Final Report Summary - SASMAP (Development of Tools and Techniques to Survey, Assess, Stabilise, Monitor and Preserve Underwater Archaeological Sites)

Executive Summary:
The SASMAP project developed new technologies and best practices in order to cost effectively locate, assess and manage Europe’s underwater cultural heritage. The aims and achieved objectives of the project were directly related to the current ethos within maritime archaeology to preserve underwater cultural heritage in situ, that is to say where it lies on or in the seabed. Within Europe this philosophy has been politically galvanised by the Valetta treaty (1992) and internationally by UNESCO’s Convention for the Protection of the Underwater Cultural Heritage (2001). Both these treaties advocate that, as a first option, the underwater cultural heritage should be protected in situ and, where possible, non-destructive and non-intrusive methods to document and study these sites in situ should be used.

SASMAP had multiple objectives that were all aimed at developing a structured and optimized approach to safeguarding underwater cultural heritage. The overall concept of the project was to use a down-scaling approach to the location and assessment of underwater archaeological sites. Having localized potential sites an up-scaling (bottom up) approach was taken to developing non-destructive and non-invasive technologies, tools and best practice methods for assessing and preserving underwater sites. The tools and methods developed were trialled and tested on European underwater sites in Denmark, Italy, The Netherlands and Greece.

The first challenge when considering underwater archaeological sites is to know their precise location – where exactly are they? The down scaling elements of the project addressed this and resulted in the development of geological models that could aid in the prediction of where coastal underwater archaeological sites can be found at a regional level. These models were enhanced with the development of new surveying and prospection methods including cutting edge satellite imagery which looked through the seawater so as to make topographic maps of the seabed of the selected trial sites. A new survey tool which can look into the seabed and visualise what is in it in 3D was also successfully developed.

Having located a site how should it be assessed? The upscaling elements of the project saw the development of remote and diver held data logging devices that characterised the site environment in situ, both in the open seawater and within sediments so as to see if the environment was conducive to the future preservation of the sites. Furthermore, a diver held sediment coring device (Vibracorer) was developed which enabled the taking of sediment samples that could also be used for characterising the site environment or obtaining information that could be used for palaeoenvironmental investigations.

It is not only the environment that needs to be assessed but also the state of preservation of archaeological materials on a site. To this end a diver held and non-destructive device for testing archaeological wood was developed in order to assess the strength and integrity of wood.

Knowing where the site is, the site environment conditions and the state of preservation of archaeological materials makes it possible to consider future management of the site – can it be preserved in situ or is it best to excavate due to the risk of loss? Both these scenarios were considered within the project and saw the development of tools and techniques to safely lift artefacts to the surface through either lifting artefacts in a block of sediment, wrapping artefacts in environmentally friendly polymer impregnated materials that cured underwater or consolidating loose sediments with environmentally friendly polymers that effectively encapsulated artefacts in a protective coating of the surrounding sediment. If a site is be preserved in situ the use of artificial seagrass to protect them from the threat of underwater currents, which can rapidly remove
sediiments leading to the exposure and loss of archaeological material, were developed.
The results and experiences of the project were published in two Guideline Manuals; the first explains the process of
archaeological research in light of development lead archaeology and is aimed at policy makers, practitioners and people who
work with cultural resource management that are not necessarily archaeologists. The second outlines the general methods
that are available for locating, surveying, assessing, monitoring and preserving underwater archaeological sites and is
illustrated with examples and from the SASMAP project.

Project Context and Objectives:
SASMAP’s purpose was to develop new technologies and best practices in order to locate, assess and manage Europe’s
underwater cultural heritage in a more effective way than is possible today. SASMAP took holistic- and process- based
approaches to investigate underwater environments and the archaeological sites contained therein. This is necessary
regardless of whether or not investigations are research driven or in connection with sub-sea development. Investigations of
underwater heritage which are associated with subsea developments in Europe often require pre-disturbance studies to

Cost effective methods to locate and assess the dimensions of archaeological sites both on and beneath the seabed are
essential. The presence and extent of potential threats to archaeology must also be determined. Threats may arise from the
natural physical environment including strong currents, from manmade hazards such as dredging, from construction work,
fish, and installation of pipe/cable lines and development of recreation centres. The stability of the site and the state of
preservation of the artefacts present must also be assessed. The various assessments provide information on how best to
approach or manage a site. If the physical and bio-/geochemical environments are unstable or pose a threat to the site, the
opportunities for stabilising it in situ must be determined. The options for monitoring the continued integrity of the site must
be identified. If none exist, it needs to be determined whether areas can be isolated that need to be excavated, or sampled
non-destructively, before information is lost.

The overall goals of SASMAP were to cultivate a synergy between SMEs and national research institutions in order to build
proof of concept instruments and develop techniques and methods that could be used to provide a structured and optimized
approach to safeguarding underwater cultural heritage. Experience gained from trialling these tools and methods on actual
underwater sites were formulated into two Guidelines aimed at stakeholders working within maritime archaeology showing
the processes of archaeological research and the tools that are available to do this and with special reference to the SASMAP
results.

Summarily the scientific objectives were:

1. To develop regional specific geological models to understand palaeogeographic developments and use them to evaluate the
   probability of finding submerged archaeological settlement sites and of preserving them.
2. To optimise the selection process of target regions ideal for non-destructive studies based on the regional specific
   geographical models. Tools used will range from regional satellite scanning of theoretical optimal target areas, detailed
   multibeam and shallow seismic surveying of selected target areas to new development and innovative use of 3D shallow
   seismic investigations of identified targets. Data from these non-destructive studies will be directly applicable to Geographical
   Information System (GIS) presentation, interpretation and modelling of the physical appearance of the archaeological sites.
   The GIS will be custom made for input of hydrodynamic and sediment regime data in order to evaluate site stability and
   preservation status.
3. To monitor biogeochemical parameters in open water and in typical littoral marine sediments by developing remotely
   operated and diver held data logging devices. Measurements will be related to the degradation of organic archaeological
   materials in the marine environment and used to assess the reservation potential of sediments.
4. To develop new technologies in the form of prototype diver-held tools for sampling sediment cores from archaeological
   sites.
5. To develop a diver held tool for assessing the state of preservation of waterlogged archaeological wood in situ underwater.
6. To develop and demonstrate innovative techniques to raise complex and heavily degraded waterlogged organic
To achieve SASMAP's goals an interdisciplinary consortium of 7 research institutions and 4 SMEs from 7 European countries was brought together. The SMEs involved included companies that are amongst world leaders in sensor technology for characterising marine environments, development of acoustic surveying instruments for oceanographic purposes, design and construction of bespoke underwater equipment for scientific purposes and design and implementation of systems for protection of off shore constructions. Their involvement in the project was mutually beneficial as many of the tools developed were in their R&D pipelines and thus the project contributed finances to this work and enabled them to be trialled on real underwater archaeological sites for the benefit of preserving Europe’s underwater cultural heritage. Institutional partners encompassed a synergistic group of researchers working with marine archaeology and conservation, in situ preservation, wood degradation, marine geochemistry and marine geophysics from museums, universities and governmental heritage agencies.

