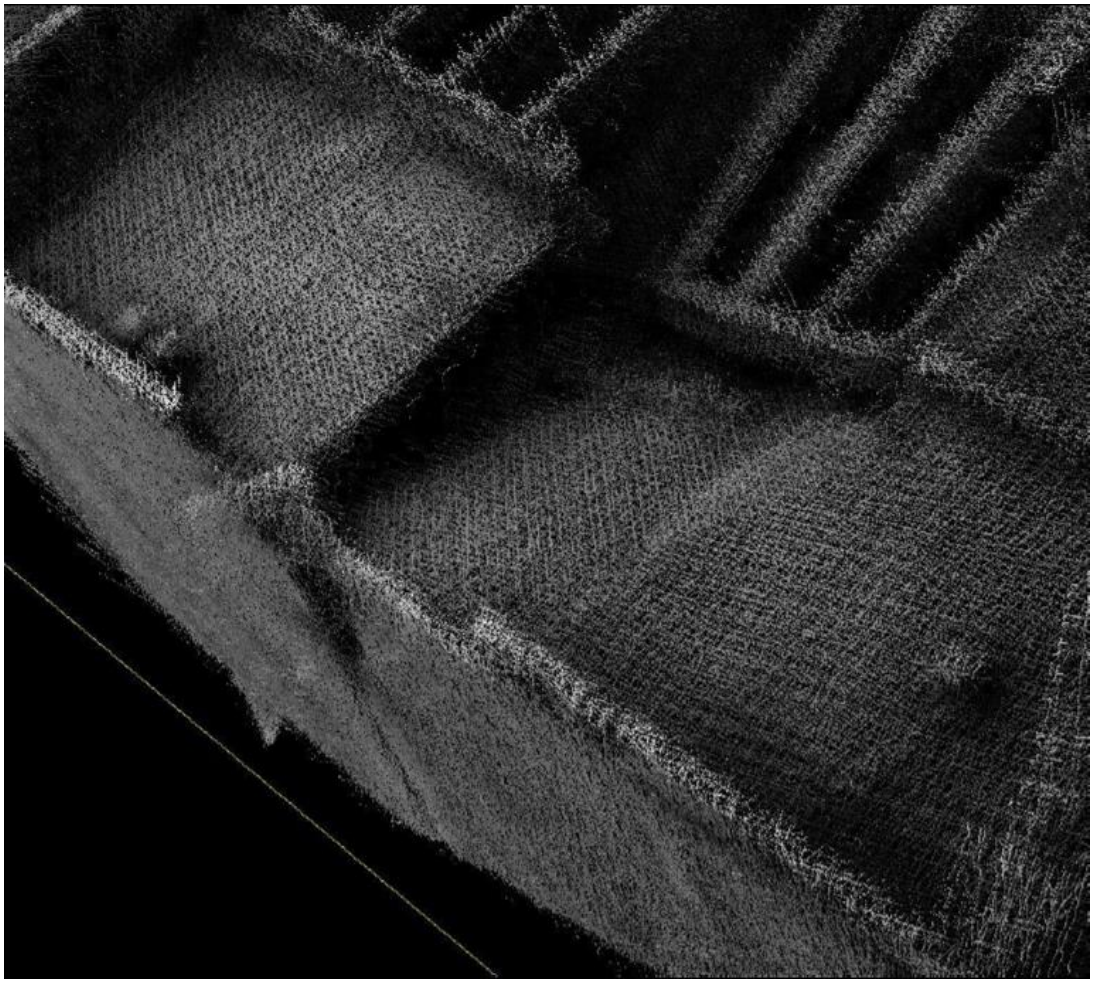

Figure 19 2018 survey collapse of hold deck 2.

4.3.7 Changes in the level of the collapsing deck were noted in the 2017 report although the comparison of the 2017 survey data against the 2018 survey data, as illustrated in Figure 20, shows that no further changes have occurred in this area. Surface difference analysis shows that the deck plate has remained stable within this timeframe (see also Figures 21 and 22).

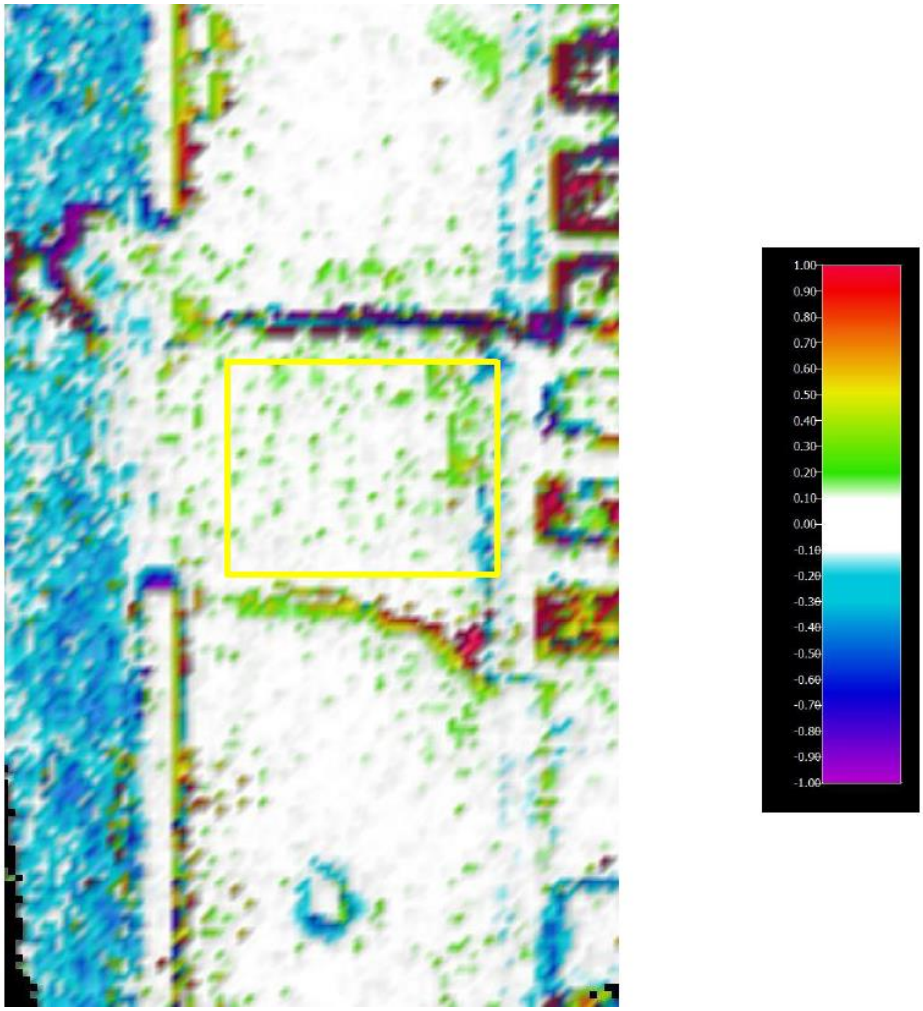

Figure 20 Key Area 2 - surface difference between 2017 and 2018 surveys.

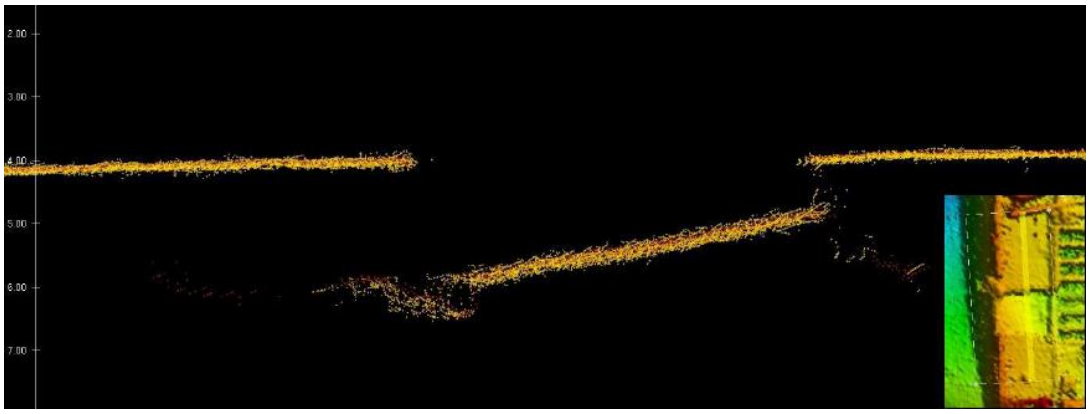

Figure 21 Profile across deck hold plate. 2018 survey (yellow), 2017 survey (red). No change noted.

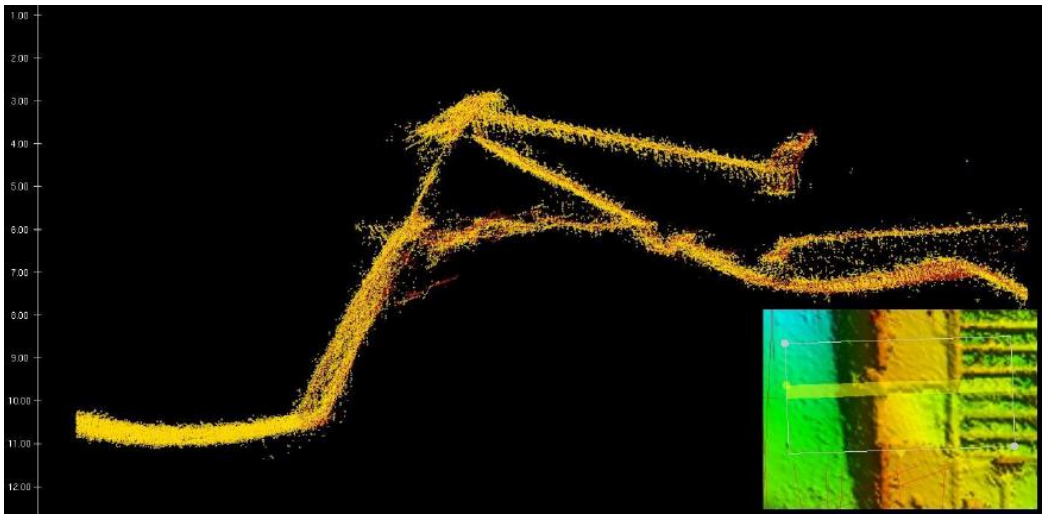

Figure 22 Profile through collapsed deck. 2018 survey (yellow), 2017 survey (red). No change noted.

4.3.8 Key Area 3 – Aperture (ID90) and hold contents (ID94)

4.3.9 The aperture on the aft end of the forward section is clearly visible in the 2018 survey dataset (Figure 23). A CARIS profile, illustrated in Figure 24, shows very good correlation between the data sets. The dimensions of the aperture have remained consistent across the datasets from the previous two years.

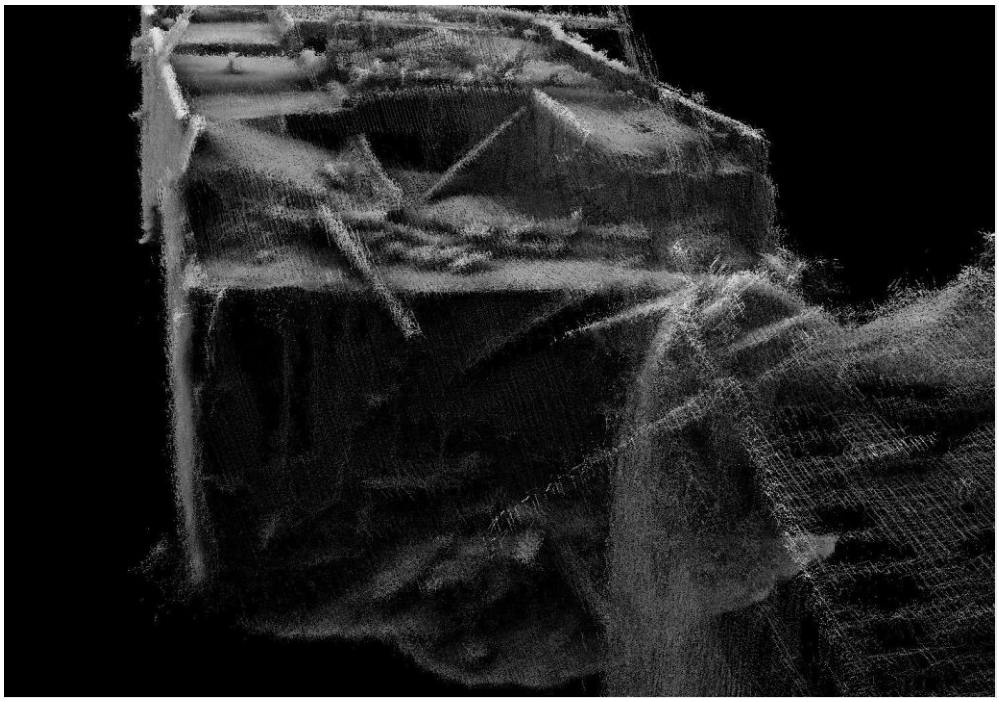

Figure 23 Aperture at aft end of forward section denoted by red dot. Internal cargo can be viewed through the aperture.

