HMS Colossus

Stabilisation Trial

Project Design

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Project Design - Colossus Stabilisation Trial

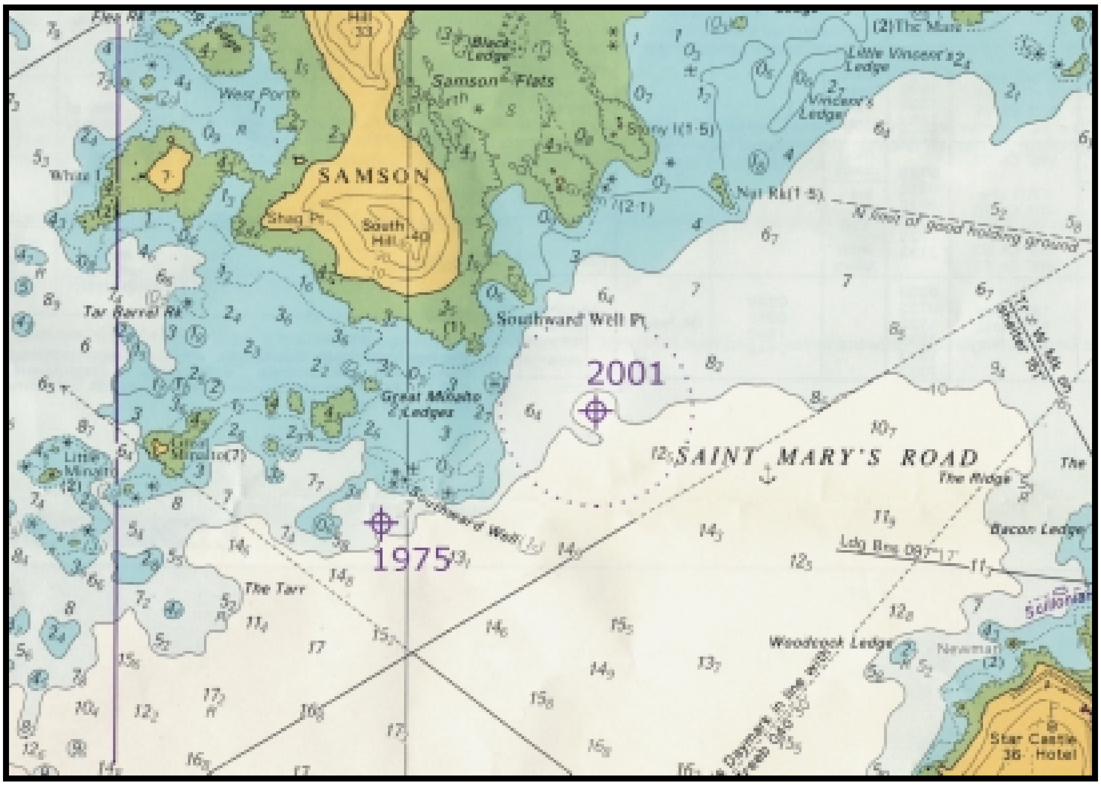
This project design was commissioned by English Heritage – project number 3593.

Background

Site description

Location

The wreck of HMS Colossus lies to the south of Samson in the Isles of Scilly. There are two main areas of wreckage, lying some 750m apart. In 1975 part of the wreck (probably the bow) was designated under the Protection of Wrecks Act. This designation was revoked in 1984. The current site, which was discovered and designated in 2001, is located at Latitude 49˚ 55'.471N, Longitude 006˚ 20'.505W (260154.906E 5535593.077N UTM zone 30, WGS84[1]).



Location Plan – Shown are the locations of the 1975 designation and the current site, designated in 2001. The dotted circle shows the extent of the current designated area.

The stabilisation trial outlined in this project design will take place within the current designated area.

[1] The survey work undertaken in 2001-2 used positions and grid references in UTM coordinates using zone 30 based on the WGS84 datum. The designation under the Protection of Wrecks Act gives the position in latitude and longitude.

Period & Type of Site

HMS Colossus was a 74 gun warship built in 1787 and wrecked off Samson in the Scillies in 1798. These 74 gun ships were one of the most successful types of the period. They were typically about 51m (170 feet) in length and had a crew of about 600. During her relatively short working life (11 yrs) she saw action at Toulon, Groix and Cape St Vincent.

In December 1798 she was on her way home to England with wounded from the battle of the Nile and with cargo including Sir William Hamilton's collection of Etruscan pottery. She was sheltering from a gale in St Mary's Roads when the anchor cable parted and she was driven onto Southward Well rocks to the south of Samson. All but one member of the crew were taken off safely before Colossus turned onto her beam ends and proceeded to break up.

Condition of Site

The site lies in a depth of about 10m of seawater at LAT[2]. The seabed around and over the site consists of coarse, white sand with fine crushed shell. Timber elements of the wreck are currently exposed on the seabed. This exposure is recent (otherwise the timber would have decayed) and appears to be due to ongoing erosion of sand from the site.

Previous work

Synopsis

Colossus was originally designated under the Protection of Wrecks Act in 1975 when Roland Morris worked on what was probably the bow section of the wreck. He recovered a large number of pottery sherds from Sir William Hamilton's collection, which are now in the British Museum. He also recovered a number of other artefacts, including iron cannon. This designation was revoked in 1984. The records relating to this work have so far not been located[3]; hopefully the recently commissioned Colossus DBA will bring them to light.

In 2001 the current site was discovered some 750m to the east of Roland Morris' site. Considerable amounts of timber were exposed on the seabed along with a row of five iron guns, standing upright, their muzzles buried in the sand – still within their gunports! Most striking of all was a twice life-size carved wooden figure, part of the stern decoration of Colossus, lying face upwards on the sand. The licensee Mac Mace and the Archaeological Diving Unit together undertook an excavation in September 2001 to recover the stern

[2] Lowest Astronomical Tide

[3] Roland Morris did however publish a popular account: *HMS Colossus – The story of the salvage of the Hamilton treasures*. Roland Morris London 1979.

decoration. This, however, proved to be too extensive to recover with the equipment available; it was therefore reburied for the winter. The area around the stern of the vessel was surveyed prior to the excavation by means of a photomosaic. The remainder of the exposed elements of the vessel were surveyed by conventional base-line survey while the excavation was in progress.

Three main tasks were undertaken in the 2002 season. The base-line survey started in September 2001 was augmented. The excavation and recovery of the stern decoration was completed and a small trial excavation within the hull of the vessel was undertaken. All this work was funded by the licensee, Mac Mace.

Location of existing archive

Copies of the survey reports for the work undertaken in 2001 and 2002 have been deposited with the National Monuments Record Centre in Swindon. They have also been submitted to the Advisory Committee on Historic Wreck Sites at the Department for Culture, Media and Sport. Copies have also been given to Wessex Archaeology, who are currently undertaking a Desk Based Assessment of the site for English Heritage.

Results of previous work

The work on site in 2001 and 2002 has established that the surviving timber represents the port side of the vessel from just forward of the main mast to the stern, and from the quarter deck rail to just below deck level on the orlop. This is lying with the port side down, partly buried in the seabed. The timber elements exposed on the seabed are part of the inner hull of the vessel.

A survey has been made of the timber which was exposed on the seabed; this was drawn at a scale of 1:20 and georeferenced. The survey shows the state of the exposed timber as of late June 2002, when survey was last undertaken. It is probable that further timber has been exposed since then.

Part of the stern decoration in the form of a carved wooden figure was recovered during 2002. This is now in passive holding in a tank on the island of Tresco – awaiting conservation by Mary Rose Archaeological Services.

The results of this work are all detailed in the Colossus 2002 Survey Report.

Reasons for undertaking the project

What makes this wreck so different from the many others in Scilly is the extent and extraordinary preservation of the timber. When first exposed the timber is in remarkable condition. It was clear from the start that this timber had not been lying on the seabed for the last 200 years. Indeed, by the end of

2002 it was apparent that timber which appeared perfect when first seen in 2001 had become decayed and gribbled. Furthermore, it became clear that more of the wreck was being exposed on the seabed as time went on. What exactly is causing this loss of sand from the site is not clear – but the sand levels have continued to fall over the site since 2001.

There were approximately 125 square metres of timber exposed on the seabed in August 2002, when the site was last systematically inspected. From the survey it would appear that there was about 80-100 square metres of timber still buried on the site at that time. From the trial excavation conducted in 2002 it was apparent that the depth of sand over the buried timber varies between 0.05m and 0.80m.

The timber which is currently exposed on the seabed will deteriorate rapidly and will soon be lost forever. If the fall in sand levels continues, more timber will be exposed and in turn begin to deteriorate.

The threat

The fabric of the vessel is remarkably well preserved; however once it is exposed on the seabed deterioration due to biological decay is fairly rapid. The timbers of the vessel are being exposed due to the sand of the seabed being eroded. The precise reasons for this erosion are not known but a more detailed discussion of this phenomenon is presented in appendix III of the 2002 survey report. The deterioration in the exposed timber in the 12 months between discovery and final survey was marked. Timbers which appeared perfect in June 2001 were visibly gribbled and decayed by June 2002. Once the timbers are weakened by biological attack they will be subject to detachment and dispersal by the tide and wave surge during winter storms.

Legal Status

The current site is designated under the Protection of Wrecks Act 1975 (order number 2403, 5th July 2001). The designation extends for a distance of 300m from position Latitude 49° 55'.471N, Longitude 006° 20'.505W.

The bows of the wreck (the Roland Morris site - Latitude 49° 55'.250N, Longitude 006° 21'.003W) were designated on 12th May 1975. This designation was revoked 7th February 1984.

The site is within an area designated as a candidate Special Area of Conservation (cSAC), EU site code 0013694, administered by the UK Marine SACs project and English Nature.

Timing

The best time to undertake installation of the protection trial would be in May 2003. Because Scilly is a popular tourist destination it is extremely difficult to book accommodation and transport materials during the months of July and August. It would be best to install early in the season to allow for retrieval of the wood samples at the 3 and 6 month intervals during summer. After late September weather is increasingly a potential problem to operations.

Early installation would also allow some preliminary results before the end of the year. This would be important if it was decided to make some partial protection to the wreck itself prior to the onset of the winter storms, usually in late October.

Access

As the trial will be conducted inside the designated area a licence to survey will be required from DCMS/English Heritage under the Protection of Wrecks Act 1975. To retrieve the timber test blocks any sediment which has accumulated over that part of the test mat will need to be excavated to recover the blocks. This could be interpreted as excavation, in which case a licence to excavate would also be required.