Project Results:
To achieve the aforementioned scientific goals the project was structured into 8 well integrated work packages (WPs). The overall concept of the project was to use a down-scaling approach to the location and assessment of underwater archaeological sites. Having localized potential sites an up-scaling (bottom up) approach was taken to developing best practice methods for preserving them in situ or ex situ. This involved development of proof of concept tools, technologies and methods.

The downscaling elements of the project focussed on development of models (WP1) to allow desk based assessment of the potential of finding archaeological sites, their stability and then how to localise and monitor these sites with remote sensing tools (WP2). Thereafter the upscaling elements focused on the development of tools and technologies and best practice to assess the marine / burial environment in terms of its effect on the preservation of the site (WP3) and in situ assessment of the state of preservation of waterlogged archaeological wood (WP4). Should it not be possible to preserve a site in situ, tools and best practice methods for the raising of poorly preserved organic artefacts were developed (WP5). Alternately, if a site was to be preserved in situ, the use of artificial seagrass mats to stabilize sites in situ, monitor their effects on sites and how typical materials used for in situ preservation interact with the marine environment were investigated (WP6). The results of the project were formulated into two open access Guidelines aimed at stakeholders working with the management of underwater cultural heritage.

The main S&T results and foregrounds can be summarised as follows:

Geological models for regional evaluation of probability of locating archaeological sites and their preservation potential (WP1) focused on the development of geological models which described the palaeogeographical and depositional environments of two shallow and coastal archaeological sites in Greece and Denmark. The models were developed in two areas of archaeological interest: in Cape Sounion (Greece) and in Tudse Hage (Denmark). Cape Sounion includes structural remains from the naval base that Athenians developed to protect the metropolis of Athens in the 5th century BC. Tudse Hage includes well preserved remains of Mesolithic settlements. Both areas are nearshore and comprise differentials in seafloor substrates ranging from rocky to fine grained organic sediments, thus providing an opportunity for testing the total approach in different environmental and archaeological regimes.

The models were created from data collected and / or held in the archives of the consortium partners (GEUS and University of
Patras) and included seismic, sedimentological, biostratigraphic AMS Carbon 14 dating data and archaeological information. These were collated rationalised and harmonised for incorporation into GIS databases enabling analysis and visualisation of the data. Based on these GIS models the changing geological environments, as well as the palaeogeography, were reconstructed with respect to sedimentary conditions and water level fluctuations (sea-level change) that have occurred over the course of time on the two case study sites. Effectively these models it possible to “strip back” layers of time at the case study sites in order to reconstruct former coastlines and thus identify the likely locations of other undiscovered / unknown sites – “hot spots” (Figures 1 & 2).

Figure 1. Example of Geo-archaeological palaeogeographical scenario 8m below present sea level (~8000 calendar years BP). Stone Age settlements and single finds from The Danish Heritage Agency’s database for archaeological finds and sites are displayed and an orange circle indicates the position of a potential hotspot area for archaeological sites (Kongemose culture). Figure 2. Schematic presentation of the Cape Sounion (Greece) study area during the Late Glacial period. The present shoreline is shown by the black line.

The information from the models of the two case study sites fed directly into WP2 Development of Tools for Surveying and Monitoring Coastal and Underwater Archaeological Sites, in which target regions (hot spots) for elements of the non-destructive surveying and down-scaling studies in the project (WPs3-6) were selected. Based on the two geological models from WP1 and the GIS, those areas at the case study sites (regions) most likely to contain archaeological remains were surveyed with a suite of air- and waterborne remote sensing geophysical tools. The airborne remote sensing technique included trialling state of the art satellite imagery techniques, which in conjunction with orthophoto aerial photographs enabled not only “seamless” maps of coast line morphology but also bathymetry (topography) of the seabed down to ca 6 metres water depth. (Figures 3, 4 & 5).

Figure 3 Satellite image of Tudse Hage/Denmark study area showing a sandy morphological feature.
Figure 4 Satellite image bathymetry for Tudse Hage study area.
Figure 5 Overlay of seabed bathymetry from satellite imagery (brown line) Danish hydrographic office bathymetry (blue line).

The satellite imagery showed good potential for mapping bathymetry at both the case study sites but was affected by seabed morphology and turbidity of the water column. Use of satellite imagery is being investigated further in the FP7 supported ITACA project (http://www.itaca-fp7.eu/) in which one of the SASMAP consortium members is a member of the external project advisory panel.

Surveys with waterborne remote sensing techniques included a variety of echo sounders for the acquisition of bathymetric data, a variety of sub bottom profilers for the examination of seismic stratigraphy within the seafloor and the detection of possible buried archaeological sites. Furthermore a variety of side scan sonar systems for the examination of the seafloor texture and the detection of possible archaeological sites lying on the seafloor and marine magnetometer to examine possible magnetic anomalies. The processing of all the data sets together with the bathymetric data revealed from the satellite imagery (produced within WP 1) led to the development of GIS maps. The comparison, combination and the synthesis of these maps led to the development of seamless GIS maps of horizontal and vertical integration (Figure 6).

Figure 6 Seamless morphology map /Digital Terrain Model of Tudse Hage based on airborne and waterborne remote sensing techniques.