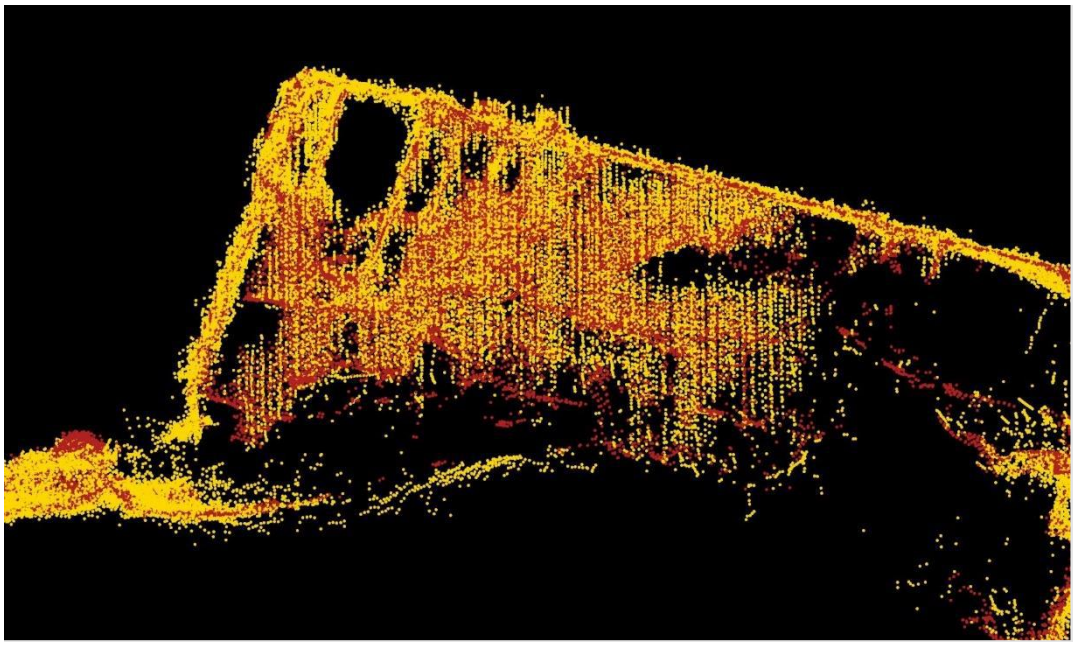

Figure 24 Aperture profile at aft end of forward section, 2019 (yellow), 2017 survey (red). Aperture denoted by red dot.

4.3.10 Whilst the hold cargo can be seen (Figure 25), the exact oblique sonar angle required for good internal ensonification was not achieved. This may be because of the state of tide or beam sector angle during that pass. The shoalest depth recorded of the internal cargo was 8m below Chart Datum (CD) compared to 7.15m in 2017 - from the data it is not possible to ascertain whether this represents a decrease in the amount of cargo visible or whether the area was not fully ensonified.

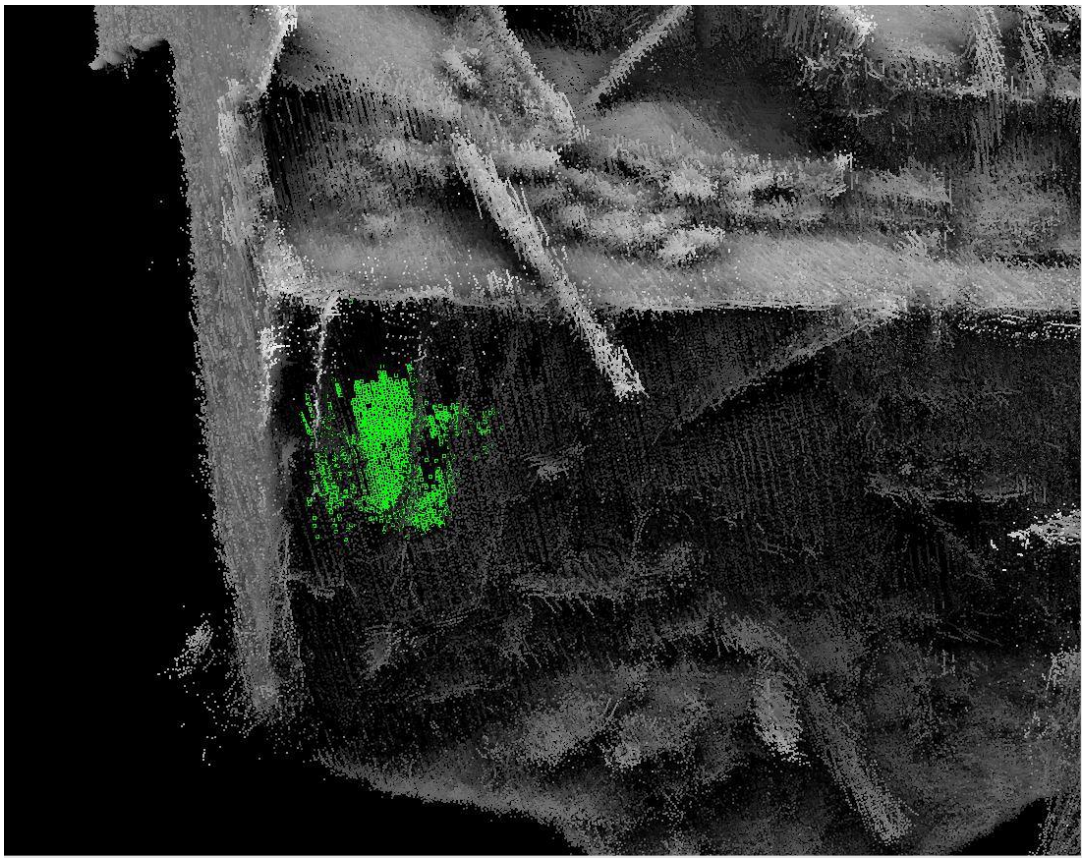

Figure 25 Hold cargo data points in green from 2018 survey.

4.3.11 Key Area 4 – Splitting of Hull (ID 22)

4.3.12 The split in the hull (ID22) is located on the starboard side of the aft wreck section adjacent to the mizzen mast (Figure 8).

4.3.13 Initial visual inspection of the point cloud data shows little change of the split in the hull over the last two years of survey (Figures 26 and 27). Using a surface difference plot and CARIS along and across profiles, no significant change has occurred. The split in the hull appears to be the same with data points inside the hull visible in Figure 29.

4.3.14 Surface differencing shows no change has occurred since the 2017 survey.

Figure 26 2017 survey - Key Area 4 split in hull.

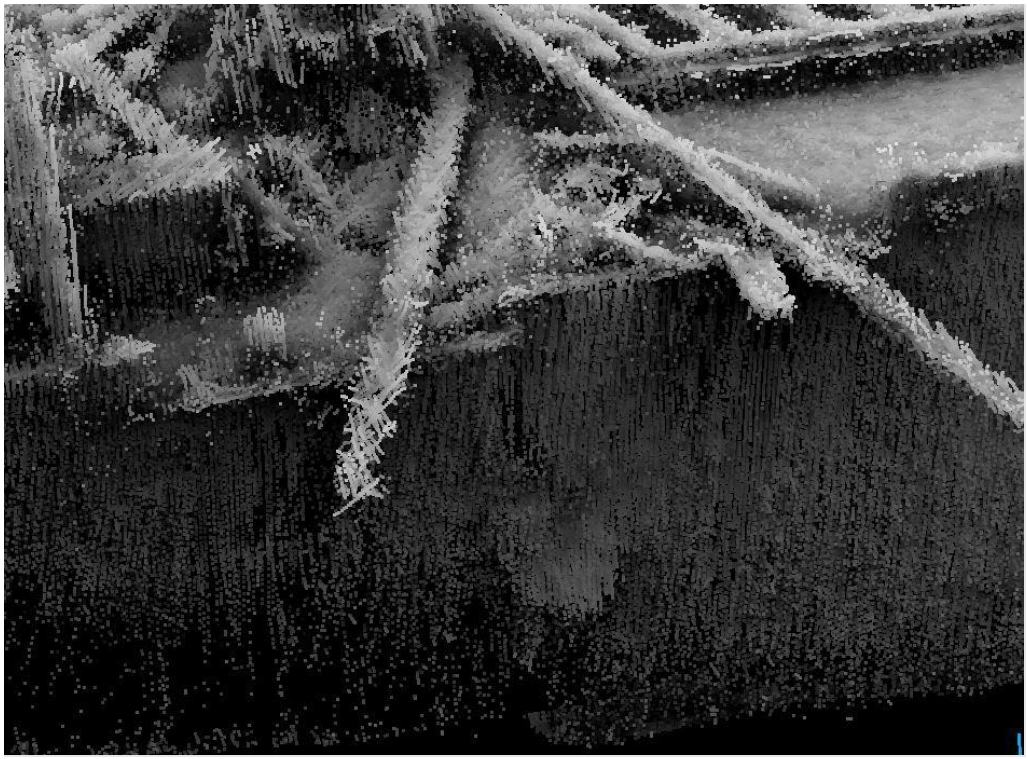

Figure 27 2018 survey - Key Area 4 split in hull.

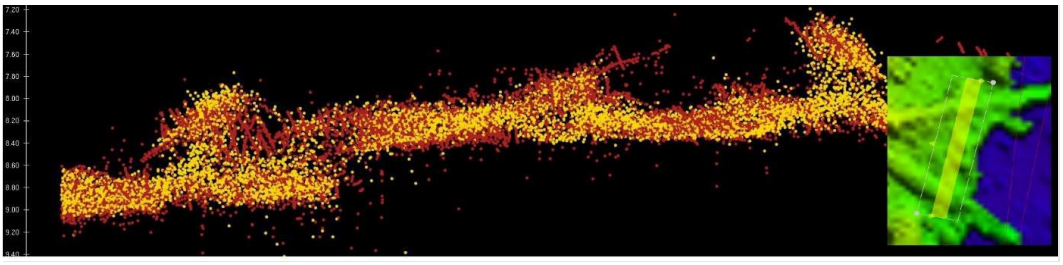

Figure 28 Profile across deck, location inset. 2018 survey (red), 2017 survey (yellow).

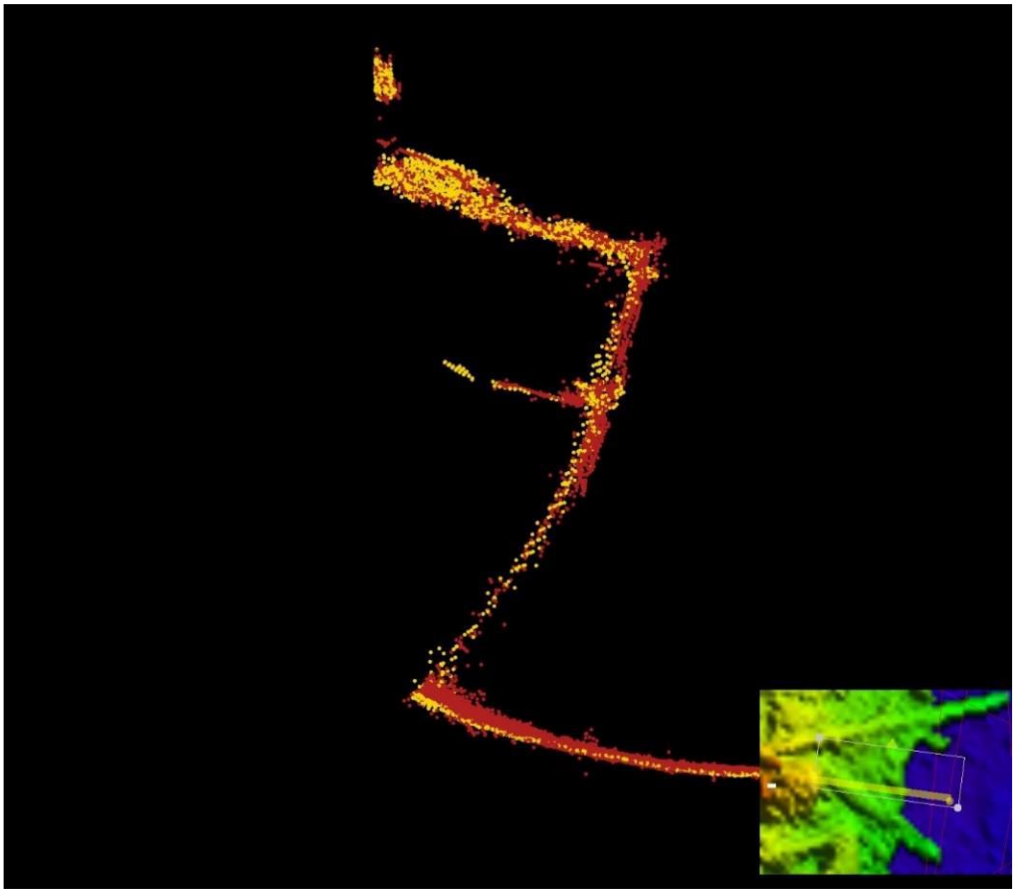

Figure 29 Profile - internal ensonification seen through hull. 2017 (yellow), 2018 survey (red). No change noted.