If data logging is to be included in the trial then a licence to excavate will certainly be required in order to bury the mooring block needed to anchor the data logging equipment.

It is also possible that a licence will be required from the Ministry of Agriculture, Fisheries and Food under the Food and Environment Protection Act 1985 part II (FEPA). This relates to anything placed on the seabed. In view of the site's cSAC status it seems likely that MAFF and English Nature will in any case need to be consulted.

Reinstatement

At the completion of the trial all the material installed on the seabed for the trial will be recovered. The seabed will be left as far as possible in the same state in which it was found. As the trial will be conducted away from the wreck there is unlikely to be any disturbance of archaeological material.

Archive deposition

Where

There will be no artefacts recovered by this project. Data and photographs will all be incorporated into the report. Copies of the Stabilisation Trial Report will be deposited with the National Monuments Record Centre in Swindon and the Cornish Sites and Monuments Record.

Recording requirements & Data storage

The report will be produced in electronic format as well as on paper. Thus a CD containing the report and all the data collected by the trial can be offered to other interested bodies – for example the Isles of Scilly Museum.

Aims and Objectives

Research design

The intention of the stabilisation trial is to ascertain whether it is possible to protect the timber which is currently exposed and to prevent the buried timber from becoming exposed. Various strategies exist for accomplishing this. The aim of the trial is to establish the efficacy and economic viability of three different protection strategies in the conditions prevailing on this site. By recording the prevailing conditions on the site it is hoped that a link can be made between the protection methods and the environmental conditions prevailing.

The results of this trial will not only inform the ultimate protection strategy for Colossus but may also be of value in suggesting strategies for other submerged marine sites.

There are two main criteria for judging the success of any particular protection scheme. Firstly, how effective is the method at preventing sediment erosion and attracting sediment deposition? The depth of any sediment accumulated will be measured in each case. Any significant accumulation of sediment will effectively result in the exposed timber being reburied. Secondly, what is the protection offered by each scheme to the timber of the vessel? This will be determined by the placement of standard timber blocks of oak and pine beneath each of the protective coverings. These will be retrieved for analysis at intervals of 3, 6, 12 and 24 months and the degree of biological decay and abrasion measured.

As well as determining the level of protection offered by each scheme it will also be established how much each method costs and whether any special problems are associated with it. From this information it should be possible to recognise which method is the most appropriate to the conditions, site importance and available resources.

At the same time as the trial areas are monitored, the sediment levels around the wreck will also be measured. This will help to establish the prevailing sediment variation at the time of the trial.

The contribution to archaeological knowledge

The stabilisation trial should allow the different methods of stabilisation to be quantified in terms of efficacy and cost. It should also be possible to identify any potential problems or difficulties associated with the protection methods under consideration. This should allow other sites to be stabilised by the most cost effective method without the need for further trials.

Integration with existing research

The use of the synthetic mesh protection method in this trial was informed by work carried out by Martijn Manders on the BZN 10 wreck and others. Correspondence with Martijn has established that considerable success has been achieved with this method; I am indebted to him for supplying details of his technique and materials. It is hoped that inclusion of the method in the trial will allow a quantified comparison with the other methods under trial. It would be helpful if the dialogue with Martijn Manders was maintained throughout the progress of the trial.

Integration with non-archaeological research

A number of survey reports by English Nature have been produced between 1978 and 1998 – some of which concern the area of the Colossus designations. It is presumed that the recently commissioned DBA will assess the scope and archaeological relevance of this work. Of particular interest is English Nature report 276 – *Isles of Scilly subtidal habitat and biotope mapping survey*. This survey included data collected using a RoxAnn Groundmaster system and a Dowty Widescan sidescan sonar. The survey area included the currently designated site and most of St Mary's Sound.

Any data collected from the seabed in this area may be of interest to English Nature and the possibility of collaborative data acquisition should be considered.

Publication

Intended publication

At the completion of the trial an outline of the methods used and conclusions reached will be offered to IJNA. To this end the editor, Paula Martin, has been contacted. She has said that she is happy to receive a submission once the work is completed but that publication in IJNA cannot be guaranteed.

Display & public information

A popular article explaining the trials could be offered to the local Scilly press/newsletter. These publications have shown considerable interest in the project in the past.

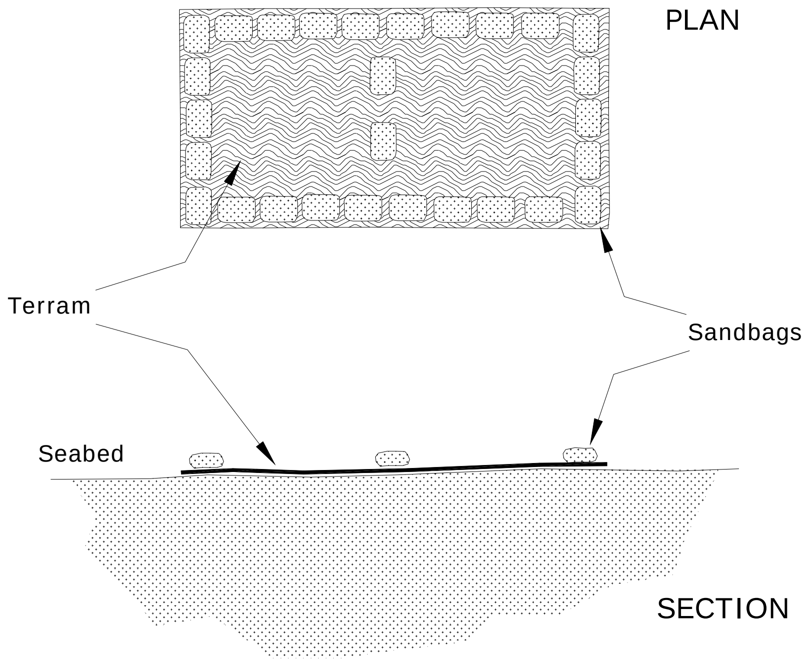
Methods Statement

Methods of stabilisation

The methods under consideration are all intended to help preserve timber and possibly encourage the deposition of sand over the area treated. Three different methods will be deployed and compared:

ST1. Terram 4000

Terram has already been used on site, notably for the reburial of the stern carving from September 2001 to May 2002. It was also used over the backfilled trial excavation. We have deployed this weighted down with sandbags. It seems to attract a limited amount of sand accumulation (typically 2-5cm) but no systematic trials of this method have yet been conducted on site. The material is cheap and easy to install.

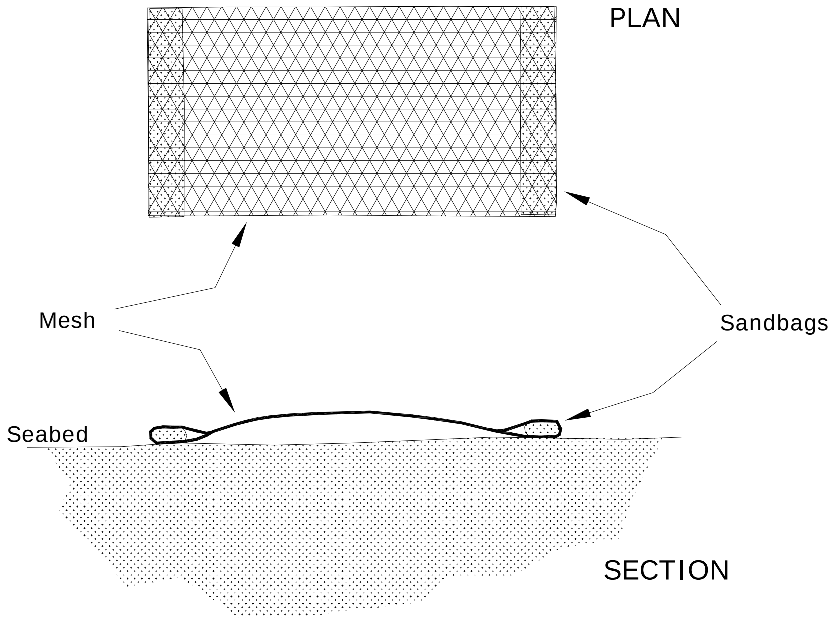


The Terram mat, 5m x 2.5m will be laid on the seabed and weighted down using continuous lines of sandbags around the edges. Some sandbags will be placed over the inside of the mat to prevent billowing. Standard sandbags will be used. These will be 0.75m x 0.45m and constructed of laminated polypropylene. Each bag will be pre-filled with 25kg of coarse builders' sand and closed using a polypropylene tie.

Further information and data sheets for Terram 4000 can be viewed at http://www.terram.com

ST2. Synthetic Mesh

This method has been used by Martijn Manders on the BZN 10 wreck. A fine polypropylene mesh is anchored to the seabed at its ends – the middle of the mesh is allowed to float above the seabed. This apparently encourages sediment deposition and forms '*an artificial reef from sand and gauze'.*



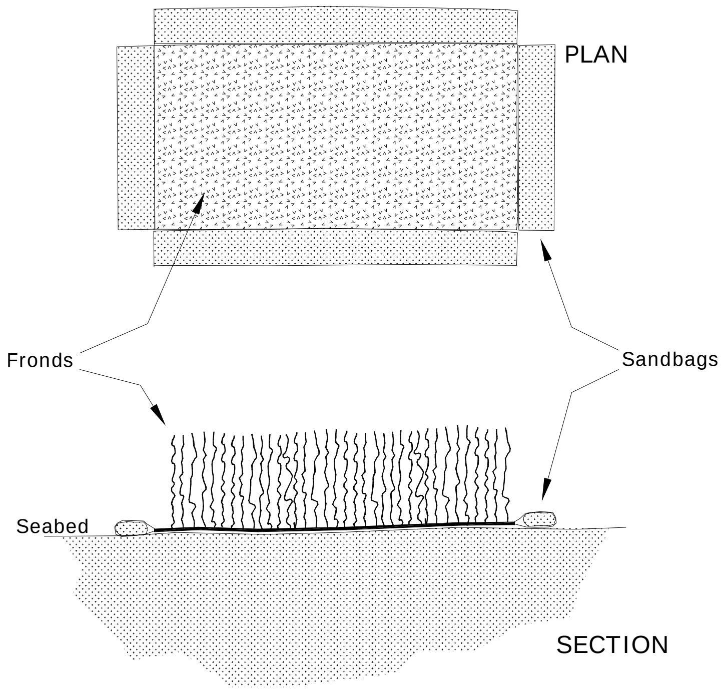
A polypropylene mesh with small aperture size will be deployed in a mat 5m x 2.5m. This will be held in position by securely enclosing a continuous line of 'standard' sandbags along the short (2.5m) sides of the mat. Cable ties will be used to fasten this enclosure. The centre of the mat will be allowed to float approximately 0.50m above the seabed.