In parallel to these activities the SME partner (Innomar) designed and developed a prototype sub bottom profiler capable of acquiring profiles of high resolution, which after processing could provide 3D sceneries of the sedimentary environment and the possible buried archaeological remains. Major steps in designing and building of the system were the design and production of small transducers and new electronic components to get a small and lightweight system and the ability of different modes of operation were achieved (Figure 7).
Surveys conducted with this innovative remote sensing technique verified the successful operation of the instrumentation. The system was trialled in Greek and Danish sites at areas proposed as highly interesting, based on the geomodels previously mentioned. These areas were determined after the conventional remote sensing surveying following the down scale methodological approach. The system was also trialled in the Texel site of Netherlands where a wooden shipwreck had been detected. Furthermore, surveys with this innovative technique were conducted in three additional sites of also archaeological importance (Northern Germany, wooden structures; Zakynthos Island, wooden ship; Lechaion gulf, ancient harbour). In all surveys the system achieved to provide detailed 3D sceneries of the seafloor stratigraphy (Figure 8) and thus detailed documentation of the palaeogeography and in the majority of the cases 3D views of buried sites which most probably are of artificial origin (i.e. archaeological). The processing of the acquired data showed that the device achieved horizontal resolution up to 15cm and vertical resolution up to 5cm.

The fully developed system had been used by the SME Innomar outside of the SASMAP project in connection with the SeArch project (www.sea-arch.be/en) funded by the Flemish agency for Innovation by Science and Technology (IWT), and aimed at the development of an efficient survey methodology and sustainable management of submerged archaeology in Belgium. The SeArch project involves academic partners from Belgium (Ghent University, Flanders Marine Institute, Flanders Heritage Agency) and the Netherlands (Deltarcs) and is coordinated by Dr. Tine Missiaen from the Renard Centre of Marine Geology at Ghent University (tine.missiaen@ugent.be). Dr Missiaen and Innomar kindly agreed to this work being presented

The results of the downscaling approach of WPs1 and 2 (geo models and mapping / surveying using remote sensing) to localise sites fed directly into the upscaling (bottom up) approach of the remaining elements of the project – WPs 1-6 on how best to manage and preserve an archaeological site once it has been discovered.

In terms of management of underwater cultural heritage the aim is to be able to see that environmental conditions are suitable for the future preservation of the site and the archaeological materials contained in them. WP3, Assessing the burial environment and deterioration of organic materials, addressed this with goals to develop tools and methods to enable the monitoring, sampling and characterisation of open sweater and marine sediments, both in situ and in the laboratory, so as to be able to assess the potential for preservation of organic archaeological materials. Within the project in situ data logging devices that could characterise the environment of marine archaeological sites both in the open water and sediment environment (to a depth of 50cm) were developed along with a diver held sediment corer. All these tools were used to assess the effects of the environment on the preservation of organic archaeological materials.

The open water data logging system was based on the pioneering “lander” technologies of SME partner Unisense and successfully developed and trialled. The parameters that could be measured were standard CTD data (conductivity (salinity), temperature and depth data) and an Acoustic Doppler Current Profiler (ADCP) in order to measure water current and direction.

A diver held underwater data logging unit which could take sediment pore water profiles in situ and down to a depth of 50cm was also developed by the SME Unisense and successfully trialled within the project. The equipment has four separate channels with the capability of measuring dissolved oxygen, pH, redox and sulphide using Unisense’ s micro sensors that are fitted with hypodermic needles to give them added robustness. To measure profiles within sediments a hollow “spear” system, which could be pressed into the sediment was developed. The concept was that the hollow spear could be hammered into the sediment to the desired depth and then the sensors placed into this to take the desired measurements. The end of the spear
Figure 10: Data logger for characterising environmental parameters in sediments. The logger has four channels and was developed to measure sulphide, pH, redox potential and dissolved oxygen.

Figure 11: Schematic of the Proof of Concept of Spear System to measure profiles in sediments.

Figure 12: The sediment spear and micro sensor in situ.

The pH Micro sensor that had to be developed to work with the equipment proved problematical in terms of its reliability. With this in mind and noting the time and resources it would take to finish the development of the sensor within the time scale of the project a Field MicroOptode Meter was developed instead. This could measure oxygen concentrations for extended periods of time and at different depths. The microoptodes are more stable than electrochemical sensors and can be buried for weeks, if necessary, thereby enabling undisturbed measurements. This device was part of Unisense’s R&D pipeline beyond SASMAP and was initially developed for use with another of their data logging units, but Unisense will develop it further to make it compatible with all Unisense data loggers.

The aforementioned data logging units were developed for non-invasive (relatively) studies in situ on or in the seabed. However, it is often necessary to be able to take samples of the seabed for subsequent analysis in the laboratory. To this end a further SME in the project, AKUT, developed a diver held sediment corer based on a vibracoring system, whereby a vibrating head The Vibracorer is a system in which a pneumatic vibrator can vibrate polycarbonate tubes up to 80 mm in diameter in order to ease the passage of the corer into the sediment. The system is safe to use for divers in terms of noise levels, which are belwo recommended safety standards for the use of underwater pneumatic tools by several European health and safety agencies. In the SASMAP project, cores of over 1 metre have been taken with this developed system. In the seabed itself, it is notoriously difficult for divers to retrieve cores. To this end, a novel lifting device was developed that features a combination of pneumatically inflatable cushions and a tube holder, which serve to pull sediment core tubes gently out of the seabed. New techniques for sealing the end of the cores, to prevent loss of sediment, were also developed. In SASMAP, the sediment cores were used to assess the burial environment in terms of its effects on the preservation of organic material and obtain material for dating, the results of which would were used in the geological models of WP1.

Figure 13: Vibracorer being tested in shallow water. The corer and vibrating head (ran off of a SCUBA cylinder shown to the left).

Using the above tools a four pronged approach was taken to characterizing the burial environment

1. In situ classification of sediments
2. Ex situ classification of sediments
3. Laboratory microcosm studies to look at turnover rates in different sediments
4. Characterisation of the actual state of preservation and microbial deterioration of archaeological wood

This approach has been successful in determining what to investigate when considering the future in situ preservation of an archaeological site. Summarily it has shown that it is of paramount importance to obtain samples of the material (in this case the project was most concerned with wood) to assess its state of preservation in order to determine whether future deterioration is likely in the environment it will be preserved in. Studies of the wood fragments taken from the Tudse Hage site were shown to be extensively degraded and, should the conditions remain the same, it is unlikely that further deterioration will occur due to the ecological constraints of the microorganisms that could cause further deterioration (i.e. they do not survive). These results also highlight the importance of understanding the post depositional formation processes on archaeological sites in general (i.e. how were artefacts deposited and incorporated in a site). Again, from the analysis of the wooden fragments it is apparent that deterioration has occurred long ago in the past – no significant difference was seen in the state of preservation of the wood regardless of depth (increasing age) within the sediment. When this was correlated with
carbon 14 dates it was seen that the formation of the site was between 6390 and 5990 (±30) years BP i.e. over 400 years and 
as stated no significant difference was seen in the overall state of preservation of the wood. Thus in terms of archaeological 
wood it is perhaps irrelevant what is actually going on within the sediment if wood is totally degraded – again reiterating the 
importance of characterizing the material to be preserved in situ as it is not always fully degraded as in the case of Tudse 
Hage. Nonetheless, if these results are to be relevant to other sites and more recent better preserved archaeological wood is 
present then characterization of the environment is still relevant. The main factors affecting the deterioration of organic 
materials are related to the amount of oxygen in the environment (oxic or anoxic) and the ongoing processes which are 
related to the physical characteristics and organic content of the sediments the material is buried in.