4.3.15 Key Area 5 – Split in Deck & Hull (ID24 & ID25)

4.3.16 Key Area 5, split in deck and hull (ID24 and ID25) on the aft section port side appears to have remained stable throughout the past two years of survey, however the deck plate appears to be buckling upwards up to 0.2m on the forward side of the crack on the deck (Figures 28 and 30-34). Cross profiles through the hull show the assumed sediment within the hold, which has been ensonified through the crack in the deck above.

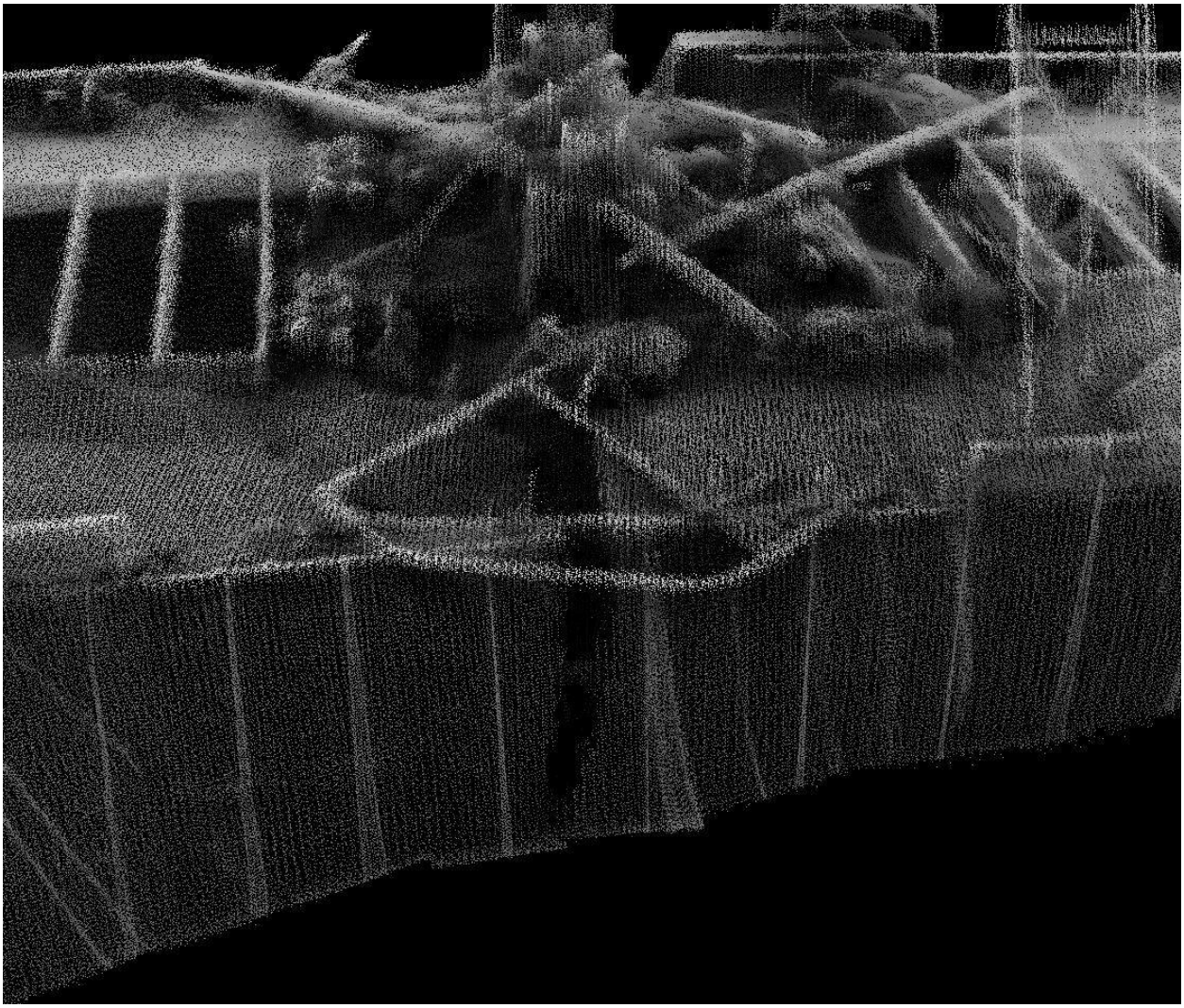

Figure 30 2017 Split in deck/crack in hull.

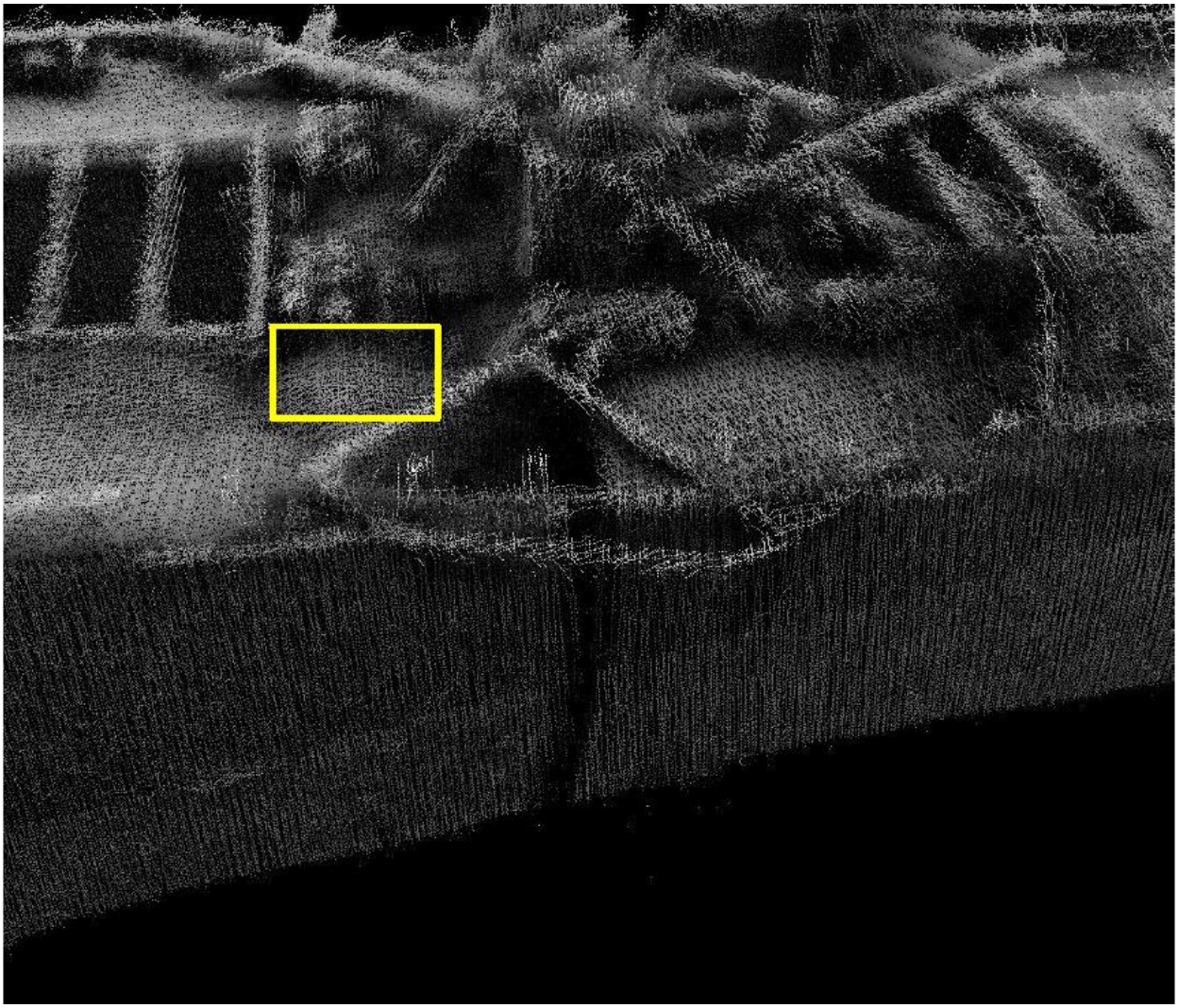

Figure 31 2018 survey split in deck/crack in hull. A buckling of the deck of 0.20m has been identified since the 2017 survey.

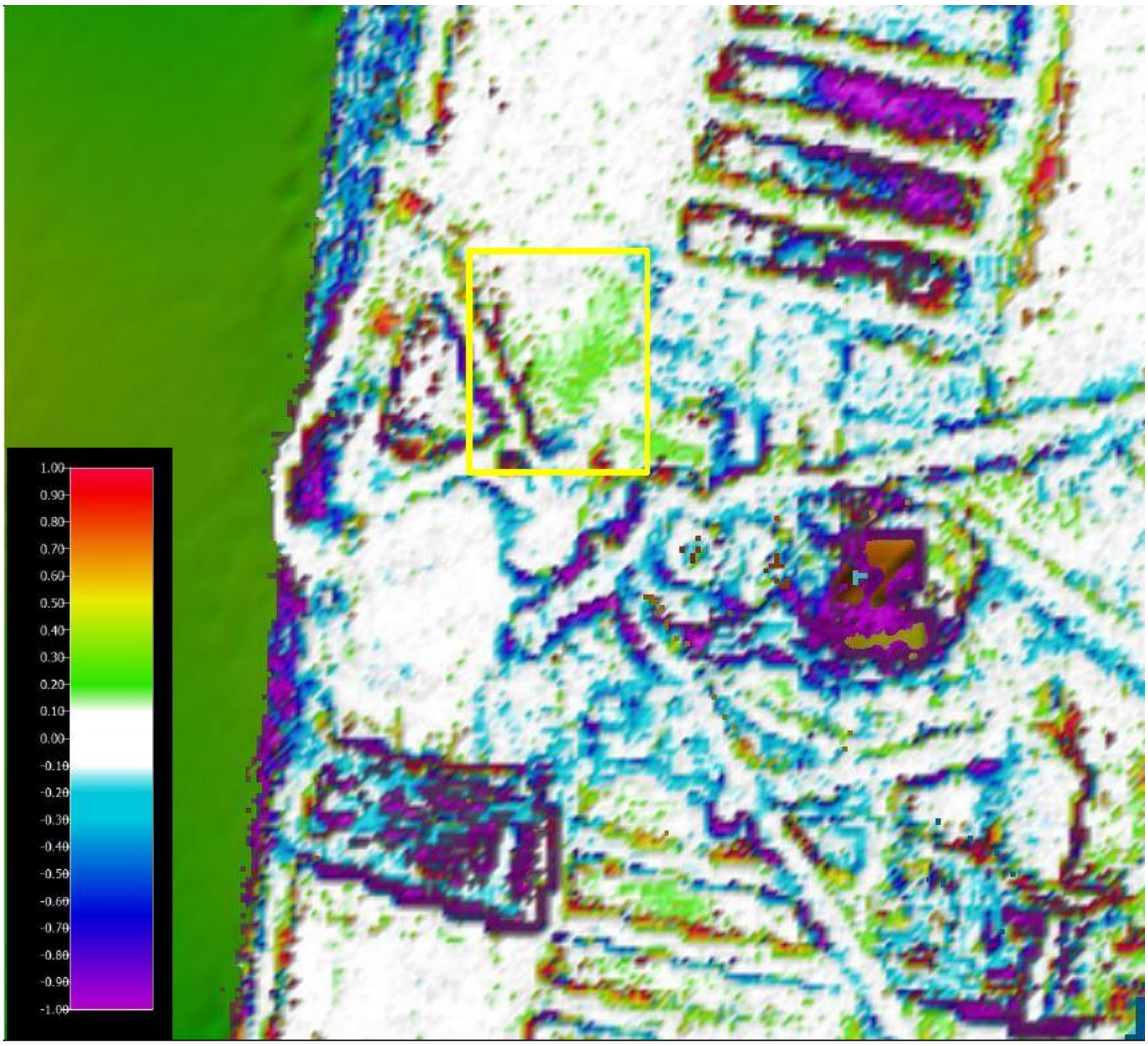

Figure 32 Surface difference plot. Yellow box indicating where buckling is seen on deck plate.