Martijn Manders has very kindly supplied details of this system including information not on the MoSS web site. Apparently, the mesh is subject to tearing and the holes can become blocked with weed or 'growth'. If this happens another layer of mesh is simply laid over the top of the old. The low cost of the mesh may make this a viable approach.

Further details can be viewed on the MoSS web site at
http://www.nba.fi/INTERNAT/MoSS/bzn10eng.htm#Protecting

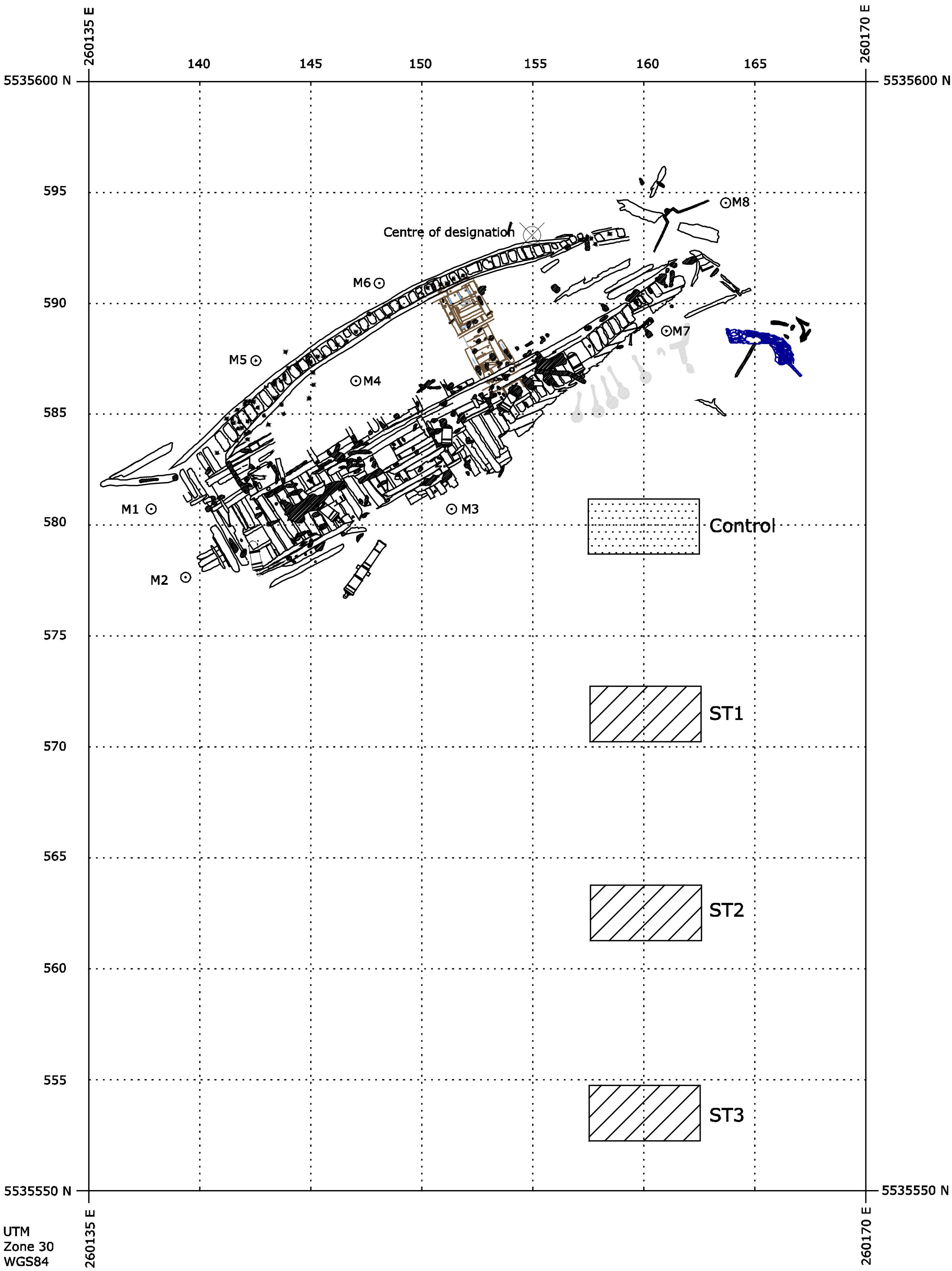
ST3. Frond Matting System

This is a commercially available system developed by Seabed Scour Systems Ltd. These mats consist of a Terram-like base material with attached floating fronds, which it is claimed will encourage the rapid deposition of sand. The mats are said to be 'self burying' and the depth of sand deposition can apparently be controlled by the frond length. Standard mats are 5 x 2.5m and cost in the region of £500 each. Phil Rees, a local marine geologist, has arranged for Seabed Scour Systems to donate one of these frond matting systems for the stabilisation trial. The only cost for the trial will be transporting the mat to Scilly.



The mats are usually anchored to the seabed using a system of intrusive iron fastenings c.1m long called 'safe anchors', or by concrete base mats. Intrusive steel 'safe anchors' are clearly not suitable for use on a fragile wreck site. The concrete base mats may be suitable but could cause difficulties where there are large amounts of upstanding ferrous concretions – as is the case on Colossus. For these reasons we are proposing to use continuous lines of sandbags contained in polypropylene mesh tubes attached to the edges of the mats with cable ties.

Further details and data sheets for the frond mat system can be viewed at http://www.scourcontrol.co.uk



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5535550 N
5535550 N
Centre of designation
M1
M2
M3
M4
M5
M6
M7
M8
Control
ST1
ST2
ST3
260135 E
260170 E
UTM
Zone 30
WGS84

Deployment

All three protection methods will be deployed in the trial. The area of the trial will be some distance from the surviving timbers, about 25m to the south of the wreck. The designation extends some 300m from the wreck so the trial would still be within the designated area. Each trial will consist of a rectangle 5m x 2.5m, spaced evenly across the main tidal flow[4] so that each area is subjected to similar conditions and is not affected by any sediment accumulation engendered by adjacent areas. These are shown as ST1, ST2 and ST3 on the trial location plan above. A control area will also be marked out but no protection will be installed in the control area.

There are good reasons for conducting the trials away from the structure of the wreck. Firstly, we will not be affecting the wreck itself should anything go wrong – there is always the possibility that we will cause scouring of the seabed as well as the protection we are seeking. Secondly, if the frond matting, in particular, performs as claimed it would, if deployed on the wreck, bury our existing primary control points rendering any further survey more difficult. We should certainly consider extending the fixed control points beyond the area of the wreck before we attempt to bury it.

Inspection

Each trial area will be inspected at the same time as the standard timber samples are retrieved for analysis – at intervals of 3, 6, 12 and 24 months after installation. Any problems or failures will be noted at these times and if practical, repairs will be effected. The amount of maintenance required by each system and especially how well they stand up to the winter storms will form an important part of the trial.

Measuring sediment accumulation

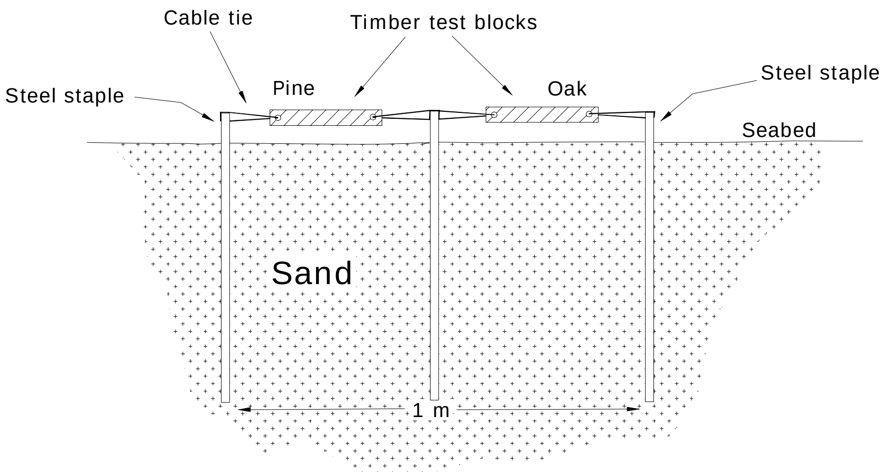
The depth of any accumulated sediment can be measured directly in the case of ST1 (Terram) and ST3 (Frond Mat) by measuring from the top of the sediment to the mat. A slightly different approach will be needed in the case of ST2 (Synthetic mesh) as sediment accumulation may occur under the mesh mat. Therefore sediment height will be referenced to the steel staples used to hold the timber blocks in place (see sketch below). The sediment height can also be recorded in the control area using this method.

Sediment level readings will be taken at installation and at 3, 6, 12 and 24 months after installation – at the same time as the standard wooden blocks are retrieved for analysis.

[4] The tide floods across the site roughly west to east and ebbs in the opposite direction.

Measuring timber preservation

Standard wooden blocks of oak and pine will be installed under the three 'mats' in each of four separate locations so that they can be retrieved at intervals of 3, 6, 12 and 24 months for analysis. The blocks will each be 0.20 x 0.075 x 0.025m. The supply and analysis of the blocks will be undertaken by Dr Mark Jones of Mary Rose Archaeological Services – see appendix I. The blocks will be placed in pairs (one oak, one pine) towards each of the corners of the mat so that retrieval can be effected without disturbing the remaining blocks. The blocks will be secured with cable ties between steel staples driven into the seabed – see sketch below. Blocks would also be placed on the seabed in the adjacent unprotected area designated as the control area.



Data logging

The possibility of collecting data relating to the sub-seabed conditions in the immediate vicinity of the standard timber blocks must be considered. Communications with Ian Panter, English Heritage regional science advisor has highlighted the desirability of collecting this data. Ian has said that the value of the trial would be enhanced by determining the changing environment as the mats cause burial of the timber blocks. To this end a quote for the supply of an underwater data logger has been obtained from Eauxsys of Camelford – see appendix III. The price quoted includes data retrieval software and training in data retrieval, recharging and recalibration.

The proposed system would monitor redox, pH, dissolved oxygen, temperature and pressure (and hence depth). It is capable of storing three months' of readings when data is automatically collected once an hour. Although the cost of the monitoring equipment is relatively high, the equipment would be reusable on other projects once the stabilisation trial was complete.