Dissolved oxygen
Oxygen has been characterized both using the in situ profiler and measuring profiles in sediment cores taken with the diver 
held sediment corer. It has also been decided and accepted with the commission that the final areas of work by the partner 
Unisense will be to develop a new optode sensing system to improve the robustness of the measuring method.

Sulphate Reduction and the measurement of Hydrogen Sulphide
When in anoxic environments, below the layer of where oxygen is present other deterioration processes will be predominant-
ly and in shallow coastal sites this will be dominated by the action of sulphate reduction bacteria that produce hydrogen 
sulphide. Hydrogen sulphide was measured using the in situ profiler and ex situ on cores.

Physical characterisation of Sediment type and ongoing processes
Using the ex situ cores sediment were characterized using general methods for assessing the turnover of organic material 
such as the particle size, water content (porosity), organic content (labile and refractive) and analysis of pore water content. 
These are relatively simple parameters for the majority of archaeological and conservation laboratories to measure in terms 
of the equipment required. This showed that in general coarser grained sediments have a higher porosity, lower organic 
material content and thus lower turnover rates. Laboratory microcosm experiments showed this general relationship to be 
true, as did the profiling results and characterization of the sediments from the ex situ core.

However, again, it cannot be stressed enough that the paramount importance is to determine the state of preservation of the 
material to be preserved. In the case of the wood from Tudse Hage as long as the wood is buried in the present low oxygen, 
sulphate reducing conditions they should be safe for the future as there is insignificant material remaining that can be 
degraded under the present environmental conditions. Furthermore this is why it is also important to understand the overall 
physical processes ongoing on the site as these may in turn cause the erosion of sediments.

Flow diagrams for generic best practice for characterizing site environment in relation to the preservation of archaeological 
wood on underwater sites both in situ and ex situ are given in Figures 14 and 15

Figure 14. In situ profiling to characterize whether a site is oxic or anoxic.
Figure 15. Ex situ assessment of sediment cores to assess the preservation potential of archaeological sites.

Waterlogged wood is one of the commonest materials found on underwater archaeological sites. An exact assessment of its 
state of preservation is necessary in order obtain bench mark data for wood that is to be preserved in situ, or re-buried, or to 
select the optimal conservation process should it be excavated and raised. WP4 Assessment of the state of preservation of 
waterlogged archaeological wood
Within the project a diver hand held prototype based on non-destructive determination of the density of the wood was 
successfully developed and trialled (Figure 16). The net effect of bacterial deterioration is that as cell wall material is removed 
and replaced with water the density of the wood decreases - the more degraded the wood the lower the density. The wood 
tester works by hammering a steel needle into the wood and determines the correlation between depth of penetration and 
energy used. By means of a standard curve for energy/penetration/strength/density, the wood tester is able to determine a 
density profile for the wood up to a depth of 120 mm with a resolution from 0.5 mm and up to 20 mm. The Profiler works well 
on densities from 100 to 800 kg/m3. The raw data from the profiler is translated to density profiles by means of a
mathematical computerised model. The concept for the instrument developed in SASMAP has proven to be suitable for both fresh (undegraded) and archaeological wood and has several advantages over existing technologies as it is not influenced by the anisotropy, depth of measurement, wood species and can be used underwater. In relation to use in marine environments the method is considered to be non-destructive as the steel needle is 3mm in diameter and many of the existing technologies also involve drilling or pressing a metal probe into the wood and still they are termed non-destructive testing. The syems is safe to use underwater by divers as there is an “arming” device, which means they system cannot be fired acciedentally.

Figure 16: The diver held underwater wood tester (WP4UW)

WPs 3 and 4 focussed on the assessment of the marine environment and the preservation of archaeological wood, knowing this information makes it possible to plan for the future management of a site and archaeological materials. If the environment is too dynamic or conducive to future preservation, or archaeological artefacts are extremely fragile, the preferred option may be for excavation and lifting of artefacts. WP5, Tools and techniques to raise waterlogged organic archaeological artefacts, addressed this question. Due to their fragility (and often complexity), organic archaeological materials from underwater sites can be challenging to excavate, support, raise and transport to conservation facilities. This is due to the inherent difficulties of working underwater (limited time and potentially harsh conditions) and in particular the crucial stage of lifting artefacts from the seabed to the surface where mechanical damage can easily occur. To surmount this, artefacts are often raised on supporting materials or in sediment blocks (block lifting), whereby the artefact is excavated with surrounding sediment and subsequently excavated under controlled conditions on land in the laboratory.

Within SASMAP several tools, techniques and methods were developed to aid in the lifting of fragile organic artefacts. A modular lifting frame (VM & NM) was developed to be able to lift sections of consolidated sediments (gyttja) that contained artefacts. The lifting frame was of a size and quality that could be used to lift sediment blocks measuring up to 100 x 40 cm. The top and bottom top part of the frame were constructed from 40x40 cm square electroplated iron profiles with vertical posts 25 mm in diameter. The total length/width of the frame was 197 x 52 cm. Both the bottom and the top part of the frame are mounted with lifting eyes spreading the weight evenly on the frame during the lifting process. The frame ensures that artefacts/sediment sections can be raised as a complete unit and it was designed so that excavation underwater could take place in a controlled manner and be completely secure during raising, transport and subsequent excavation in the laboratory.