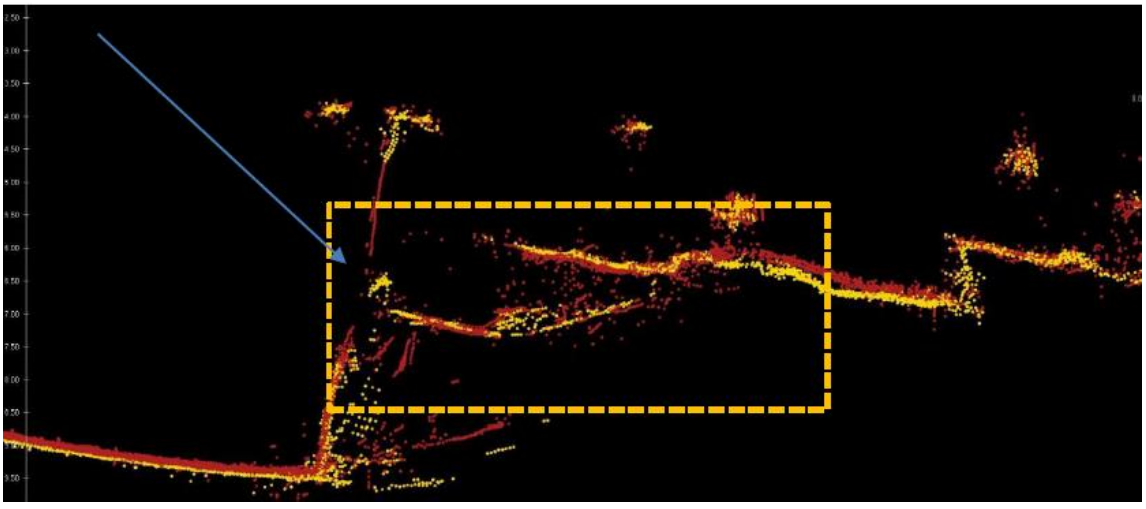

Figure 33 Profile through hull 2017 survey (yellow), 2018 survey (red).

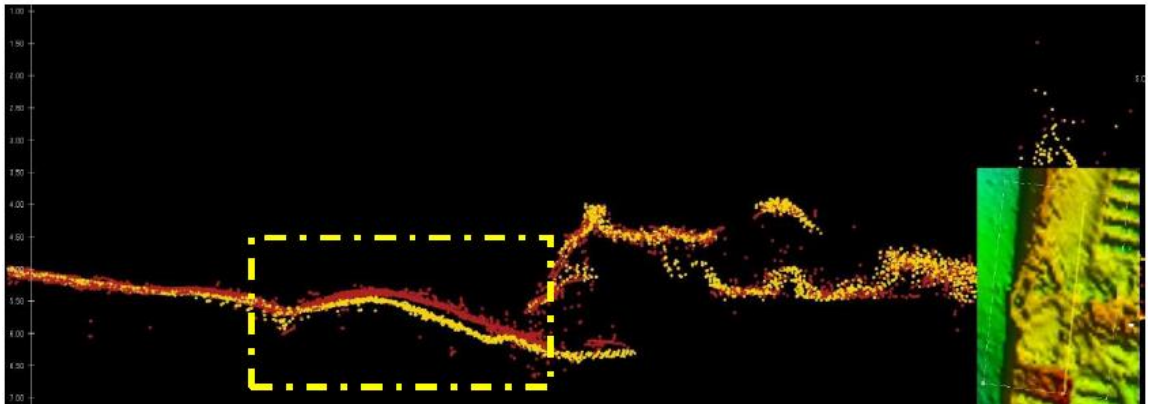

Figure 34 Along deck profile showing buckling of deck plate. 2017 survey (yellow), 2018 survey (red).

2.11 Key Area 6 – Collapsing bridge deck area (ID43, ID45 & ID46)

4.3.17 Key Area 6 encompasses the collapsing bridge deck at the forward end of the aft section. This area showed significant degradation in the previous surveys between 2014 and 2015. The 2017 survey data indicates that further changes occurred however, the most recent survey shows that degradation has stabilised and smaller changes of less than 0.5m are noted to some of the previously protruding deck plates in the 2018 survey (Figures 35-37).

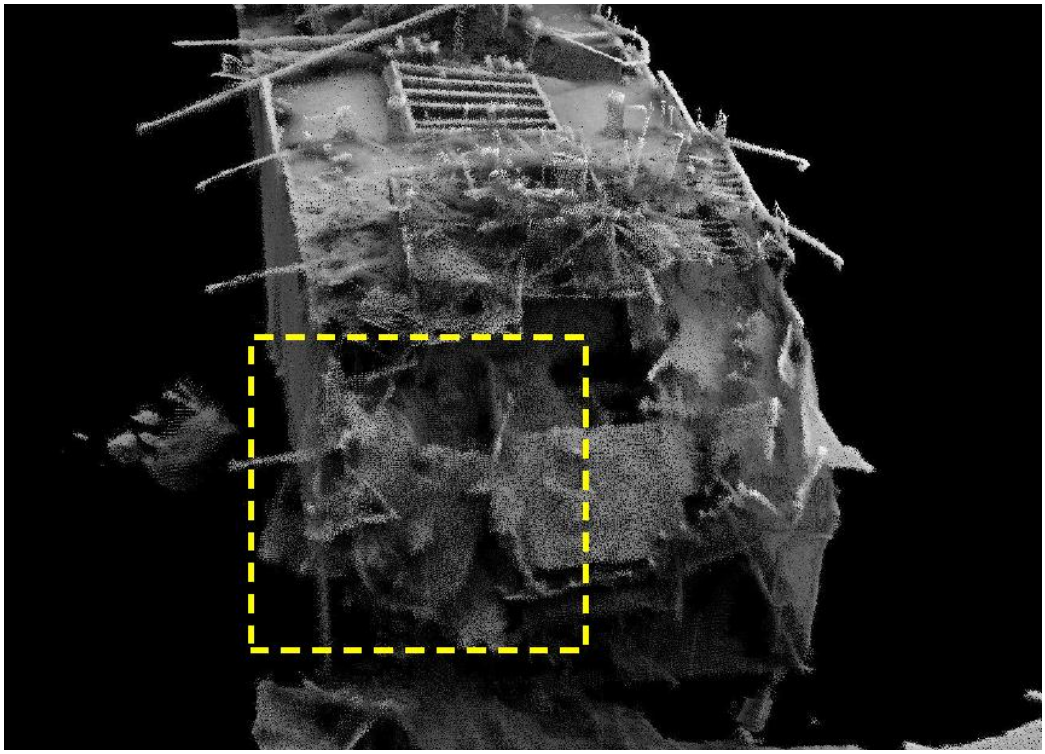

Figure 35 2017 survey Key Area 6.

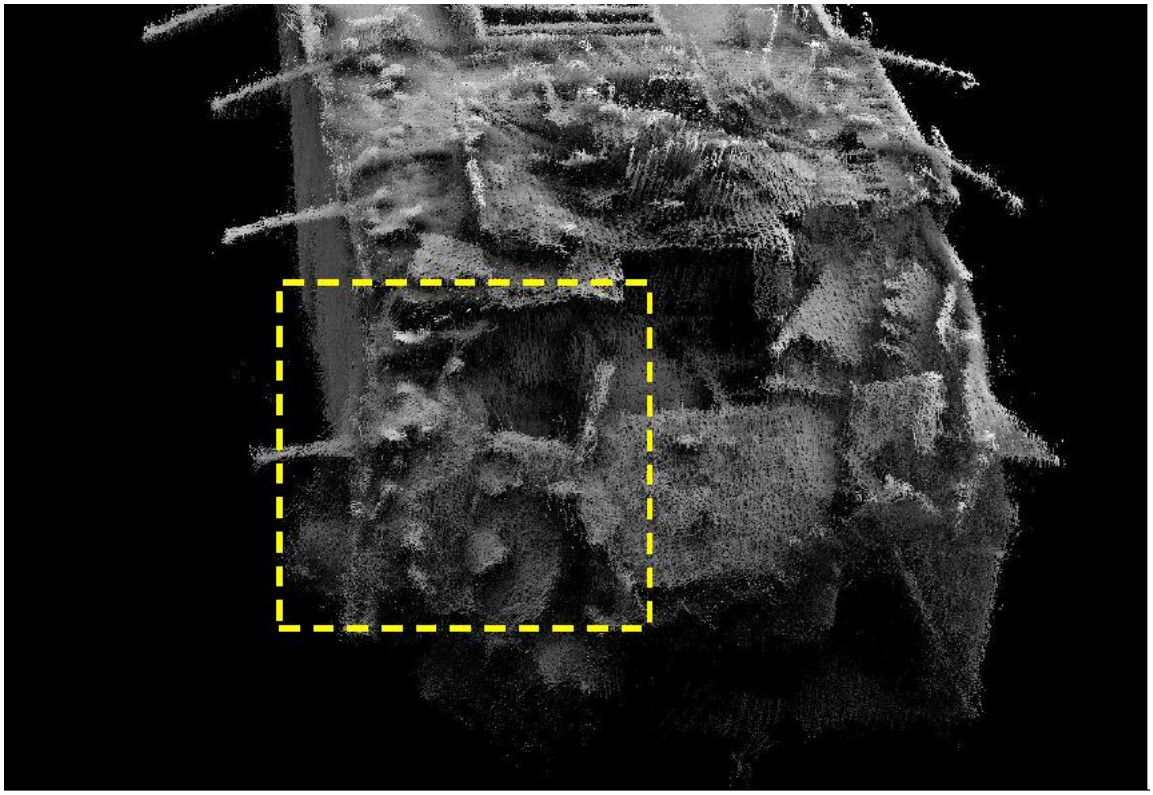

Figure 36 2018 survey Key Area 6.

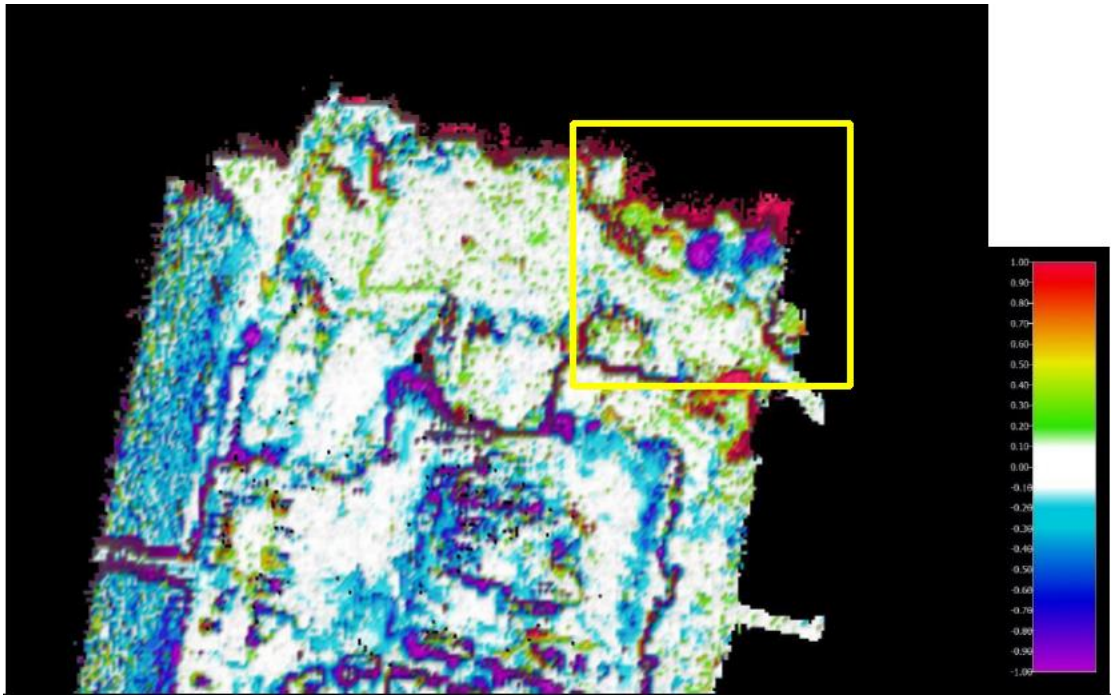

Figure 37 Surface difference showing changes to the aft section starboard upper deck level between 2017 and 2018 surveys.