As only one location can be monitored at once the data logging probes would be installed in the first instance next to the timber blocks under ST3 - those scheduled for retrieval after three months. Thus three months worth of data would be collected from under the frond mat in the vicinity of the 3 month blocks. The reason for choosing this trial mat first is that it is the system considered the most likely to cause rapid sediment accumulation.

After the first three months the probes would be placed in the location under ST2 where the three month blocks were retrieved from – the next three months would then gather data on how long ST2 took to establish stable conditions in the area of the probes. Another set of 3-month blocks would be installed at this time adjacent to the probes to allow the condition of the blocks to be directly related to the data collected. This is dependant on the speed, depth and nature of the any sediment accumulation formed by system under trial.

The data logger would then be recovered for the winter. This is because retrieval in November-December could be problematic and there is a greater risk of the unit being damaged in the winter storms. The data logger would be redeployed with the sensors positioned under ST1 when the 12 month blocks were recovered (spring 2004).

The result of this series of deployments would be a set of '3-month' test blocks from each of the three geotextile mats with a set of corresponding data from the sub-sea data logging. This data would consist of redox (ORP), pH, dissolved oxygen, temperature and depth readings taken once every hour for a three month period from the immediate area of the corresponding timber test blocks.

Mark Jones has stated the usefulness of using data loggers to monitor the conditions under the geotextile mats – see appendix I. However, he also recommends the use of four data loggers (or possibly one with four sets of probes) so that the readings are made simultaneously (i.e. subject to the same seasonal variations). This would be an extremely costly operation. The cost to benefit ratio would need very careful scrutiny.

David Gregory recommends that the use of any data logger is deferred until the results of the MoSS trials are published, probably in 2004 – see appendix IV. As the trial needs to be installed early in the year, and no later than May (in order for the 3 and 6 month retrievals to take place before the winter), this would effectively delay the trial until 2005. Given the current rapid deterioration of the site I feel that this timescale is unacceptable.

In view of these conflicting opinions I have included schedules and budgets for the project with and without the sub-sea data logging. If a consensus on the use of a data logger cannot be reached then the trial should be monitored using the standard timber blocks only.

It should be pointed out that if it is decided to deploy the sub-sea data logger that it takes 6-8 weeks to manufacture. Thus it would need to be ordered by the end of March 2002 to be sure it would be ready in time to deploy in the installation phase of the project in May 2003.

For a more detailed timetable of the logistics of data logger deployment see the 'Timetable' below.

Background Sediment levels

It is proposed that, at the same time as the geotextile trial mats are installed, a number of sediment level monitoring points are established around the wreck. The positions of these are shown on the plan of the trial areas labelled M1-M8. These will consist of 10mm x 0.50m steel reinforcing rods driven into the sand. The locations chosen include positions in close proximity to the edges of the surviving structure – where any scouring is most likely to occur. These points will be georeferenced by direct measurement from the existing primary control points.

The height above sediment will be measured from the top of these pins to a 1m straight edge placed on the seabed in two directions (north-south and east-west). Using this method any localised scouring caused by the steel pin itself will not affect the readings. Measurements will be taken at installation (May 2003) and at the monitoring intervals (3, 6, 12 and 24 months) when trial mats are monitored and the sample timber blocks are recovered.

Resources and programming

Staffing and equipment

The team

Archaeological Manager	Kevin Camidge
Diving Manager	Mac Mace
Standby Diver	Andy Williams
Survey Assistant	Anna Cawthray
Consultant	Dr Mark Jones (MRAS)

Kevin Camidge was the archaeologist responsible for the survey and excavation work undertaken on HMS Colossus in 2001 and 2002. He produced the report of this work in the 2001 and 2002 Colossus Survey Reports.

Mac Mace is a commercial diving contractor in the Isles of Scilly. He is currently the contractor responsible for maintaining the moorings in the Scillies for the Duchy of Cornwall and for Tresco estates. He has successfully completed major diving contracts in the islands including the rebuilding of St Mary's Quay in 1997. He completed an NAS I training course in 2001. He was also the licensee during the survey, excavation and recovery operations on HMS Colossus in 2001 and 2002. He has his own purpose built diving support vessel which comes complete with standby diver (Andy Williams) and boatman (Paul Jane).

Anna Cawthray is a professional dive instructor who works in the Isles of Scilly. She has completed an NAS I training course and was a member of the HMS Colossus survey team in 2001 and 2002. Her knowledge of the site and its control points will be invaluable to the project.

All the members of the team have worked on the survey and excavation of this site during the 2002 season. They are all familiar with the site and its conditions, and more generally with the difficulties of working in Scilly. The team is used to working with each other and know what can be expected of each other.

Team tasks

The project will be managed and written up on completion by Kevin Camidge, who will also be responsible for producing the periodic progress reports for English Heritage. Dr Mark Jones of Mary Rose Archaeological Services will be responsible for the supply and analysis of the standard timber blocks used in the trial (see appendix I for details). He will also undertake the analysis of the data recovered from the sub-sea data logger if it is deployed as part of the trial. He will submit a report to the project manager for inclusion in the final Stabilisation Trial Report.

Mac Mace will be the diving contractor on the project. He will provide the diving support vessel, diver, boatman and standby diver. He will undertake, under the supervision of the project manager, the installation of the matting system and any excavation required to enable the test blocks to be retrieved. All work will be carried out to the relevant Health and Safety regulations.

All survey and position fixing will be performed by the Project Manager (Kevin Camidge) supported by the Survey Assistant (Anna Cawthray). They will also be responsible for installing, retrieving and maintaining the sub-sea data logger if it is deployed.

Materials

3	Geotextile mats,	ST1 (Terram 4000)
		ST2 (Synthetic mesh)
		ST3 (Floating frond mat)
20	Standard pine blocks 0.20 x 0.075 x 0.025m	
20	Standard oak blocks 0.20 x 0.075 x 0.025m	
120	Sand bags – 0.75 x 0.45m each pre-filled with 25kg coarse sand.	
50	Steel staples 0.50 x 0.15m formed from 10mm reinforcing rod	
25	Steel survey pins 0.40m x 10mm diameter	
25	Steel survey pins 0.50m x 10mm diameter	
300	Assorted cable ties	
3	30m survey tapes	
2	Drawing boards	

Misc. stationery and drawing supplies and packing materials.

Equipment

Mac Mace has tendered to supply the diving support vessel (details below) with HSE diver, standby diver and boatman as a package. He also carries $1 million employers and public liability insurance.

Diving support vessel (Mac Mace)

Purpose built dive support boat, of all steel construction with 12 separate watertight compartments and large moonpool. Currently certified by the MCA with Loadline Exemption to 20 miles in favourable weather and carrying Solas Liferaft. Twin 120 hp 6 cyl diesel engines provide propulsion and power to the auxiliary equipment.

- Hydraulic Hiab Crane 1.5 tonne at 1 metre with 4 metre reach.
- Hydraulic drum winch 1.25 tonne pull on gantry over moonpool.
- Hydraulic capstan for heavy lifts (up to 6 tonne) through moonpool.
- Godiva water pump producing up to 22,500 gph at 150psi providing fire fighting facility, and power to venturi-operated reaction dredge.

Recording equipment (Kevin Camidge)
Laptop computer for survey plotting and sub-sea data logger download
Underwater camera system (Nikonos V and 15mm lens)

Sub-sea data logger
Custom made by EauxSys Ltd of Camelford
With sub-seabed probes for Redox (ORP), pH, Dissolved Oxygen, Temperature and Pressure (Depth). Capable of storing one reading per hour for up to three months.

Timetable

The project events are sequential in nature. There would appear to be very little scope for tasks being accomplished simultaneously. The project naturally splits into a number of events, each of which is outlined in a separate table below. Tasks marked ** are only required if the optional sub-sea data logger is deployed.

Initial installation

TASK	DURATION	OPTIMUM DATE	PERSONNEL
**Order sub-sea data logger	6-8 weeks	March 2003	KC
Source and order materials	½ day	April 2003	KC
Ship materials to St Mary's IOS	5 days	April-May 2003	KC
Local equipment purchase and assemble and check equipment on St Mary's quay IOS	½ day	May 2003	KC and MM
Familiarise the team with the equipment and practice deployment on land	½ day	May 2003	Site Team (KC, MM, AW, AC & TA)
Mark out and survey in the test areas and sediment monitoring points – as shown on the trial location plan above	1 day	May 2003	Site Team
Install the test blocks for the control area. This consists of four sets of blocks. Each set is one oak and one pine block	½ day	May 2003	Site team
Install the test blocks for ST1 (Terram 4000) trial	½ day	May 2003	Site team
Install the mat for ST1 (Terram 4000) – secure with sandbags	1 day	May 2003	Site team
Install the test blocks for ST2 (synthetic mesh) trial	½ day	May 2003	Site team
Install the mat for ST2 (synthetic mesh) – secure with sandbags	1 day	May 2003	Site team
**Deploy sub-sea data logger and install sensing probes adjacent to the 3 month test samples under ST3 (frond) mat	1 day	May 2003	Site team
Install the test blocks for ST3 (frond mat) trial	½ day	May 2003	Site team
Install the mat for ST3 (frond mat) – secure with sandbags	1 day	May 2003	Site team
Final inspection. Photograph the mats and test blocks in the control area.	½ day	May 2003	Site team
Demob		May 2003	Site team
Write progress report and submit to EH	½ day	May-June 2003	KC

Monitoring and retrieval (3 months)

TASK	DURATION	OPTIMUM DATE	PERSONNEL
Initial inspection and damage report. Photograph the condition of the mats.	½ day	Aug 2003	Site team
Recover the 3-month blocks from the control area	¼ day	Aug 2003	Site team
** Recover the sub-sea data logger, recharge batteries and download data. Change any sensors necessary and recalibrate.	1 day	Aug 2003	KC & AC
Measure sediment accumulation. Excavate any sediment accumulation over the 3-month blocks under ST1 and recover the test blocks	½ day	Aug 2003	Site team
Measure sediment accumulation. Excavate any sediment accumulation over the 3-month blocks under ST2 and recover the test blocks	½ day	Aug 2003	Site team
** Reposition sub-sea data logger and install probes next to new 3-month blocks under ST2 (synthetic mesh) mat.	½ day	Aug 2003	Site team
Measure sediment accumulation. Excavate any sediment accumulation over the 3-month blocks under ST3 and recover the test blocks	½ day	Aug 2003	Site team
Make good any damage to the test mats. Measure the 'background' sediment levels (M1-M8)	½ day	Aug 2003	Site team
Pack and ship sample blocks to MRAS		Aug 2003	KC
Demob		Aug 2003	Site team
Write progress report and submit to EH	½ day	Aug-Sept 2003	KC