In practice the frame is lowered to the seabed to the seabed (a) a narrow channel around the sediment block to be lifted has to be cut to the required depth. The sediment at the end of the frame is removed (b) and the block is “undercut” by strong thin electroplated iron plates, which are pressed in under the block with the aid of a manual hydraulic pump (c). In this instance a manual hydraulic pump was used and functioned well. The pump used had a pressure of 4.5 tons but manual pumps up to 10 tons pressure can be used for dealing with very consolidated sediments, such as clays. Following this, rods are fitted to the sides of the frame and the top part of the frame (d), which allow the aluminium side plates to be fitted (e). Finally lifting shackles and strops are mounted on the lower frame (f) in preparation for lifting the frame and sediment block to the surface (g, h). The proof of concept lifting frame as currently designed can easily be adjusted to take sediment blocks greater than 40cm in depth and would require modifications should blocks greater than 40cm wide. However, the principle of the proof of concept shows the potential for the safe lifting of sediment blocks by suitably qualified divers.

Figure 17. The process of using the lifting frame underwater

The lifting frame was devised for use in consolidated sediments, such as gyttja. If the artefacts lie in unconsolidated sediments, such as sands and gravels, a different approach is needed. Ideally these types of sediments should be “consolidated” around the artefacts before it is lifted, potentially as a block lift. To achieve this series of methods were trialled. Consolidation of sandy sediments with user / environmental friendly polymers was trialled by ISCR-MBAC developing an innovative method of impregnating a sandy seabed with polymers which then cured (solidified) upon exposure. ISCR-MBAC tested the system to transform the water and the sediment that incorporate the fragile archaeological find into a gel, in order to securely block lift to the surface. Experiments were conducted in the ISCR-MBAC Laboratory, and in the Underwater Park of Baiae (Naples), which has an area of about 176.6 hectares with archaeological remains of the Roman city and infrastructures.
of Portus Iulius. Baiae was a famous seaside town much prized in antiquity for its temperate climate, beautiful setting and the properties of its mineral waters which have been exploited since the second century BC. It was the most popular resort of Roman Aristocracy and the Imperial Family up to the end of the third century AD, when the seismic activity caused the submersion of the city. Now the remains of villas, baths, roads and warehouses lie underwater along the seaside to a distance of 400-500 meters. At the end of the experimental phase the system of Water and Sediment consolidation was developed using Carbogel, a Super Absorbent Polymer (S.A.P.) which has often been used in restoration works. This is a neutralized polyacrylic acid that absorbs water and sediment, with a controlled molecular expansion and controlled hardness. By varying the crosslinking agent the properties of the polymer could be changed:
1. The water solidification time (from 10 seconds up to several minutes)
2. Polymer expansion volume
3. Hardness of the water gel
4. Acidity of the system
The polymer was impregnated into the seabed using an innovative pressurised system as shown in Figure 18.

Figure 18: Schematic of the S.A.P impregnation system

The use of the system is shown in Figure 19. a) A cylinder in dimensions appropriate to the size (and shape) of the artefacts to be, recovered needs to be constructed. The SAP mixture is placed in a waterproof box and taken underwater. b) The cylindrical box is positioned on /over the artefact(s) to be recovered and placed / buried into the sediment with the aid of a water pump. The polymer is mixed with fresh water or salt water (this depends upon the different polymers tested) inside the cylinder and is distributed underwater all over the area that needs to be transformed into gel. c) Once the water has solidified in the sediment, the system (sediment solidified /artefact) can be safely lifted to the surface and transported to the laboratory. d) In the Laboratory the SAP is solubilised using deionised water or fresh water or removed using spatulas. The cylinder not only facilitates the safe lifting and transport of the artefacts but can also be used as a “holding tank” for storage of artefacts in the conservation laboratory.

Figure 19. Use of the SAP system for consolidating sandy sediments in order to raise fragile artefacts

A further method to consolidate sandy sediments was freezing with liquid nitrogen and carbon dioxide. Laboratory feasibility studies worked well with freezing showing no adverse effects on artefacts and successfully consolidating sands. Preliminary field trials (Figure 20) were also successful but could not be carried out underwater due to safety reasons – if water entered the system there was a risk of explosion. The method does show potential outside of the SASMAP project and could be a successful method for geological / sediment purposes to obtain samples of sandy or gravelly sediments on dry land

Figure 20. Freezing system for sandy sediments showing excess carbon dioxide being vented

A final method for raising fragile organic artefacts was the situation if artefacts are lying exposed on the seabed and not necessarily covered with sediments. As mentioned the major problem of lifting such artefacts is bringing them to the water surface and then through the water / air interface and onto a boat / dry land. It is this last phase that due to wave action that artefacts can often be damaged. To surmount this problem, artefacts are often placed on a support and strapped / wrapped to the support. This idea formed the basis of the last methods which were trialled within the project ISCR-MBAC trialled two methods; i) wrapping artefacts in 3M TM Scotchcast TM Plus casting tape and ii) using carbon fibre sheeting treated with cured epoxy-time enclosed in a plastic vacuum bag.

The 3M™ Scotchcast ™ Plus Casting Tape is a lightweight, strong and durable casting tape used in orthopaedics and combines the benefits of a fiberglass casting tape with the handling ease of plaster. The tape (bandage) contains a synthetic polyurethane resin which, when in contact with water or simply exposed to moist air, hardens, enabling immobilization of fragile artefacts yet being extremely lightweight and durable. The 3M™ Scotchcast ™ Plus Casting Tape was tested in a tank with sea water (Figure 21), and then its effectiveness was validated underwater in the village “Gran Carro” (Bolsena Lake).
The Scotchcast proved easy to use in order to recover a wooden fragile archaeological object, furthermore it is user and environmentally friendly and can easily be removed post lifting (if it is in direct contact with the archaeological find too). This product is useful for first aid interventions because it is easy to find on the market but it has the limitation that it can only be used for small objects. In fact, the maximum size of the tape measures 4 m X 10 cm.

Figure 21. The 3M™ Scotchcast ™ Plus Casting Tape tested in laboratory

The use of a sheet of carbon fibre in a plastic vacuum bag was tested both, in the ISCR- MBAC laboratory, and at the Iron Age Village “Gran Carro” (Bolsena Lake) and in the Underwater Park of Baiae (Naples). This procedure used “composite materials” encompassing sheets of carbon fibre, previously treated with cured epoxy-time, in a plastic vacuum bag. This structure provided support and protection during the recovery of fragile artefacts from an underwater archaeological excavation.