4.4 List of Features

4.4.1 Across much of the wreck, no changes were identified in the 2018 survey data when compared with the data from the 2017 survey. The following table lists those ID features where changes were or were not identified.

4.4.2 Changes were noted at ID24 and ID 25 which relate to Key Area 5 and ID 43, ID45 and ID46 which relate to Key Area 6, the changes in these areas were discussed earlier in this report.

Table 1: Comparison of ID features and related key areas between 2017 survey and 2018 survey data.

ID Number	Feature	Location	2018 Status
ID04	Crack in hull (Key Area 1)	Port side, forward section	No change observed
ID08	Collapse of hold 2 deck (Key Area 2)	Port side, forward section	No change observed
ID96	Aperture (Key Area 3)	Aft end, forward Section	No change observed
ID22	Split in hull (Key Area 4)	Starboard side, aft section (near aft mast house)	No change observed
ID24 ID25	Split in deck Split in hull (Key Area 5)	Aft section, port side.	Change observed
ID43 ID45 ID46	Boiler room casing Collapsing bridge deck (Key Area 6) Collapsing boat deck	Forward end, aft section	Change observed
ID01 ID02 ID03	Separation of the hull in two sections Forward section Aft Section	Wreck site	No change observed
ID09	Severe buckling of hull plating	Port side hold 2	No change observed

ID Number	Feature	Location	2018 Status
ID10	Buckling of hull plating		
ID12	Buckling of hull plating	Port side hold 2	No change observed
ID14	Holes in deck plating	Port side hold 1	No change observed
ID16	Horizontal crease in hull plating	Starboard side hold 2	No change observed
ID19	Severely horizontal buckling of hull	Starboard side hold 2	No change observed
ID21	Bends in deck plating	Starboard side hold 2	No change observed
ID27	Holes in boat deck	Port side aft section	No change observed
ID35	Indications of tween deck cargo	Port side, hold 2	No change observed
ID37	Indications of tween deck cargo	Hold 3	No change observed
ID38	Hold 1 catch supports	Hold 1	No change observed
ID39	Hold 2 catch supports	Hold 2	No change observed
ID40	Hold 3 catch supports	Hold 3	No change observed
ID41	Hold 4 catch supports	Hold 4	No change observed
ID42	Hold 5 catch supports	Hold 5	No change observed
ID47 ID48	Engine room skylight & casing	Central superstructure	No change observed
ID50	Forward gun & gun tub	Bow	No change observed

ID Number	Feature	Location	2018 Status
ID51	Stern gun & gun tub	Stern superstructure	No change observed
ID52 ID53	20mm gun Tubs	Adjacent to fore mast	No change observed
ID54 ID55	20mm gun tubs- stern superstructure	Stern superstructure	No change observed
ID56	20mm gun tubs – laying on seabed	Starboard side aft section	No change observed
ID57	20mm gun tubs- upturned on boat deck	Central superstructure	No change observed
ID59	Port anchor	Port side, bow	No change observed
ID60	Foremast and mast house	Forward section	No change observed
ID61 ID62 ID63	Foremast cargo and handling booms	Forward section	No change observed
ID64 ID65 ID66	Main mast and mast house	Forward section	No change observed
ID67 ID68 ID69 ID70	Mizzen mast & mast house	Aft section	No change observed
ID71	Bilge keel	Port side, forward and aft sections	No change observed
ID72 ID74	Life raft racks	Adjacent to main mast	No change observed

ID Number	Feature	Location	2018 Status
ID75		Adjacent to hold 5	
ID76	Anti-torpedo net cage	Port side, mizzen mast	No change observed
ID77	Propeller and rudder	Stern	No change observed
ID78	Forefoot	Bow	No change observed
ID95	Bow section	Bow	No change observed
ID80 ID81	Lifeboat davits	Starboard side, aft section	No change observed
ID82 ID83	Lifeboat davits	Portside aft section	No change observed
ID84	Lifeboat davit		No change observed
ID85 ID86	Debris on seabed Debris on seabed	Gap between forward and aft	No change observed
ID92	Port and starboard lighting towers	Central superstructure	No change observed
ID07	Break in gunnel	Portside hold 2	No change observed
ID13	Holes in deck plating	Portside hold 2	No change observed
ID15	Collapse of deck and hatch coaming	Portside hold 3	No change observed
ID17 ID18 ID20	Hole in hull plating Severe discontinuity of hull plating Large hole in hull plating	Forward section, starboard side	No change observed
ID23	Split in deck plating	Aft section, starboard side	No change observed

ID Number	Feature	Location	2018 Status
ID28	Collapsed boat deck	Starboard side aft mast	No change observed
ID29	Boat deck missing above walkway	Starboard side, aft section, (forward end)	No change observed
ID30 ID31	Hole in lower hold cover Collapse of lower hold cover	Hold 2	No change observed
ID33	Collapse of lower hold cover	Hold 4	No change observed
ID34	Indications of tween deck cargo	Starboard side, hold 1	No change observed
ID79	Lifeboat davit	Starboard side, aft section (forward end)	No change observed
ID11	Hole in hull plating	Forward section, port side	No change observed
ID49	Gunnery officer's cabin	Aft section, central bridge block	No change observed

4.5 Contents of Cargo Holds

4.5.1 The content of each of the five hold areas are highlighted within the point clouds below (Figures 38-42). Holds 1, 2, 3, and 5 all show sediment accretion of up to approximately 0.25m. Hold 4 shows the greatest loss of approximately 0.8m in the southern half of the hold when compared with the 2017 survey.

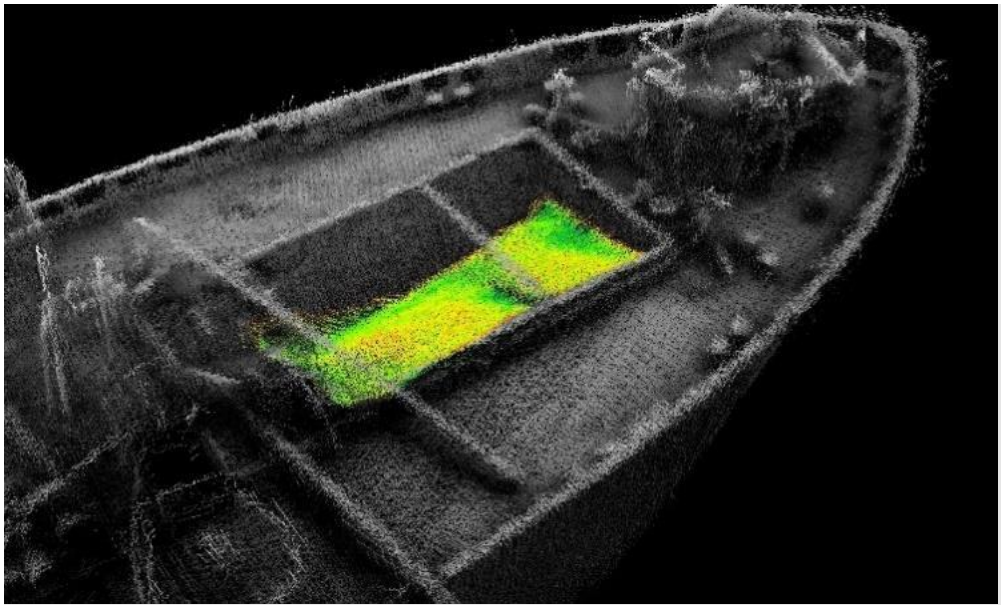

Figure 38 Hold 1 sediment content.

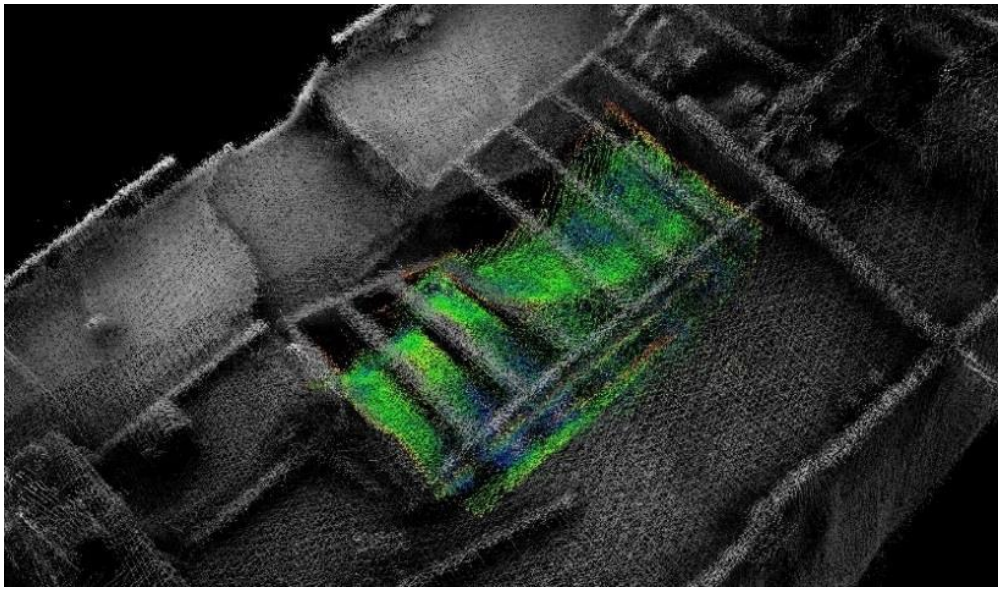

Figure 39 Hold 2 sediment content.

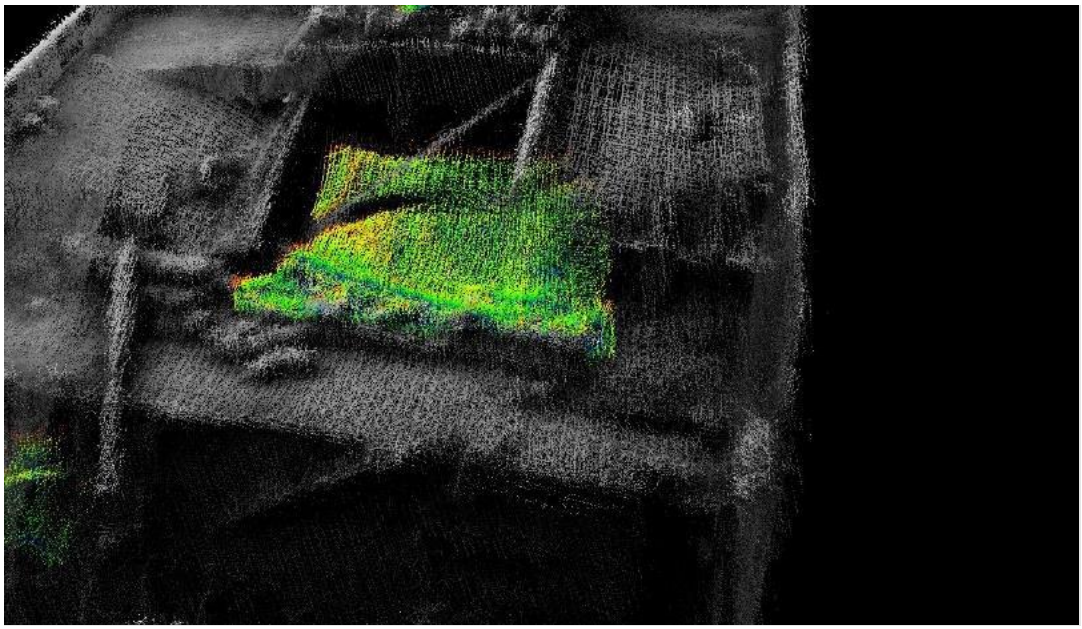

Figure 40 Hold 3 sediment content.