Monitoring and retrieval (6 months)

TASK	DURATION	OPTIMUM DATE	PERSONNEL
Initial inspection and damage report. Photograph the condition of the mats.	½ day	Oct 2003	Site team
Recover the 6-month blocks from the control area	¼ day	Oct 2003	Site team
** Recover the sub-sea data logger, recharge batteries and download data.	1 day	Oct 2003	KC & AC
Measure sediment accumulation. Excavate any sediment accumulation over the 6-month blocks under ST1 and recover the test blocks	½ day	Oct 2003	Site team
Measure sediment accumulation. Excavate any sediment accumulation over the 6-month blocks under ST2 and recover the test blocks	½ day	Oct 2003	Site team
Measure sediment accumulation. Excavate any sediment accumulation over the 6-month blocks under ST3 and recover the test blocks	½ day	Oct 2003	Site team
Make good any damage to the test mats. Measure the 'background' sediment levels (M1-M8)	½ day	Oct 2003	Site team
Pack and ship sample blocks to MRAS		Oct 2003	KC
Demob		Oct 2003	Site team
Write progress report and submit to EH	½ day	Oct-Nov 2003	KC

Monitoring and retrieval (12 months)

TASK	DURATION	OPTIMUM DATE	PERSONNEL
Initial inspection and damage report. Photograph the condition of the mats.	½ day	May 2004	Site team
Recover the 12-month blocks from the control area	¼ day	May 2004	Site team
** Redeploy the sub-sea data logger next to new 3-month blocks under ST1 (Terram 4000) mat.	1 day	May 2004	KC & AC
Measure sediment accumulation. Excavate any sediment accumulation over the 12-month blocks under ST1 and recover the test blocks	½ day	May 2004	Site team
Measure sediment accumulation. Excavate any sediment accumulation over the 12-month blocks under ST2 and recover the test blocks	½ day	May 2004	Site team
Measure sediment accumulation. Excavate any sediment accumulation over the 12-month blocks under ST3 and recover the test blocks	½ day	May 2004	Site team
Make good any damage to the test mats. Measure the 'background' sediment levels (M1-M8)	½ day	May 2004	Site team
Pack and ship sample blocks to MRAS		May 2004	KC
Demob		May 2004	Site team
Write progress report and submit to EH	½ day	May-June 2004	KC

Monitoring and retrieval (15 months)

** This entire event can be omitted if the data logger is not deployed in the trial.

TASK	DURATION	OPTIMUM DATE	PERSONNEL
** Recover the sub-sea data logger, recharge batteries and download data.	½ day	Aug 2004	KC & AC
** Recover the new 3-month test blocks (adjacent to data logging probes)	½ day	Aug 2004	Site team
Pack and ship sample blocks to MRAS		Aug 2004	KC
Demob		Aug 2004	Site team

Final monitoring and retrieval (24 months)

TASK	DURATION	OPTIMUM DATE	PERSONNEL
Initial inspection and damage report. Photograph the condition of the mats.	½ day	May 2005	Site team
Recover the 24-month blocks from the control area	¼ day	May 2005	Site team
Measure the 'background' sediment levels (M1-M8)	¼ day	May 2005	KC & AC
Measure sediment accumulation. Excavate any sediment accumulation over the 24-month blocks under ST1 and recover the test blocks	½ day	May 2005	Site team
Measure sediment accumulation. Excavate any sediment accumulation over the 24-month blocks under ST2 and recover the test blocks	½ day	May 2005	Site team
Measure sediment accumulation. Excavate any sediment accumulation over the 24-month blocks under ST3 and recover the test blocks	½ day	May 2005	Site team
Excavate the accumulated sediment from over the trial mats and recover the trial mats (ST1, ST2 and ST3)	1 day	May 2005	Site team
Pack and ship sample blocks to MRAS		May 2005	KC
Demob		May 2005	Site team
Write final report and submit to EH. Write account of the trial for IJNA	6 days	June 2005	KC

Appendices

I. Analysis of standard timber samples (Dr. Mark Jones MRAS)

1. Background

Following concerns expressed about the amount of archaeological wooden wrecks becoming exposed and at risk from degradation, one possible option has been to consider the opportunity for *in-situ* protection. This protection should ideally be similar in character to that of the original burial environment. In order to understand the processes that contribute to the preservation and degradation of wooden archaeological remains in the marine environment, the ecology and nature of pelagic and benthic environments of wreck sites needs to be investigated. A programme of ecological and environmental monitoring of a site will indicate if a site is under threat and whether protective measures are necessary to preserve the wreck timbers. Methods of underwater wreck site evaluation developed here are based on research experience in *in-situ* protection of sea and land based projects and of studying organic archaeological material.

The project undertaken here is aimed to determine the environmental conditions of the Colossus wreck site and to identify existing and future threats to the long-term stability of wreck material exposed at this sites.

2. Monitoring Programme

A programme of ecological and environmental monitoring has been devised to assess the threats to wreck material exposed and protected at the Colossus wreck site. This will help us understand the processes that contribute to the preservation and degradation of shipwreck material in this area. Archaeologists are aware that the decomposition dynamics of the underwater wreck environment will play a major role in determining how much of a wreck will remain for future analysis. Knowledge of the decay rate of a site will indicate whether wooden archaeological material is in immediate danger of being lost, and if *in-situ* protection measures are necessary to preserve the site.

To characterise and determine the decomposition rate of wood at a wreck site, investigations of both pelagic and benthic environments are necessary. The pelagic open circulation environment is classified as the most hazardous for wood in the five biological hazard classes, (EN 335-1, 1992). Exposure of wood test samples in the pelagic environment will identify organisms responsible for wreck timber decomposition. A hydrographical monitoring of this site is also recommended.

The benthic environment at each site will be influenced by the stability of the seabed. This can result in shipwreck timbers being either entirely covered with sediment or exposed to aerobic conditions that favour deterioration.

Physicochemical studies of the sediments at each wreck site will indicate the nature, origin and its stability. Additionally, micro-biological studies will demonstrate whether the benthic environment of each site encourages wood deterioration or provides a safe preserving environment.

3. Methodology

The Seawater Environment (Pelagic)

- **Exposure of wood test blocks**

Oak and pine (indicative of timbers used in the construction of historic ships) samples placed at each test site will be used to identify attack by biological agents such as wood boring animals and microbes. Timber samples will be exposed for periods of 3 months, 6 months, 12 months and 24 months. On retrieval from the marine environment, the samples should be wrapped in a damp cloth soaked in seawater, sealed in a barrier foil and placed in a cold container and air freighted to Portsmouth immediately for examination and analysis. All blocks should be attached to a suitable frame and secured to the seabed.

All exposed samples will be examined for the following features:

(i) Bacterial Activity
(ii) Fungal Activity
(iii) Wood borer attack
(iv) Mechanical or Physical Damage
(v) Weight Loss
(vi) Chemical Deterioration
(vii) Contaminants

(i) Bacterial Activity and (ii) Fungal Activity

Scanning electron microscopy will be used to identify both bacterial and fungal activity in exposed wood test samples. Sections of exposed wood, 0.5 to 1 mm thick, will be fixed using 4% glutaraldehyde in 0.1 M phosphate buffer at 4 hours. Following a buffer wash, samples will be post-fixed using 1% osmium tetroxide in 0.1 M phosphate buffer overnight. Dehydration will then be carried out in a graded ethanol series, 15 minutes in each of 10% steps. Absolute ethanol will then be gradually substituted with acetone, and then critically dried in a Polaron E3000 apparatus using liquified carbon dioxide. As the drying agent. Dried material will then be examined under a scanning electron microscope.

(iii) Wood Borer Attack

The degree of attack on wood blocks by crustaceans and molluscs will be assessed by visual examination and x-radiography. The extent of surface destruction will be evaluated as a function of the number of galleries and their distribution. Table 1. The five point rating scheme of ASTM D 2481 will be adopted.

Table 1. The five point grading system.

Grade Number	Description of Condition	% Surface destruction
1	No more than trace	0
2	Light attack	1-19
3	Moderate attack	40-59
4	Heavy attack	80-100
5	Destroyed by attack	Failure

Identification of marine wood borers

Wood-boring organisms will be removed from the test and ship timber samples and fixed in 4% glutaraldehyde in phosphate buffer. Identification of the organisms will be based on the keys of Turner (1966,1971) and Kuhne (1971).

(iv) Mechanical or Physical Damage

Movement of water across the wreck site can cause destruction to exposed archaeological wood. This can result in mechanical damage by abrasion. Under such conditions, the wood surface is subject to a form of sand blasting and can cause very rapid erosion.

(v) Weight Loss

Weight loss experiments will be carried out on exposed samples to determine the rate of biological degradation at each wreck site.

(vi) Chemical Deterioration

Wood is composed of complex mixtures of polysaccharides (sugars) and lignin (cross linked phenolic polymers. Exposure to the marine environment and to wood degrading organisms will result in changes to the chemistry of archaeological wood. Both exposed wood samples and ship wreck timber will be analysed using nuclear magnetic resonance spectrometry. At least nine different carbon types can be identified in a typical CP-MAS ^{13}C NMR spectrum and can be related to different polysaccharide and lignin component.

(vii) Contaminants

Salt and mineral infiltration of test wood samples and shipwreck timbers will be analysed using x-ray microprobe analysis. Certain major and minor constituents of seawater are involved in the process of wood degradation in seawater. Their presence or absence will help identified future preservation strategies.

In-situ Protection

In order to protect exposed archaeological ships' timbers from further degradation at the wreck sites, a physical barrier system could be employed as a form of *in-situ* protection. To assess the suitability of the physical barrier method against damage caused by water movement and wood boring organisms, a variety of synthetic barriers will be tested at the site.

Test wood samples of oak and pine will be placed beneath the various barriers and exposed at the site for varying periods of time (3 months, 6 months, 12 months, 24 months). Following exposure, samples are wrapped in a damped textile soaked in seawater, sealed in a barrier foil and placed in a cold box for immediate transportation by to Portsmouth.

All exposed samples will be examined for the following features:

(i) Bacterial Activity
(ii) Fungal Activity
(iii) Wood Borer Attack
(iv) Mechanical or Physical Damage
(v) Weight Loss
(vi) Chemical Deterioration
(vii) Contaminants.

dataloggers.