The procedure (Figure 22) is such that a polyethylene vacuum waterproof bag is shaped in the form of the artefact to be recovered. A multilayer “sandwich” composed by Peel Ply tissue, carbon sheet and Peel Ply tissue is inserted with the number of layers of the sandwich depending on the dimensions and weight of the artefacts. The plastic bag is closed and air evacuated to create a vacuum and the whole bag is then ready to be taken underwater (Fig 22a). On the seabed the two mats in carbon fabric are positioned above and below the artefacts (Fig 22b) and after waiting for the resin to harden (about 12 hours) the upper mat and the lower mat are joined with plastic clamps and brought to the surface (Fig 22c) where it can be safely opened in the laboratory (Fig 22d).

The results showed that that the carbon fibre fabric, impregnated with epoxy resin, acts as a protective “shell” that adheres to surfaces, protecting the artefact by rapid drying and preventing possible trauma caused by the poor state of preservation of the material. A good characteristic of this system is that it could be used for small and large artefacts (light and heavy), with or without sediment, because it is a modular system that can be adapted to many different conditions (depending on the state of preservation of the artefacts, environmental situations etc.). Furthermore, it may also act as an effective container for temporary storage of waterlogged organic artefacts.

Figure 22. Use of carbon fibre impregnated with treated with cured epoxy-time enclosed in a plastic vacuum bag.

The final theme of SASMAP entailed the situation where a site was to be preserved in situ and was addressed in WP6, In situ stabilisation of underwater archaeological sites. Sites which are preserved in situ are threatened by the effects of underwater currents which can cause sediment to be removed from sites, leading to their exposure. Upon exposure, sites are susceptible to mechanical abrasion and erosion, which can lead to their total loss. Furthermore, wooden artefacts can, under the right environmental circumstances, be attacked by wood boring organisms such as shipworm, which can also lead total loss of archaeological materials within relatively short periods of time – years or decades rather than centuries or millennia. The most cost effective, environmentally friendly methods to protect archaeological sites and materials relies upon limiting the access of oxygen and this can most simply be achieved by covering with sediment. However, simply covering with sediment may not be sufficient as it may itself be washed away. Within SASMAP an innovative method which takes advantage of currents and sediment transport within the water column to either entrap sediment and create a burial mound or disperse currents so that seabed erosion was reduced was developed. The SME partner Seabed Scour Control Systems (SSCS), is a world leader in scour control systems to prevent seabed scouring and erosion for the offshore industry (gas and oil pipelines, offshore wind turbine footings). To achieve this they use mats of artificial sea grass, which float upright in the water column and entrap passing sediment particles, effectively creating an artificial seabed. The mats and deployments systems were developed further in a mutually beneficial manner for both the SME and the archaeologists within the consortium. The current mats need to be deployed by a diver and it was desirable for SSCS to develop a mat which could be more easily deployed from the surface. Archaeologically speaking the consortium wanted to test the applicability of the mats to protecting shallow water submerged archaeological sites, which are under threat from near shore and coastal erosion.

Within the SASMAP project SSCS developed mats and variations thereof that could be deployed using alternatives to the anchors that are used to affix their standard mats.
There were five principal objectives were:

1. Development of an Edge Weighted Frond Mat (Artificial Seagrass).
2. Development of a deployment frame for installation of the mat.
3. Trial various mat-specifications i.e. frond length, mat density and mixed frond length/density.
4. Development of the mat/frame to achieve a reduced installation time and eliminate the need for (a large amount of) divers.
5. Sandbag weighted mats. Artificial seagrass mats with an apron surrounding them were also trialled. In this way the mats could be weighted using sandbags when on the seabed.

The Edge weighted mats and lifting frame were successfully developed and the mats trialled around the area of the previously mentioned Tudse Hage site in Denmark. They were also trialled on a 17th century shipwreck which sank on the Texel Roads, east of the island Texel in the Netherlands. At this location, threatened by natural erosion, ships anchored between 1500-1800 to be (un)loaded for the Amsterdam harbour. Despite the shelter the island provided against Northwest winds, hundreds of ships went down during the centuries. One of these was the (possibly) North-German merchant-ship BZN10, which carried Iberian jars, slate, barrels with grapes and anchovy, and several small objects. This site was extremely dynamic with large amounts of sediment transport around the site - perfect for the trials.

The new edge weighted mats were easy to deploy and the newly developed frame by SSCS made it possible to deploy a single mat within 8 minutes, in rough weather conditions and poor visibility (Figure 23). It was also possible for a single person to attach a new mat to the frame, making the whole process more effective. Importantly the mats stayed securely in place in The Netherlands and Denmark and are a non–intrusive method, which is important for their installation on archaeological sites. Even the strong tidal current in The Wadden Sea did not move the mats. The edge-weighted system therefore works perfectly in securing the mats without disturbing the soil (including the fragile archaeological remains) underneath.

Because it is not always possible to use a big crane-operated vessel due to the location of a site (in Baiae for instance), SSCS also developed special mats which could be weighed down using sand bags along the edges. In Baiae (Italy) these were successfully deployed. Although it was labour intensive to fill all the sandbags, they kept the mats secure in place (Figure 24).

Both in The Netherlands and Italy there was significant sedimentation. In The Netherlands only after a few days most of the mats disappeared under a thick layer of sand as was shown by repeat monitoring of the mats with multibeam sonar (Figure 25). Also one of the characteristics of the seagrass is its dynamic function. The fronds may not keep the sand permanently trapped but if the sand washes away the fronds will rise again and start slowing down the current again with as a result, sedimentation will take again. Finally throughout the trials of the artificial seagrass mats it was observed that the mats served as a nursery for many fish and other sea life (Figure 26).

Potential Impact:
SASMAP was funded under the call ENV.2012.6.2-6 Development of advanced technologies and tools for mapping, diagnosing, excavating, and securing underwater and coastal archaeological sites. The description of the call was:

Sea-level rise, human activities-offshore, drilling, fishing, dredging and construction, put at risk sustainability and authenticity of European underwater, coastal cultural heritage and submerged landscapes inundated since the post-glacial sea-level rise. The topic aims to develop innovative non-destructive technologies, tools and methodologies to improve the early detection...
and location of underwater and coastal archaeological sites, to guide the process of underwater survey and to excavate archaeological remains while securing their conservation, compatible with their future management and monitoring. Case studies should show how the techniques and instrumentation developed are effective with realistic trials on submerged sites. Training needs for technology use should be addressed. Cooperation between scientific institutions, enterprises, SMEs, and with public or responsible authorities is expected.