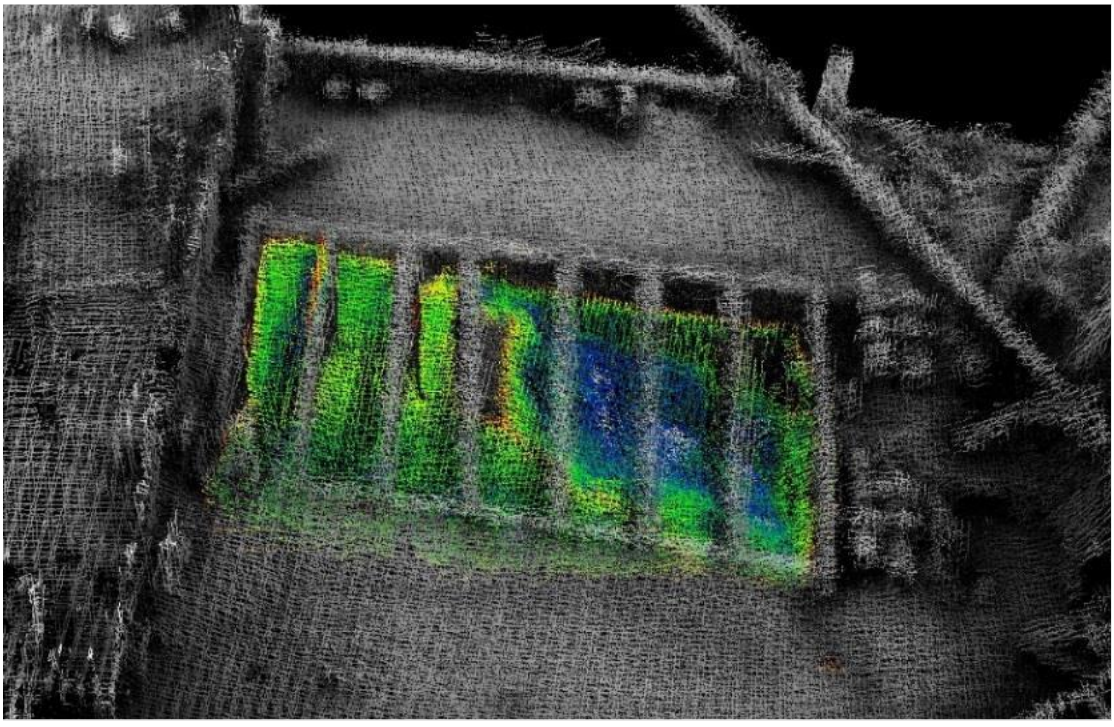

Figure 41 Hold 4 sediment content.

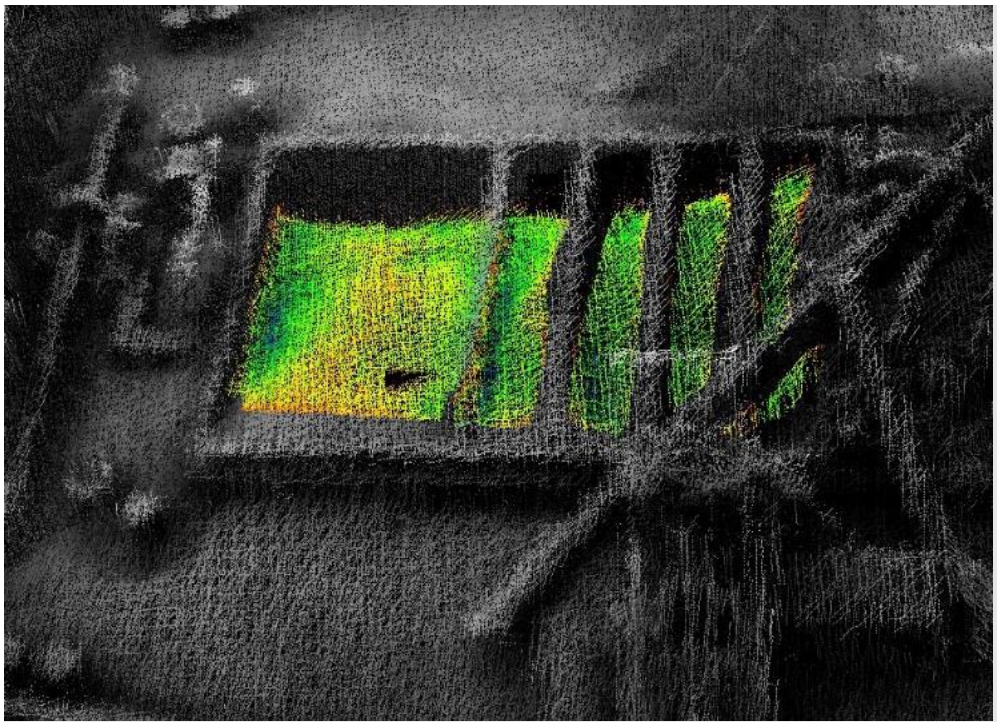

Figure 42 Hold 5 sediment content.

4.6 Laser Survey

4.6.1 The laser scan results are illustrated in Figures 43-45. The three masts are well defined within the laser data and show good correlation with the bathymetry derived points on the foremast stay and on the life raft davit. Unfortunately, due to the angle of the MBES heads and the height of tide when the MBES data was acquired a vertical data gap of approximately 1m exists between the Laser and MBES on the main mast structures.

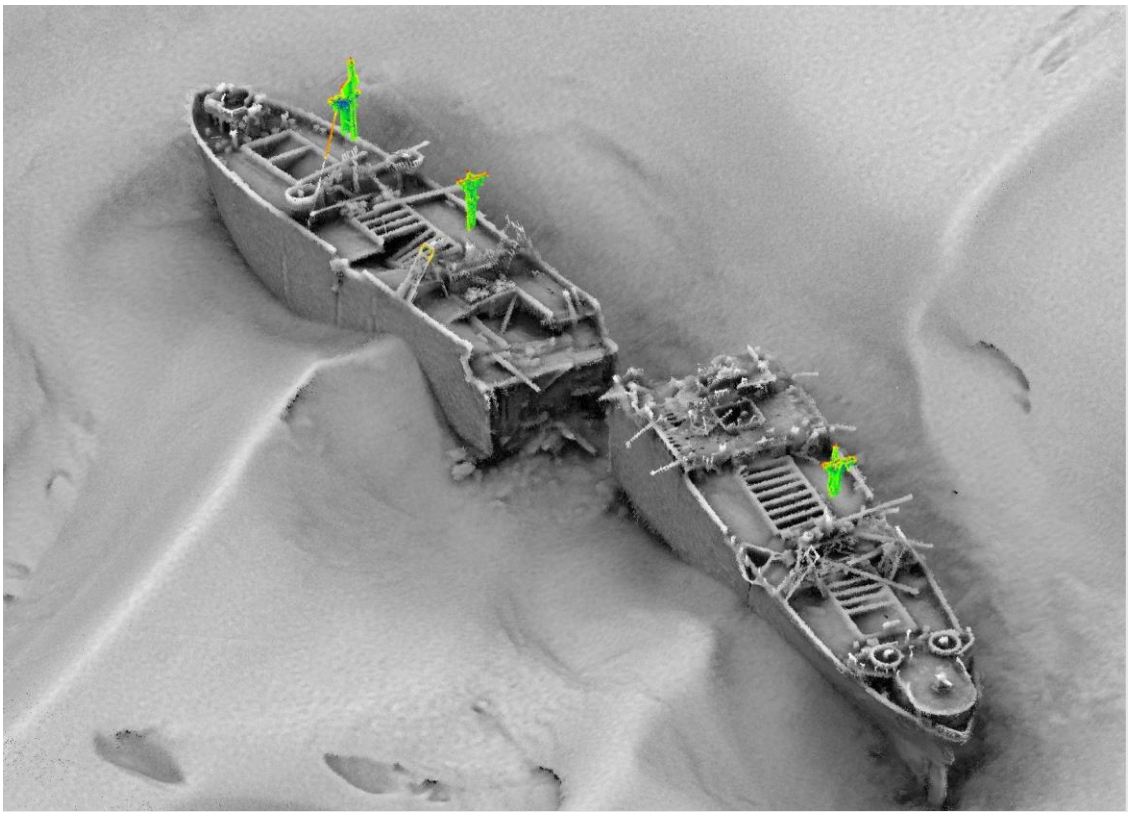

Figure 43 2018 survey Laser scan data points (green to red) integrated with the MBES data.

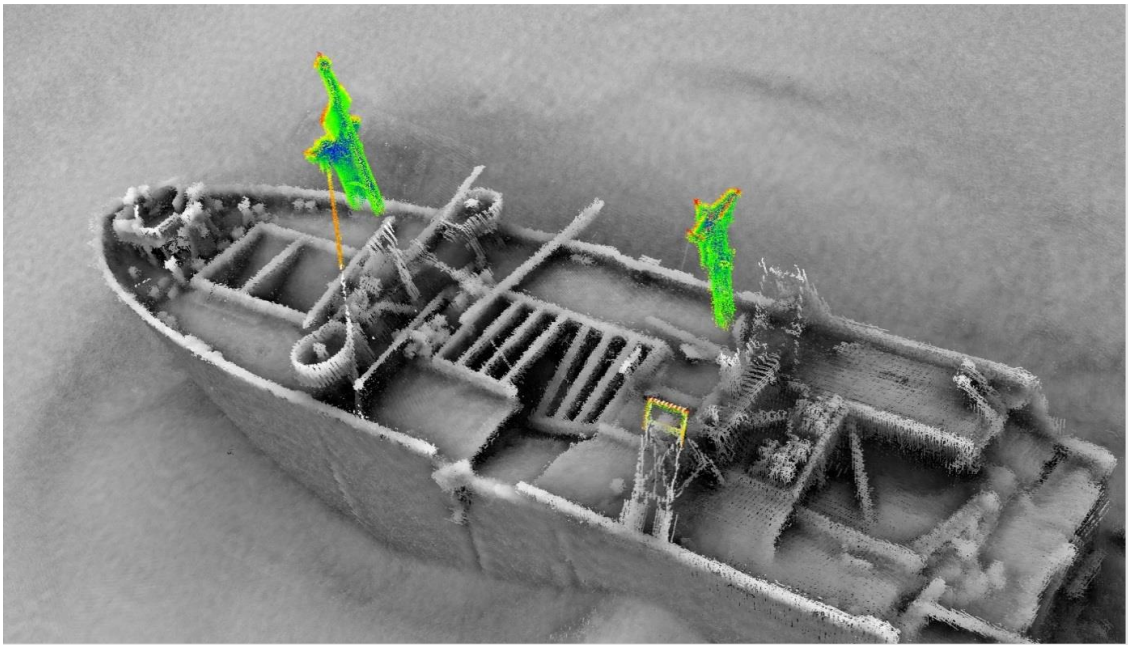

Figure 44 Fore and main mast area from 2018 survey data (laser data in green to red).

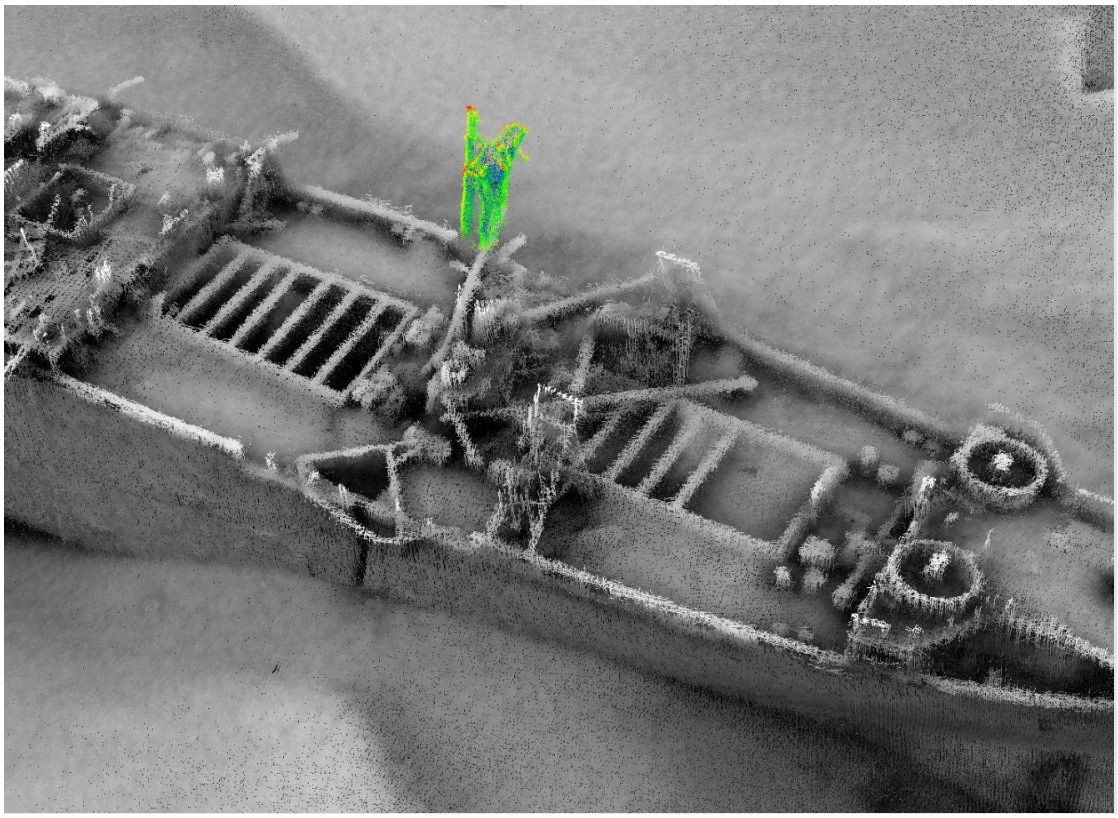

Figure 45 Mizzen mast from 2018 survey data (laser data green to red).