The level of physical and biological degradation at a wreck site is a function and a reflection of the complexity of the environment. Hydrographic parameters such as currents, temperature, dissolved oxygen, pH, salinity, turbidity, depth and redox potential are factors that influence the type, rate, and level of degradation. In terms of biological deterioration, the most important parameters are temperature, salinity and oxygen levels.

To monitor the effectiveness of in-situ protection at the wreck site of HMS Colossus, monitoring of hydrographic conditions beneath and above the physical barrier systems at the three test sites (A,B,C) should be investigated. The datalogger should be placed close to the protected wood block samples beneath the barrier system (at test site A) for a period of 3 months. Following this period, the the datalogger should be removed from test site A and placed next to the test samples at site B for a 3 month period. The datalogger should be set to record site conditions on an hourly basis. When site B has be continuously monitored for 3 months, the datalogger should then be deployed at site C for a similar period of time. After deployment at each site, the data obtained should be downloaded and the loggers cleaned and recalibrated before re-deployment at the next test site. Following deployment at each test site, interogation of data will help decide which physical barrier system provided the wood test samples with a stable and protective environment.

To eliminate seasonal variations during this study, it is recommended that four dataloggers are purchased and one deployed at each test site underneath the barrier system simultaneously. The fourth datalogger to be deployed above the seabed. I realise that this would be costly but I believe it necessary in order to eliminate the effects of seasonal variations.

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II. Seabed stabilisation (Phil Rees)

To: K. Camidge

From: F.P.Rees

CC:

Date: March 26, 2003

Re: A Proposal for conducting studies to stabilize the seabed sediments in the vicinity of the wreck of the Colossus, off the island Samson on the Isles of Scilly.

Further to receipt of your confirmation to provide technical input for proposed studies on the stern section of the wreck of the Colosuss, I am pleased to provide the following statement.

It is my understanding from information provided in the 2002 Report on the Colossus, is that upwards of 120 square metres of timbers from the stern section of the wreck is lying exposed on the seabed at a depth of -10 metres LAT. For the most part, the buried section of the wreck is in a very good state of preservation until the timbers became progressively exposed on the seabed at which time they are subject to rapid degradation largely due to the effects of lamnaria (gribble worm) and other organisms.

The seabed in the vicinity of the wreck comprises a loose shelly sand of variable thickness overlying a more competent sequence of fine to medium dense sand.

Evidence from previous excavations of historical wrecks and from knowledge gained from the Colossus to date, has demonstrated that the exposed sections of the wreck including objects lying on the seabed are attacked by a combination of physical, chemical and biological action.

From a physical standpoint, the interaction of the tidal stream currents and wave spectra create movement of the sediments on the seabed particularly over spring tidal periods and more importantly in storm conditions. The forces acting on the seabed created by the tidal stream are diurnal with a flood and an ebb flow which can create currents estimated at 1.0 metre per second at the wreck site. The direction and amplitude of the tidal stream currents should be established by conducting site specific measurements using an acoustic doppler current meter* - see attached oceanographic study proposal. This data should be used in conjunction with available wave spectra data to determine the likely effect of storm conditions at the wreck site location. Any protection system should be designed to withstand these storm conditions.

For a given tidal flow condition, the surface sediments at the wreck site will almost certainly be in a constant state of flux (movement). This will cause the sand to be raised into suspension to create a bed-load movement with saltation effects which will cause constant abrasion to any wood or features exposed on the seabed.

Chemical action can be caused by a number of processes which include the categories of general corrosion, microbiologically assisted corrosion, differential aeration and erosion corrosion. In almost all cases the corrosion processes will be related to the redox potential of the surrounding sediment and the exposure to an oxygenated environment. For instance differential aeration will have almost certainly have been responsible for the necking of the copper rods present on the wreck site.

As previously mentioned, it is apparent from site observations that the most significant source of degradation is biological. This is mainly caused by the action of wood burrowing organisms such as limnoria lignorum which resembles an ordinary wood louse some 6mm in length.

Even so, it is remarkable that so many artifacts have survived for so long and in such good condition. This indicates that the burial conditions in the intervening 200 years have been able to interrupt the degradation processes which are clearly evident as soon as the wreck becomes exposed.

It is apparent that even with a few tens of centimetres of sand cover, the environment undergoes a significant change by reducing the amount of available oxygen which inhibits both biological and chemical action. The sediment cover also provides protection from seabed scour action.

The purpose of the stabilisation trials is to monitor a number of techniques to reduce the rate of degradation of the wreck by creating a sand berm over the wreck site. In the initial phase it is proposed that the trials are conducted in the vicinity of the wreck in preference to the wreck itself. It is advocated that the test areas are conducted sufficiently far apart to ensure that there is no mutual interaction. In this respect a distance of at least 5 metres is recommended.

The design premise is to stabilize the sand cover over the wreck by providing a cover of sand to a depth of up to one (1 metre) which is sufficiently stable not only able to remain in situ during the spring tidal period but also capable of withstanding the effects of the bottom orbital velocities due to storm wave conditions. In the case of the effects due to wave action it is considered that some of the sediment cover may be temporarily lost but that the cover would be reinstated by natural processes.

The technique which has been proposed is designed to minimise the effects of seabed scour and erosion by reducing the velocity of the current using buoyant polypropylene fronds. The effect of reducing the current velocity causes sand particles in suspension to be deposited into the fronded area of the mat to form a permanent natural and dense sand berm.

The fronds which are attached to a geo-textile mats are made up into parallel lines of high tensile strength fibrillated buoyant fronds typically 1.25 metres high. The mattresses are supplied in a variety of sizes and are HSE approved for diver/ROV safety during installation.

Whereas the standard T12 (5m x 2.5 m) mats with the standard 1.25 metre frond length would be advocated for the wreck site, in order to conduct effective monitoring of the blocks it is proposed to utillise a shortened frond mat length of 625mm to provide easier access to the test wooden blocks during the trial period. In order to create the equivalent viscous drag there is an option to increase the density of the fronds, albeit that this could create intertwined matting which could prove difficult to remove by simple jetting.

The frond mats are transported on a galvanized spool system which can be deployed over the side of the vessel onto the seabed. The diver can then simply secure one end of the mat by driving ground anchors into the seabed. The mat can then be spooled off the reel and the edges secured using sand bags. If necessary the spool itself could be used as part of the sediment accretion. This would not only initiate the sand build up but would also help stabilize the frond mat in the first few days following installation.

The frond mats are normally fixed to the seabed using ground anchors but in those instances where this would adversely affect the wreck then weighted sandbags can be used. In order to facilitate installation it is proposed to weave a weighted bar into one end of the mat to enable the diver to unroll the mat on the seabed.

The company who has developed the system, Seabed Scour Control Systems Ltd, has offered to provide a mat to our specification together with the required ground anchors. SSCS would require reimbursement of any transportation/logistics costs to and from site. The cost of shipping the mat which weighs 100kg and is 5.8 metres long from Gt Yarmouth to Penzance is £200 + VAT, based on providing 3 days notice. The cost of trans-shipping to St.Marys is £50, hence the total carriages charges based on 3 days notice is estimated @ £300. The shipping costs are scheduled to be increased in April.

The key benefits of the system can be summarized by:

Low installation costs

It provides a permanent solution that should not require maintenance.

Stops scour immediately upon installation

Progressive build up of permanent mass fibre reinforced sandbank

Environmentally acceptable

Effective in shallow and deeper water

Provides impact damage protection by cushioning structures with energy absorbing sand

Load bearing solution if required

The technique has been used for scour protection in the offshore oil industry since 1984 and has been utilized in high energy shallow water environments. – see separate list of applications submitted by SSCS. – www.scourcontrol.co.uk

It is our understanding that a FEPA license may be required to install the mat systems to undertake the trials. Advice should be sought from DEFRA to ascertain specific requirements but it is understood that it may take up to 8 weeks to receive approval from the date of submission. – see www.mceu.gov.uk

It should also be noted that other permissions may be necessary as the location is a designated area of Special Area of Conservation (SAC). – see www.ukmarinesac.org.uk

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III. Sub-sea data logger (David Precious)

Dear Mr Camidge
It was good to talk to you regarding the project to monitor the conditions on the 'Colossus'. We would propose that the equipment we supply would be a self contained submersible datalogger measuring the following parameters.

Redox (ORP)
pH
Dissolved Oxygen
Temperature
Depth

The system comprises a measuring and datalogging system housed in a cylindrical waterproof housing. Dimensions of the instrument are 115mm diameter and 625mm long. The sensor connections are positioned on one end of the instrument. In this version the pH, Redox and Dissolved Oxygen sensors are supplied on 5 metre long flying leads to allow positioning into the sediment aroundthe site. The datalogger has an internal battery pack with a capacity of 12 AmpHr sufficient for up to 3 months deployment on the seabed. Data is stored on a separate battery supported PCMCIA memory card.

In operation the data logger powers down to a low power standby mode to minimise battery demand. At the appointed time interval, the datalogger switches on, takes a set of readings and stores them onto the memory card. The datalogger then reverts to standby mode.

In order to recover data, the instrument is recovered from the seabed and connected to a computer running the PC software ***'TimeTa**g'*. This software also allows the settings and calibration of the instrument to be adjusted.

Batteries are high capacity metal nickel hydride type, and the instrument is connected to a special battery charger in order to re-charge the cells. Charging takes 12-14 hours.

In order to mount the data logger a suitable concrete sinker needs to be provided, the prevailing conditions will dictate the size and shape of the sinker. The sinker will have some brackets to clamp to the data logger, we will advise you of the requirements when you reach this part of the project. This work can be done by a local engineering firm.

You should budget for some running spare, pH and redox electrodes are not immortal and may need to be replaced annually at a cost of about £250.
The dissolved oxygen sensor will need to be refurbished between deployments, the kit supplied should suffice for several years operation.

Because of the interest we have in these particular archaeological applications we are offering to support the general maintenance and servicing of the equipment for the next two years. In addition we will supply training and support on data analysis.

Basic price for the data logger to the above specification:

£6750

This is all inclusive.

Delivery 6 – 8 weeks from date of order.

Let me know if you need any further information.

David Precious.