Furthermore, the call specified:
Expected impact: Contribute for future standardization by developing best practices and affordable solutions in terms of cost user friendliness that could be widely used at European level. The results of the research in this area should have a high potential for transferability, clearly benefit SMEs and create a favourable economic impact on the sectors of activities concerned.
Specific feature: This topic is mainly addressed to SMEs, in appropriate partnership with research institutions and other stakeholders. Involvement of R&D performing SMEs is encouraged to ensure maximum impact. Involvement of SMEs carrying out non technological tasks is appropriate.
Additional eligibility criterion: Projects will only be selected for funding on the condition that the estimate EU contribution going to SMEs is 30% or more of the total estimated EU contribution for the project as a whole. This will be assessed at the end of the negotiation, before signature of the grant agreement. Proposals not fulfilling this criterion will not be funded.

In the following we analyse the impact of the results of SASMAP directly relevant to the call

IMPACT 1 Benefits for SMEs

The SASMAP consortium included four SME partners who were already leaders in their respective fields including development and global supply of technologies for: oceanographic acoustic surveying (Innomar (DE)), characterising and monitoring marine environments (Unisense (DK)), construction of bespoke underwater equipment for scientific purposes (AKUT (DK)) and design and implementation of systems for protection of off shore constructions (Seabed Scour Controls (UK)). From the start of the project the overall EC requested budget for the SMEs was 36.9% of the total project budget, which rose to 42% at the conclusion of the project and with the SMEs own investment in time in the project being on average 30% more than initially planned. The SMEs own further investment relates in part to the fact that from the outset the project was to be a mutually beneficial endeavour. The SMEs were asked what was in there R&D pipeliness and how this could be exploited to develop their own business plans and markets, at the same time as addressing the particulars of the call and investigating and protecting Europe’s underwater cultural Heritage. Thus, the majority of SME partners saw the finances of the SASMAP project as a supplement to fulfilling their own R&D ambitions.

The impact of these new technologies has had wider implications than just the SASMAP project and has enabled the SMEs to increase their business profiles. Impacts for the specific SMEs are as follows:

Innomar (IMAR): The SASMAP project facilitated the development of what is now termed the SES2000- Quattro parametric sub bottom profiler. This fitted into the company’s SES-2000 family of parametric sub-bottom profilers and fills a gap in the company’s existing portfolio. The proposed parametric multi-transducer sub-bottom profiler has closed a gap in available survey equipment in general. While side scan sonars can acquire seabed data with high resolution and full coverage, there is a lack of such data to locate buried objects. To protect cultural heritage, detailed site investigations to locate possible archaeological objects are increasingly required by authorities before starting dredging activities e.g. for pipe laying or harbour extensions. Outside of the field of archaeology there are other demanding tasks for the survey industry such as searching or monitoring pipelines and cables as well as risk mitigation at prospective offshore building sites (e.g. windfarms, bridges, tunnels). All these applications require data with high spatial density and accuracy not only from the seabed but also from the sub-seafloor sediments, which the new equipment will provide.

Throughout the development Innomar have been actively disseminating the concept of the equipment and its potential use to...
a wide range of potential customers including maritime archaeologists, oceanographic researchers and companies involved in
the offshore industry. This has been through seminars, industrial exhibitions and show cases in Denmark (x2), Germany (x3),
UK (x2), Norway, Korea, Japan and Belgium. The equipment was well received and the successful development of the 3D SBP
has advanced it from a proof concept through to prototype and will be launched as a new product at the forthcoming Innomar
Workshop in Germany in November 2015.

Partner 3 Unisense (UNI): The SASMAP project allowed the company to develop products for a new market segment
(archeology). Within the project the company has developed an open water data logger, sediment profiler and field micro
optode meter for sub surface monitoring of dissolved oxygen. Of particular benefit to the company was the opportunity to
develop The Field MicroOptode Meter which can measure dissolved oxygen concentrations for extended periods of time and at
different depth in sediments. The microoptodes are more stable than electrochemical sensors and can be buried for weeks, if
necessary, thereby enabling undisturbed measurements. This device was initially developed for use with the company’s
existing Field Micro sensor Multimeter, but Unisense will develop the product further to make it compatible with all Unisense
data loggers. Unisense will continue the development of a common field system platform that enables use of the Field
MicroOptode Meter on all of their field instruments. Furthermore, it is expected to integrate the ADCP and CTD devices from
the open water data logger on other Unisense field instruments so that all the new instruments developed within the SASMAP
project can be used for a broad range of applications in marine science and research. The sediment profiler was developed and
applied with success. It is a difficult application and the sediment profiler was continuously improved during the project. The
Guideline Manual 2 produced in the project describes how this instrument can be applied to characterize the nature of the
burial environment in terms of its effect on the preservation of archaeological material. More studies are needed in order to
determine the full potential of this instrument and we hope that this work will be continued by the archeological community.
The collaboration with the scientific institutions in the project has been crucial in order to understand the requirements for
this application. Unisense believe that the newly developed tools will gradually be known to scientists within the field of
archeology and thereby open a new market for Unisense. We also expect to increase sales to existing markets since the new
instruments will be closely integrated in our complete portfolio of field instruments.

Partner 4 AKUT (AKUT): The SASMAP project has enabled the company to develop two unique pieces of equipment; an
underwater wood tester and a sediment coring device. The purpose of the wood tester (coined the WP4UW) is to make non-
destructive evaluation of the state of degraded wood found in marine environment both in situ and in the laboratory. The tool
is diver hand held and operates to a water depth of 30 meters. At present the device can be used on any wood
(archaeological, recent, waterlogged, wet or dry) both over and under water. The WP4UW can be exploited by anyone (e.g.
archaeologist, foresters, construction companies, harbour authorities) with the need for assessing the density of wood
samples to a depth of 120 mm’s from the surface of the wood. The interpretation of data still needs expert assistance (new
business area for AKUT). As there are no other devices on the market that can be used underwater the WP4UW may be
patentable, but the complexity and high cost of the equipment and the need for expert knowledge of wood properties,
combined with a relatively small marked, make it unlikely that other companies will copy the product, thus protection of the
intellectual properties rights are considered to be unnecessary. As the WP4UW is still a prototype, AKUT is at the moment only
offering the service to make density analysis for customers and has been well received within the archaeological/
conservation world with the company being asked to showcase the equipment and potential consultancies in Denmark, the
Netherlands, UK, Sweden and Australia. AKUT will undertake further research and development, and in the future offer custom
made devices.