5 Results – The Seabed

5.1 General

5.1.1 The seabed survey fully covered the area of the identified previously in Figure 1.

5.1.2 Across the site, water depths vary between 20.1m below CD in the scour pit surrounding the wreck of the SSRM (off the Port-bow quarter), and 5.1m below CD on the top of the sandbank at the northeast of the survey area.

5.1.3 Examination of the surface difference plot between the 2017 and 2018 surveys shows that for the most part, the site has remained stable (Figure 46).

5.1.4 Deposition has occurred on the starboard side of the of the aft section the wreck, with an increase in sediment of up 0.5m.

5.1.5 Small patches of scouring occur around the survey area with the deepest scouring located approximately 35m southeast of the aft section where localised scouring has occurred. The shape of this localised scouring can be seen in Figure 46 (red circle) and appears to be angular in nature. To the west of the wreck there is also evidence of sand wave migration in a north westerly direction (Figure 47).

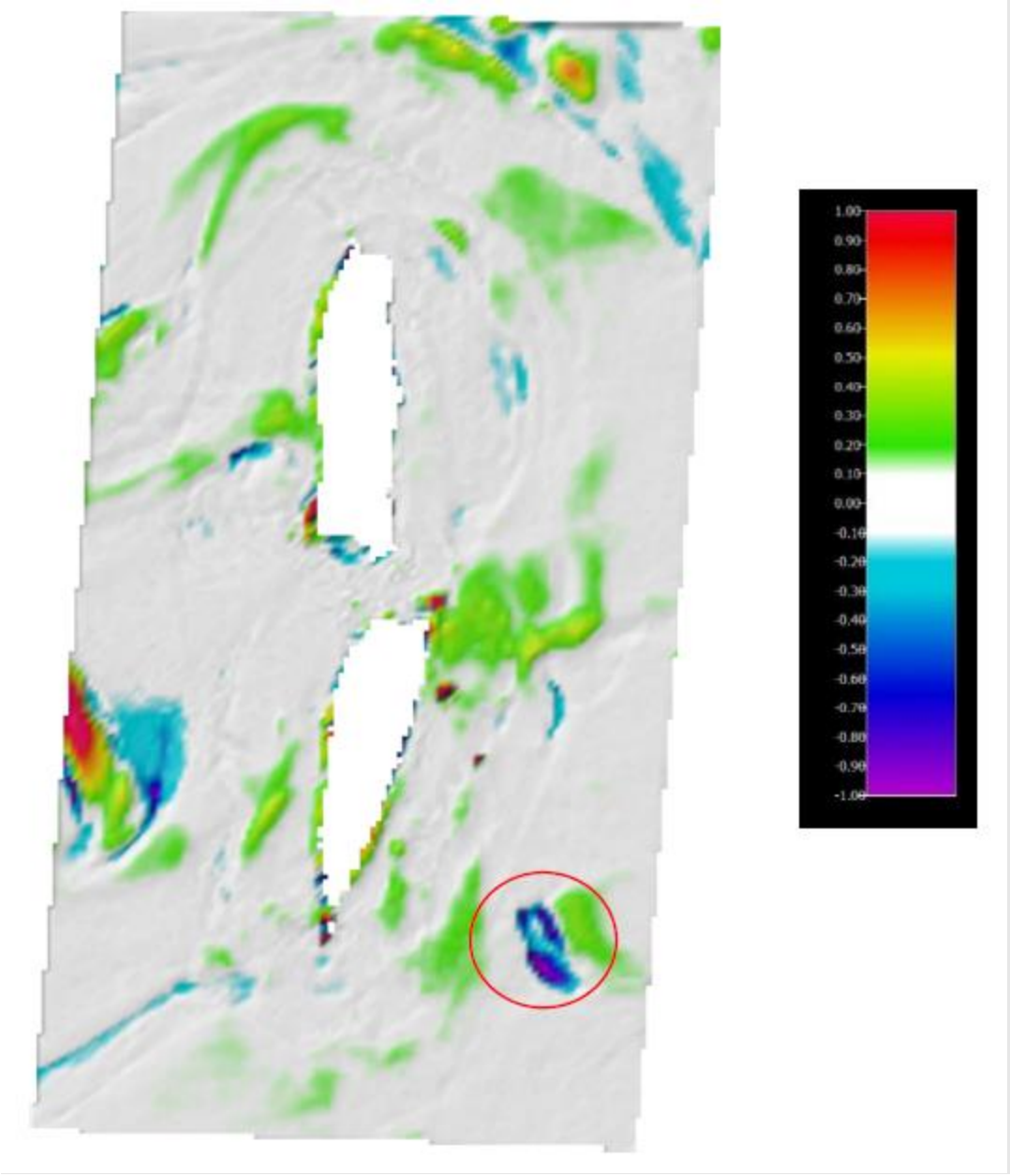

Figure 46 Surface difference results between the 2017 and 2018 surveys.

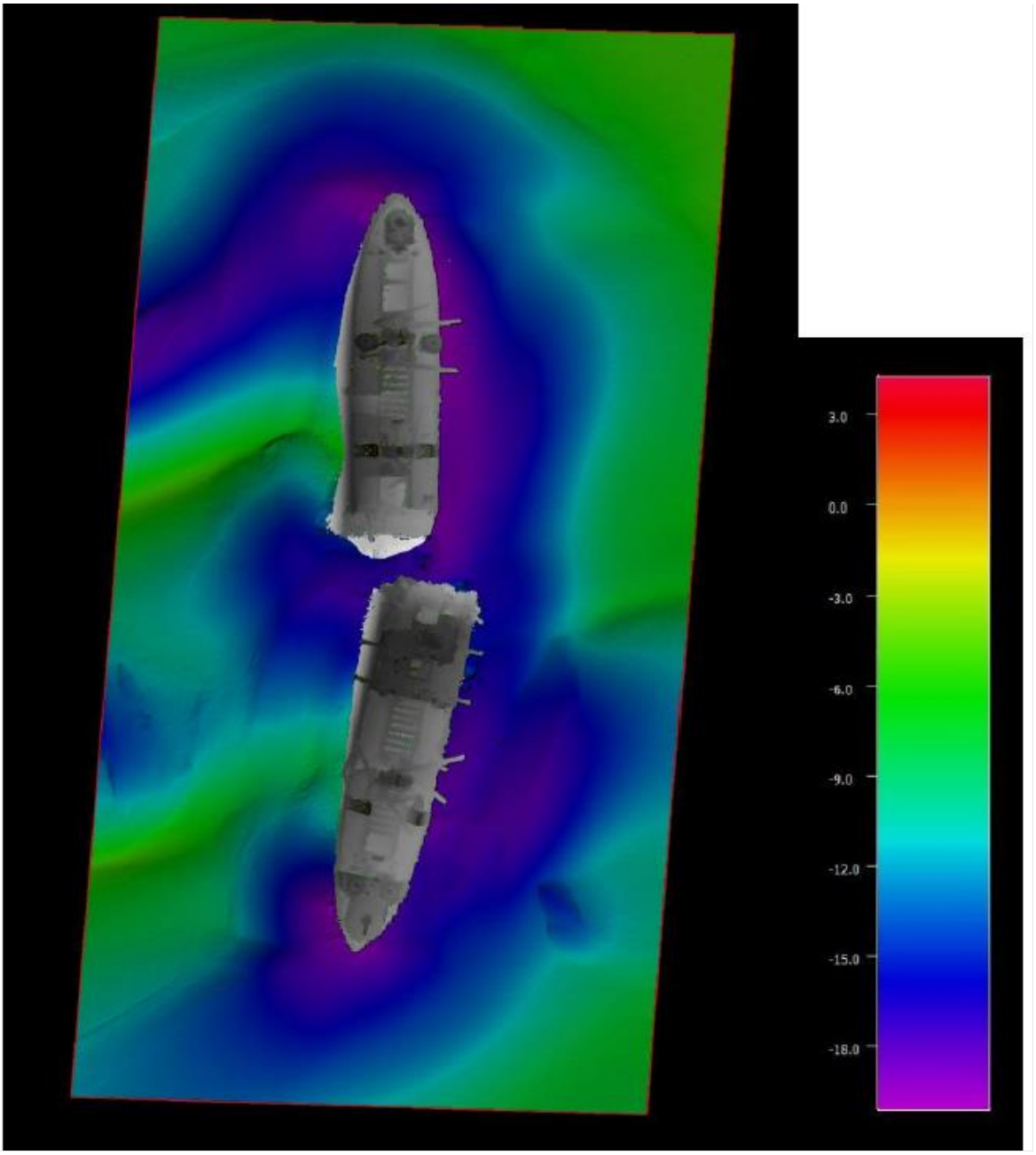

Figure 47 2018 survey 0.25m shaded relief bathymetry.

5.2 Seabed between forward and aft sections

5.2.1 A surface difference plot shows evidence of a minor loss of material in the gap between the two sections. Whilst not immediately clear in the 3D point cloud data, a profile view in CARIS shows elevated debris that was previously overhanging but now has now broken off leading to a loss of elevation (Figures 48 and 49).

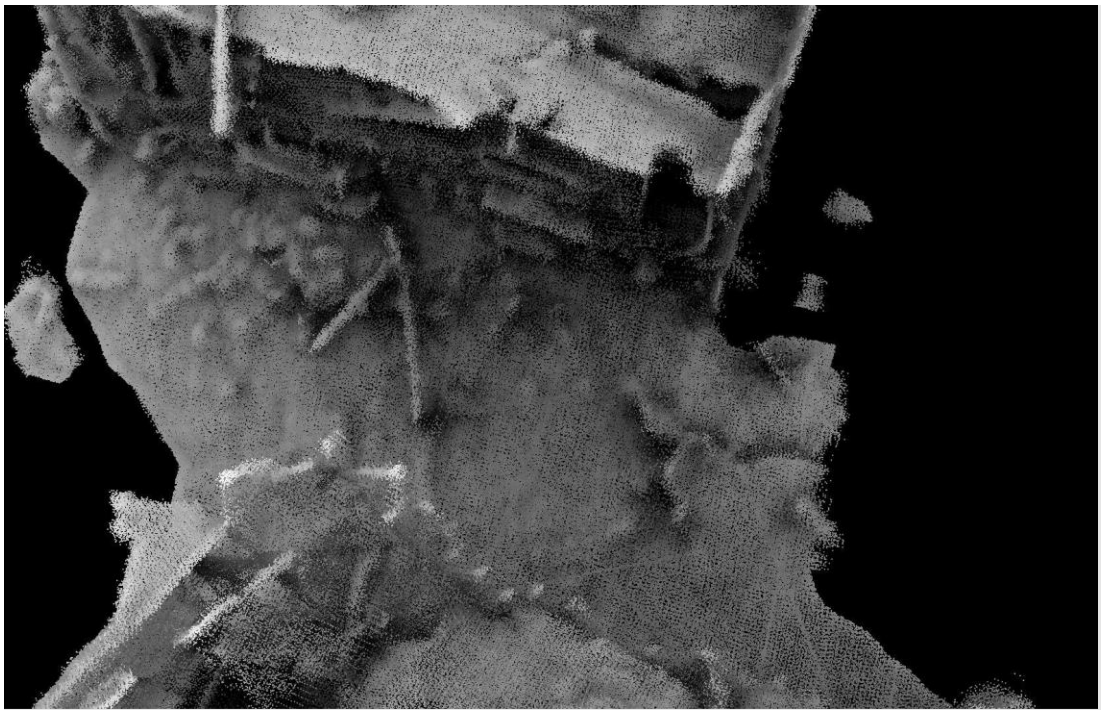

Figure 48 2017 Survey between the fore and aft hull sections.