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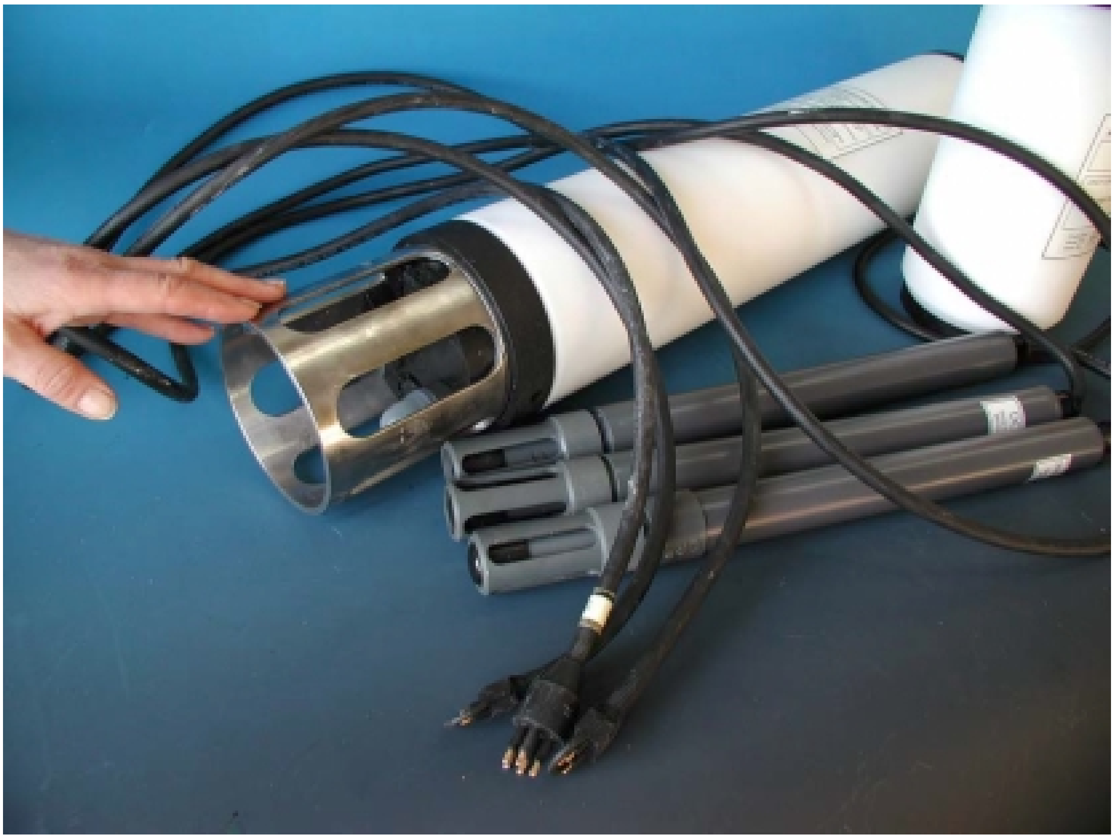

IV. In situ stabilisation trial: Review and Recommendations (Dr. David Gregory)

1. Introduction

Reviewing the site report for the archaeological fieldwork carried out in 2002 (Cammidge, 2002a) it is apparent that the site of *HMS Colossus* has been de-stabilised, perhaps due to a "100 year storm event" in the beginning of the 1990's, which has lead to several threats to the integrity and future preservation of the site. These can be characterised as:

- The timbers exposed are susceptible to degradation through wood borer activity
- The several cannon found on the site are now either completely exposed or partially exposed which will affect their rate of corrosion.
- Exposure of parts of the wreck site to active scour and erosion of sediments.

My particular area of specialisation is the deterioration of wood and iron in the marine environment. This report will discuss the threat of wood borers and micro organisms to the biodeterioration of the timbers and methods to mitigate for these. In addition the use of sacrificial anodes to stabilise the iron cannon will be discussed. Experience of the physical deterioration (scour / sediment erosion) of sites is given, with a recommendation to contact researchers specialising in this field.

2. Deterioration of timbers

The most significant threat to the exposed timbers of the *HMS Colossus* is marine woodborers, which are prevalent at the site. These may cause damage and loss of archaeological information in a relatively short period of time. After the marine borers, fungi and bacteria are the next agents of deterioration to consider. These micro organisms have a relatively minor part to play in the total breakdown of wood in seawater but their activity will affect its long-term preservation.

The question in this instance is how can the growth of these organisms be prevented? The major factors influencing the colonisation by marine borers are temperature, salinity, depth and dissolved oxygen content of the water (Kristensen, 1969; Becker, 1971; Eaton and Hale, 1993: 287-307; Von Arbin, 1995). The "determining" factor for colonisation by marine borers is the dissolved oxygen content; if there is little or no oxygen present they cannot respire and survive. Similarly, oxygen is a limiting factor for most marine fungi and levels of less than 0.30 ml / litre (approximately 0.5mg / litre) has been reported to prevent their growth (Kohlmeyer and Kohlmeyer, 1979: 44). Bacteria, unlike the marine borers and fungi, can survive in environments with very low oxygen concentrations. However, in typical littoral marine sediment only the first few millimetres of the sediment are oxygenated, although bioturbation by invertebrates, wave action or other cultural and natural processes may extend this oxygenated zone downwards (Ferrari and Adams, 1990; Ziebis *et al.*, 1998). Depth of sediment does affect the numbers of micro-organisms present; relatively high numbers of aerobic bacteria and fungi occur in the first few centimetres of most marine sediments but numbers taper off in deeper sediment layers and it has been reported that anaerobic bacteria only survive to a depth of 50 - 62cm (Zobell, 1946, 24; Florian, 1987: 15) This has been confirmed through analysis of archaeological wooden poles, which had been buried at a depth of 50cm (Bjordal et al 2000) which showed degradation through bacteria and experimental work with modern wood blocks buried at 50cm below the surface of the seabed (Gregory, 1999). Re-burial is the best method available to us at present for protection of the timbers from these organisms. Re-burial as a means of long-term storage is not a new idea and has been proposed and practised for many years (De Jong, 1981; Jespersen, 1985, 1986; Stewart *et al.* 1995; Elliget and Breidhal, 1991; Oxley, 1998). **To the best of our knowledge an optimal re-burial depth would be 50cm**.

3. Method of Re-burial

The *HMS Colossus* group have suggested (Cammidge, 2002b) the use of:

- Frond matting system developed and supplied by Seabed Scour systems
- Terram 4000
- Synthetic mesh.

Terram 4000 has been used successfully to inhibit the colonization of woodborers in Mediterranean waters (Pournou, 1998), yet this has only been used in experiments where wood blocks were covered with the terram and not where a whole site has been covered in the geotextile. It would seem sensible to consider using terram in cases where “loose finds” are to be packed prior to re-burial – as in the case of the carving Oscar found on the *Colossus*.

However, to completely cover a site the use of a frond matting system or synthetic mesh would potentially be advantageous. An example of the use of frond matting is reported by Elliget and Breidhal (1991). Artificial seagrass matting at a cost of 100,000 Australian dollars, in 1990, protected the brig *William Salthouse* and the measure seems to have been successful although the site still suffers from episodic erosion of sediment. Perhaps this cost may be prohibitive for total protection of the site. However the group working on the *Colossus* have obtained a sample of the material, which could be used in a trial.

The synthetic mesh has been used in the protection of a Dutch shipwreck in the EU MoSS project. Having discussed the material with Martin Manders from the Dutch Institute for Ship Archaeology, it is the woven mesh one sees on the outside of buildings during construction work – the aim being to stop construction debris falling on passers-by. The material is sold under the generic name of “debris netting” and there are many suppliers of this material. One such supplier in the UK (http://www.allplas.co.uk) was selling this material (2x 50 metres) at approximately 50 GBP per roll in March 2003. Manders’ method of deploying this material in Holland was simply to roll the matting loosely over the site, attach the lengths to each other with the use of cable ties and anchor the ends with a length of chain. As the netting should be fairly loose over the site, sand particles can move through the mesh and are then slowed and drop out of the water column, effectively re-burying the site – basically the same principle as the frond matting but less expensive. Obviously the environmental conditions at the site in Holland may differ from those on the *Colossus*. The site in Holland has extreme underwater currents and, as far as I am aware, fine grained sands. Under all circumstances I would recommend a small-scale trial comparing the various re-burial methods in order to ascertain which gives the most satisfactory results under the prevalent conditions.

4. Monitoring of the Re-burial mound

Monitoring of the burial mound has to be considered in terms of:

- How effectively is an anaerobic environment being established within it?
- The effect the mound has on the timbers
- The effect of scour and erosion around the re-burial mound

4.1 Establishment of an anaerobic environment

There has been a significant amount of research, both in terms of archaeological monitoring and microbial ecology in assessing the processes ongoing in the marine environment.

4.1.1 Dissolved Oxygen

It is clear that the presence of oxygen within the environment greatly affects the type and growth of colonising organisms on wood. As mentioned, oxygen levels within marine sediments are often very low, approaching anaerobic, and the accurate determination of oxygen levels may be problematical.

4.1.2 Redox potential and pH

Both have been suggested as good indicators of the oxidising or reducing nature of the environment (Caple, 1998; Stewart et al., 1995). Oxidation involves the loss of electrons while the process of reduction can be viewed as the gaining of electrons. In order to maintain electrical neutrality overall, it is clear that oxidation of one species must be accompanied by the reduction of another somewhere in the system: hence the concept of redox - the simultaneous occurrence of reduction and oxidation (Pollard, 1998: 63). Oxidising environments are those in which there is a tendency for chemical species to lose their electrons - this tendency can be measured in terms of the redox potential, Eh. Conversely, reducing environments are those where chemical species are encouraged to take up electrons from their surroundings. In practice, a chemically inert platinum electrode is used, which can transfer electrons to or from the environment, and the potential developed is measured relative to a standard cell which itself is calibrated relative to the standard hydrogen electrode. With particular reference to marine sediments, Pointing (1997) has measured the redox potential of sediments taken from the site of the Mary Rose and Pournou

(1998), using specially constructed apparatus, has measured the redox potential in situ on the site of the Zakynthos wreck. pH is often measured in conjunction with redox potential as these two parameters together can aid characterisation of the natural environment and provide a better understanding of its chemical behaviour (Baas Becking et al, 1960).

4.1.3 Concentration of oxidised or reduced chemical species

Further to measuring redox potential, it is possible to measure the concentrations of oxidised or reduced chemical species present in the sediment. Marine sediments exhibit a profile of chemical species distribution ranging from an oxidised zone at the surface, where levels of oxygen, nitrate and ferric ions are relatively high, through a transitional zone to a reduced zone where the concentration of the aforementioned ions is virtually zero and instead levels of ferrous, sulphide and ammonium ions are appreciable. These chemical changes with depth in the sediment are connected to a change in habitat conditions from aerobic to anaerobic (Atlas and Bartha, 1993: 268-269). Stewart *et al.* (1995) have measured the concentration of ammonium, nitrate, sulphate and sulphide from pore water extracted from the re-burial mound at Red Bay.