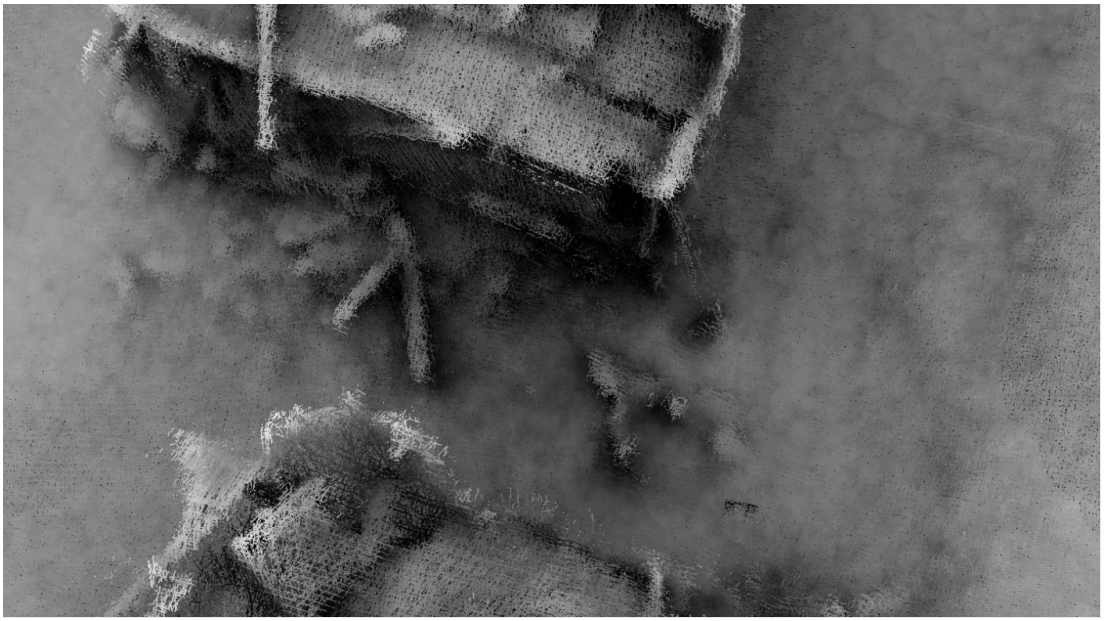

Figure 49 2018 Survey between the fore and aft hull sections.

5.3 Cefas Equipment

5.3.1 A further brief survey was undertaken to confirm the position of some Cefas instrumentation that had been deployed just outside the SSRM Exclusion Zone.

5.3.2 The Cefas seabed MiniLander, equipped with oceanographic recording equipment, was successfully located and no scouring was evident on the seabed around the lander in the data collected. Figure 50 and Figure 51 show the Cefas equipment on the seabed.

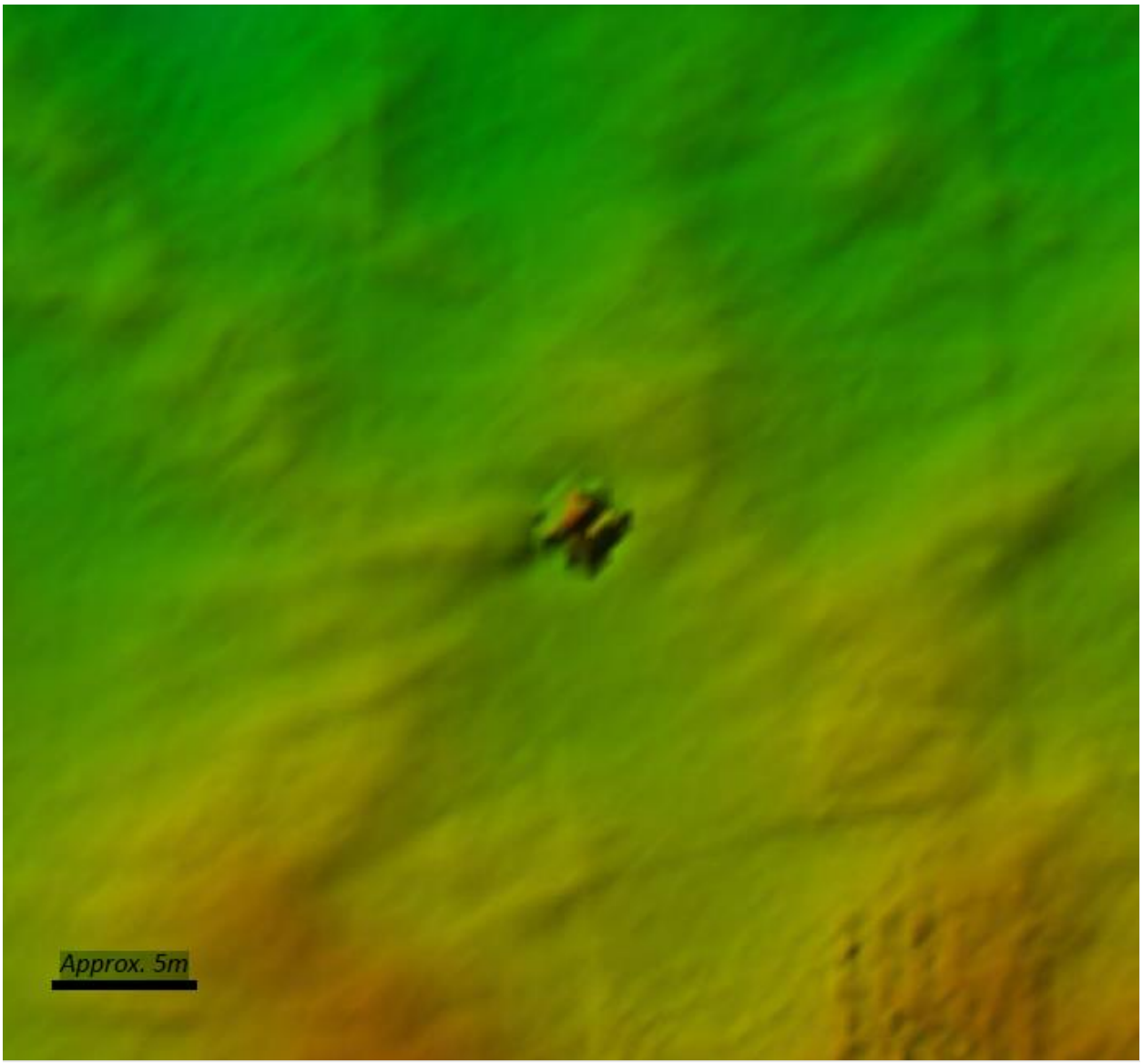

Figure 50 Shaded relief bathymetry of CEFAS MiniLander on seabed.

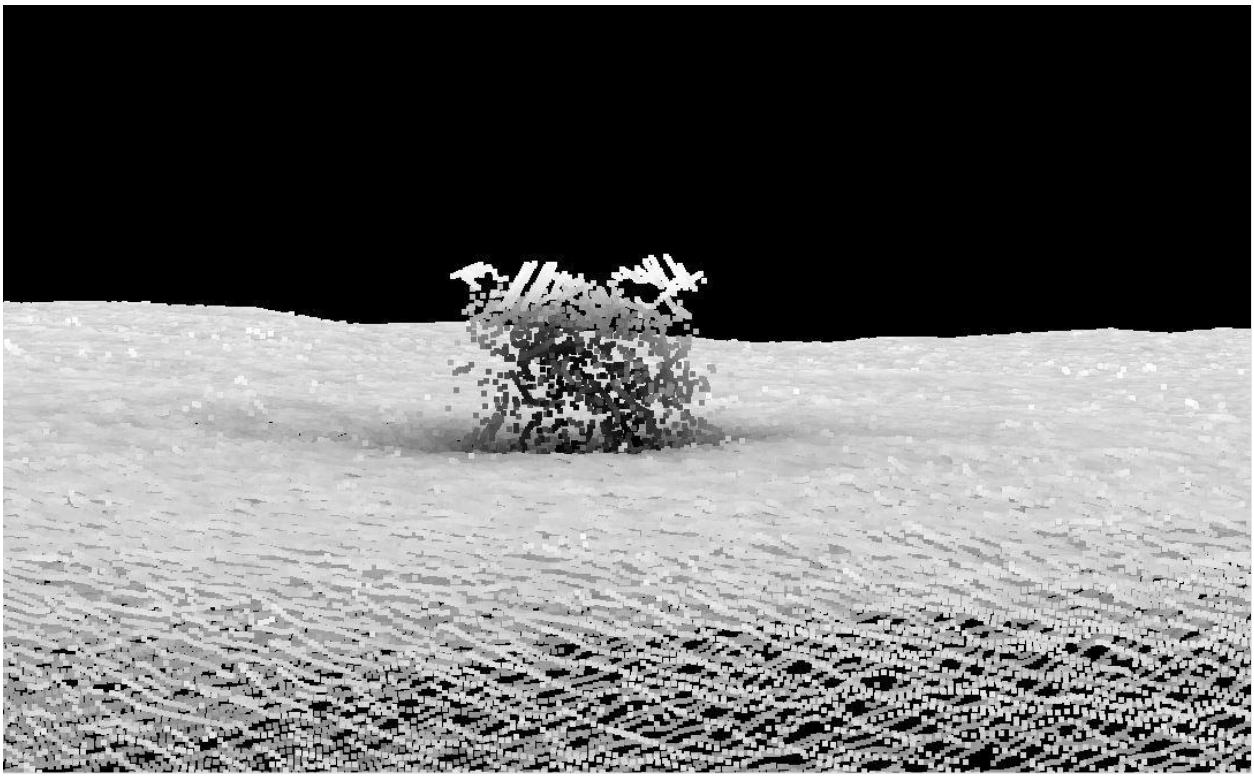

Figure 51 Point cloud imagery of CEFAS seabed instrument.

6 Conclusions

6.1.1 The results of the 2018 survey have been assessed by a thorough comparison of point cloud and sliced historical HDCS CARIS data. The data have been compared in a systematic way, which provides the most successful way in measuring the degradation of the wreck.

6.1.2 To provide consistency in reporting the current state of wreck degradation, the paragraph layout has remained consistent with previous reports and identical images and measurements reproduced where possible. Nomenclature and vessel structural ID remained the same to replicate the previous survey report so a true comparison could be made.

6.1.3 The 2017 and 2018 survey datasets were compared to get an indication of the current evolution of the degradation of the SSRM.

6.1.4 As with the previous methodologies for processing and visualisation of the wreck, the data has been displayed in Cloud Compare for all 3D point cloud images. Cloud Compare contains specialised shading tools which facilitate the high-quality visualisation of point cloud images. Any comparative measurements have been made in CARIS HIPS and SIPS where the data sets can be sliced and spatially compared with greater accuracy.

6.1.5 Deterioration of the wreck was shown to be lower than previous surveys with fewer areas of changes noted. The key finding in the analysis of the 2018 survey data was the forward edge of the aft wreck section (Key Area 6, ID43, 45 & 46) and encompasses the boiler room casing, the collapsed boat deck, the remains of the bridge deck, and accommodation block. Following its collapse between 2014 and 2015, this area has remained reasonably stable with one further area of subsidence noted on the starboard boat deck with several of the previous hanging sheets of metal breaking free and now residing on the seabed. Differences of less that 1m are noted on the difference plot and consist of smaller sheets of decking subsiding.

6.1.6 The fractured deck plate at the Key Area 2- ID 08, (collapse of the hold 2 cargo deck) has remained stable over the past year. Subsidence was noted between 2016 and 2017.

6.1.7 Key Area 5 - Split in deck and hull (ID24 &ID25). The split in hull remains in the same state of deterioration and the contents inside the crack have been

ensonified to the same level as previous surveys. There is evidence of upwards buckling of the deck plate by 0.2m forward of the split.

6.1.8 Key Area 4 - the splitting of the hull has not shown any evidence of deterioration when compared with previous datasets.

6.1.9 Key Area 3 - the aperture at the aft of the forward section was surveyed with good clarity and no changes have been noted to the opening. The cargo inside was ensonified to a height of 8m CD.

6.1.10 Surface difference across the wreck has shown a general reworking of sediments with changes of up to 0.3m seen across many of the decks. Sediment reworking is evident in the lower holds and is deemed to be of a cyclical nature, varying through tidal patterns and storm events.

6.1.11 The 2018 survey provided a high-resolution dataset which compares well to the previous dataset. Deposition has occurred on the starboard side of the of the aft section the wreck, with an increase in sediment of up 0.5m.

6.1.12 Small patches of scouring occur around the survey area with the deepest scouring located approximately 35m southeast of the aft section where localised scouring has occurred. The shape of this localised scouring can be seen in Figure 46 above and appears to be angular in nature. To the west of the wreck there is also evidence of sand wave migration in a north westerly direction.

6.1.13 The previous seabed contact list was overlaid on this year's bathymetry data. One item from the contact list falls within the survey area. This contact is still present.

6.1.14 The survey just outside the no-entry exclusion zone successfully located the Cefas subsea instrumentation within 4m from its quoted position.

6.1.15 No scouring was evident on the seabed around the Cefas lander in the collected data.

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