The methods for determining the aforementioned parameters have included: sampling pore water and shipping samples to the laboratory for analysis; measurement *in situ* with specially designed apparatus (spot measurements); measuring pore water in the sediment with data loggers; taking sediment core samples and analysing them in the laboratory.

Equipment to measure *in situ* (either spot measurements or with data logging capabilities) is readily available, yet I recommend that it would be prudent to wait to determine which monitoring system should be applied to the project. Here at the National Museum we are developing a system with microelectrodes, which can measure pH, redox, sulphide and dissolved oxygen both *in situ* and from core samples. However, it is relatively expensive and only gives spot measurements. Data logger systems such as those currently being developed and employed by the Moss project (http://www.nba.fi/INTERNAT/MoSS/eng.htm) are also expensive yet they give continual logging of pH, redox, dissolved oxygen, turbidity, conductivity, amongst other things. They will give an indication of seasonal changes but work on the basis of monitoring pore water collected in “dip wells” pushed into the seabed rather than measuring directly in the sediment themselves. The MoSS project is due to be completed in 2004 and thus it may be worth waiting to see the conclusions of the project. A very simple and cheap method to assess the development of an anaerobic environment, and the effect the burial mound has on the preservation of the timbers, would be to incorporate sacrificial wood blocks in the mound.

4.2 Monitoring the effect of the re-burial on the preservation of the timbers

In the re-burial system fresh blocks and blocks of archaeological wood (samples from the site) should be included. One of the advantages of including wood blocks in the re-burial mound is that they can serve as a proxy indicator for the environmental conditions. Through macro and microscopic analysis it is possible to tell which, if any, woodborers are present and importantly which microorganisms are present.

Microscopic analysis will enable determination of the type of degradation present, extent of deterioration and the condition of the wood (Blanchette *et al*., 1990 ; 1991). The morphology of the deterioration can give an indication of the type of microbial decay, i.e. fungal or bacterial, and knowing this, inferences can be made about the environmental conditions in which the wood has been buried. For example, the presence of decay by soft rot fungi, characterised by cavity formation within the secondary cell walls and by cell wall erosion, would indicate that there is sufficient oxygen within the environment for the fungi to survive and that the environment will not be conducive to preservation. Conversely, if soft rot is absent and there are signs of bacterial attack, inferences about the burial environment can similarly be made depending on the morphology of the deterioration. The occurrence of bacterial attack in situations that could be characterised as near anaerobic suggests that some bacteria are capable of degrading wood in situations where fungi are completely excluded because of the limited oxygen. Studies on wood exposed in aquatic environments or other waterlogged situations where oxygen may become limiting have shown deterioration by erosion and tunnelling bacteria (Blanchette et al. 1990: 169). Thus although the presence of erosion and tunnelling bacteria would indicate deterioration it would also show that environmental conditions were near anaerobic and therefore conducive to preservation.

The system of incorporating wood blocks could follow the method used on the re-burial of the Basque whaler *San Juan* in Red Bay, Labrador (Stewart et al.; 1995). Here a series of blocks were placed in the re-burial mound at different depths suspended on a length of polypropylene rope. These were simply removed at predetermined times by placing a crow bar through a loop at the top of the line and pulling the wood blocks up.

It is recommended that blocks of archaeological wood, modern pine and modern oak. Sufficient samples should be placed to allow sampling after 3, 6, 9, 12 months 3, 5, 10, 20 and 50 years. Mark Jones at the MRAS has been contacted to analyse the blocks. Without knowing what analyses have been specified, I would recommend keeping things simple. Physical analyses such as weight loss of the blocks and change in density will give a rapid assessment of the overall state of preservation. Wood borers could be identified (although interesting perhaps not totally necessary as in this instance we are interested in their absence or presence. However, Simon Cragg or Rod Eaton from Porstmouth University may be interested in their identification). Microscopic analysis either by light microscopy or scanning electron microscopy would determine the types of microorganisms causing deterioration.

4.3 Scour and Erosion of the site

Phil Rees, a geologist, has been working with the matter of the causes of erosion and scour and I would certainly defer to his experience and knowledge. However, it is recommended that English Heritage should contact Dr. Justin Dix at the University of Southampton to act as an external evaluator of any suggested proposals related to scour and erosion. The prospect of continuing scour and erosion around the burial mound is the most significant threat to the site and a robust and reliable method of monitoring this should be employed. My experience of monitoring scour around a site is limited and has considered only the effect rather than the cause. In this case the cause of the scour should be considered at the outset of the project. We have had success with using a simple system of scaffolding poles placed vertically into the sediment around a burial mound. These were marked off with insulating tape and change in sediment level was periodically measured against the scaffolding poles. Another method we have had success with is using a simple echo sounder, periodically making transits over the site and then making 3D contour models and overlaying these to monitor any changes

5. Corrosion of the Cannon and cathodic protection

The *in situ* measurement of electrochemical parameters such as surface pH and corrosion potential, E_{corr}, to assess the condition of iron artefacts has been pioneered over the last two decades by Dr. Ian MacLeod and his colleagues at the Western Australian Maritime Museum. Their work has shown the potential for this non-destructive method of assessing the archaeological potential of metal objects on a wreck site and for stabilising metal artefacts *in situ* (MacLeod, 1987; 1989; 1995; 1996; North, 1976; 1982).
The E_{corr} is the voltage of the corrosion cell that exists between oxidation of the iron and reduction of the dissolved oxygen in oxygenated seawater. The voltage of the corrosion cell, which is measured by a high impedance digital voltmeter, refers to the difference in electrical potential between a silver chloride reference electrode (Ag/AgCl, seawater) and a working electrode in contact with the corroded metal. The working electrode is normally made of platinum or a metal whose polarisation characteristics are such that it will not contribute electrically to the cathodic reaction. If the pH at the metal surface is also measured it is possible to plot this and the E_{corr} onto a Pourbaix diagram, in order to determine the nature of the processes that are controlling the stability of objects in their particular environments.

In addition to monitoring the corrosion potential and surface pH it is possible to cathodically protect the cannon by attaching sacrificial anodes. A sacrificial anode normally comprises a metal such as a zinc or aluminium alloy, electrically connected, for example by copper cable, to the artefact, which is a less reactive metal, such as iron (British Standards Institute, BS7361, 1991). The iron artefact gains protection as the electrons released from the corroding anode flow through the copper wire into the artefact, i.e. the artefact is the cathode of the corrosion cell while the seawater completes the circuit. This effectively lowers the corrosion potential and hence the corrosion rate. Furthermore, as electrons flow into the artefact they will tend to cause a reduction in the acidity levels in the solution trapped between the concretion / metal artefact interface as hydrogen is evolved. The effective change in polarity of the artefact will assist in the removal of chloride ions. In north Western Europe this method has been tried on the cannon of the wreck at Duart Point, Isle of Mull Scotland (Gregory, 1999b). It can be seen that this method did indeed slow the rate of corrosion and has been successful in other instances (Gregory, 2000; MacLeod, 1989; 1996). However, the anodes do need to be regularly monitored to check that they are still effectively working and not being pacified by hydroxide coatings (formed by the reaction of zinc and aluminium with seawater) Furthermore, depending on the state of preservation of the cannon the anodes can be exhausted quite rapidly and need replacing after a relatively short time. An additional complication is that not all cannon are lying exposed. Five are partially buried and will end up completely buried as part of the re-burial of the timbers whereas four are apparently lying exposed at varying distances from the main area of the wreckage. Thus obviously it would be difficult to monitor the corrosion potentials of buried cannon post attachment of any sacrificial anodes. If a corrosion study of the cannon is carried out it would be worthwhile gathering baseline E_{corr} and pH data on all cannon and stabilising the exposed cannon with sacrificial anodes. To the best of my knowledge there has been only limited scientific study concerning the effect of corrosion rate on reburied iron.

6. Other thoughts

6.1 Extent of the site

The site of the Colossus is in two areas. The stern section, which is the focus of this project proposal, was located in 2001 some 750m northeast of the fore section. The fore section was located and designated in 1975 and subsequently un-designated in 1984. The meaningfullness of only designating and protecting half of the wreck seems questionable. Can this not be rationalised so that both sections of the ship can be included in the project? If not what is the justification for only preserving the stern section? The answer to this question may be apparent from previous reports on the site but I am unaware of these.

6.2 Debris Trail

The Archaeological Diving Unit has conducted a magnetometer and side scan sonar survey between the two areas of the site. This apparently showed several anomalies, which may relate to the wreck. This information is essential for assessing the extent of the site and potential areas where further erosion / scour may lead to further exposure of archaeological material. Furthermore, based on the soundings made around the periphery of the wreck in September 2001 it is apparent that there is significant sediment overlying the bedrock in the area (ca 3m). It would therefore be beneficial to conduct a sub bottom profiler survey over this area. As can be seen from the research of Quinn et al. (Reference) on the site of HMS Invincible, such a survey proved useful in the interpretation of the site and could be applied to the management of this site. Southampton University's High Resolution Marine Geophysics Group (Web page reference) may be able to offer assistance in this matter. If the ADU information is not available, side scan sonar could be conducted simultaneously with the sub bottom profiler survey. It is recommended that this be discussed with the aforementioned Dr. Justin Dix.

7. Conclusions

Aspects for any future stabilisation of the *HMS Colossus* should include:

- Examining the justification for only protecting half of the shipwreck
- Analysis of the side scan and magnetomoeter data gathered by the ADU
- Supplementing the previous geophysics with a sub bottom survey to assess the extent of the site and the possibility of other artefacts lying in the debris field. If the data collected by the ADU is unavailable or unprocessed repeating the side scan survey.
- Assessing the hydrodynamics of the site and perhaps modelling the effect of scour around any proposed re-burial mound
- Trial re-burial phase using the materials suggested by the *Colossus* team: Terram 4000 (for individual artefacts) debris netting and artificial seagrass. Full re-burial can be discussed pending the outcome of this trial.
- Monitoring within the re-burial mound should, in the first instance, be conducted by analysis of modern wood blocks. Monitoring of other parameters using dataloggers etc should be assessed following discussion and the outcome of the EU funded MoSS project.
- A study of the state of the preservation of the cannon should be undertaken. Future actions (stabilisation with sacrificial anodes) can be discussed pending the outcome of such a study.
- A reliable and robust method for monitoring further scour and erosion should be discussed and developed.

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