The purpose of the sediment coring device, the Vibracorer, and the lifting device is to improve diver deployed sampling
techniques for sediments, not only for the purposes of this project, but in general (dating, pollen other environmental analyses
requiring sediment sampling) without disturbing the layers of sediment, which are very difficult to sample due to their often
mobile nature. The corer is constructed in such a way that discrete layers within sediments can be easily sub sampled in order
to characterize both sediment type and pore-water composition in the laboratory. As both the corer and the device for
retrieval of the cores are diver handheld devices, they can be used from shore or small vessels without needs for lifting frames
etc. The vibracorer and the lifting device can be exploited by anyone with need for analysing the first 2 metres of the seabed
e.g. archaeologists, geologists, construction companies, survey and environmental authorities. The device can be used by
anyone with sufficient diving skills. In order to ensure quality of the samples additional training is required. Although used differently, vibracoring is a well-known technique and therefore we judge that protections of the Intellectual Property Rights are not feasible. The device developed for retrieval of the cores has not been seen before and therefore patenting will be attempted. The vibracorer and the retrieval device have reached a stage where it can be used for fieldwork by trained personnel. AKUT will undertake further research and development, before the devices will go into production.

Overall AKUT’s participation in SASMAP has had several important impacts, notably in: new business areas in the field of underwater services; new product lines of unique equipment; increased number of staff and increased expertise in the fields of wood technology, underwater equipment, quality assurance of sediment cores, materials, pneumatics, manufacturing, underwater fieldwork, electronics and process control. Furthermore this has had unforeseen benefits for the company including International networking (also outside of EU) in the field of science and underwater technology. In order to exploit the full potential of the achieved results AKUT will expand the staff further with personnel having administrative, marketing and diving skills and is will be reorganized accordingly in the foreseeable future. Although AKUT see the potential of further / future EU funding as providing resources for further development of the tools developed the experience from SASMAP has been that the administrative load with reporting and documentation has been out of proportion with the resources in a small company. In many aspects the time spent on administration has detracted from work on developing the equipment and has resulted in many (unpaid) working hours in this matter.

Partner 5 Seabed Scour Control Systems (SSCS). One the major impacts for the SASMAP project on the company will be to trial and develop our products to work in shallower waters. There is an increasing demand for this from customers having to deal with near shore / coastal erosion The exposure of the company through the project will also help us to continue our increasing development into markets in the near and far east.

The purpose for the tools developed was to enable SSCS to complement their range of scour protection products with the introduction of the “weighted Frond Mat”, which enabled frond mat deployment without the need to use subsea tooling traditionally required which includes the reliance on divers and hydraulic equipment which can impact on the vessel to be used – particularly when operating in inshore and near shore environments. A secondary benefit is that the tools developed enable mats to be deployed without the need for divers, as the deployment frame can be activated remotely or by a suitable Remotely Operated Vehicle. These tools are exploited by the various markets, both nationally and internationally that SSCS currently work with, including offshore oil and gas and offshore wind, as well as smaller scale applications such as that experienced during SASMAP and other nearshore / inshore environmental or civil works where large vessels may not be available or suitable. The development of the SSCS Weighted Frond Mat has allowed SSCS to approach projects where the traditional method utilising divers is not deemed viable – this is particularly beneficial in the UK and EU where divers are being utilised less and less in the offshore wind and oil and energy markets. The effect of this development has been recognised in some of our markets and is expected to provide an increased contribution in the future company business strategy.

As part of the company’s ongoing marketing and brand awareness campaigns we plan to include the SASMAP project information and the product developments as a crucial part of all such activities including seminar presentations / talks, client meetings, news and magazine features. Currently the SSCS Weighted Frond Mat and Deployment Frame have been included in activities including: SSCS company profile, SSCS website (www.sscsystems.com/scour) product video which has been used at events such as the Suffolk Chamber of Commerce Networking event, SSCS Track record document and project case study, numerous company presentations and articles in industrial magazines including Dock Yard magazine, the Marine and Maritime Gazette. The company has also received first prize in the GY Spirit of Enterprise Awards 2014 – category for “Great Business Idea”

Development of the SSCS frond mats and deployment frame will be an ongoing process based on feedback from the various applications and clients. To date the following developments have been made or are currently in discussion outside of SASMAP and following input from clients: grab handles to be added to the deployment frame to assist with easier manoeuvring when in the water – particularly when using an ROV to manipulate the frame; the long weighted tubes, which were originally a single 5m+ long object have now been halved to allow for easier handling when filling and manoeuvring the filled tubes; potential development of a 5m x 5m Weighted Frond Mat to achieve the same offering as the company’s Anchor Retained Frond Mats. No exploitable Intellectual Property Right Measures are not foreseen with these developments as it is not
deemed relevant due to the application of the tools being developed and the general information are already in the public domain.

IMPACT 2 Development of advanced technologies for locating, mapping and diagnosing underwater archaeological sites.
The work packages involving the down scaling elements of the project (WP1 and WP2) saw the development of two models to study sea-level change in significantly different coastal environments in Denmark and Greece. These models were subsequently visualised with the aid of GIS and enabled prediction of where coastal archaeological sites may potentially be found. The Danish model has already had an impact in terms of development led archaeological investigations whereby the Danish developer EnergiNet / Denmark have expressed an interest in the Danish model. It is one of the leading companies in building off-shore windfarms and underwater power cables with projects throughout Danish waters. One of the major projects they are conducting is a windfarm in Smallandsfarvandet where they consulted the project partner GEUS to investigate and evaluate the area from the archaeo-geological point of view. A geological model was constructed based on seismic and bathymetry data, following the SASMAP downscaling approach of WP1. The investigation aimed at finding “Hot spot” areas where stone age settlements could be located based on the interpretation of the geological model, radiocarbon dating, and the sea level curve of the area. The results of these interpretations delineated areas of high archaeological potential where further “zoom in” surveys and investigations could be conducted by the Danish Ministry of Culture. The geological interpretation considerably aided the archaeological investigations and proved to be a very cost effective method in reducing the required budget for the project.

Within this phase of the project the SME Innomar also successfully developed a sub bottom profiler which was trialled on sites in Denmark and Greece (where the above GIS / models were developed) and also in Germany and the Netherlands and was broadly successful in identifying and visualising sub surface anomalies at a resolution hitherto unavailable. As shown by the impact for Innomar (above) this has also been a success for the future markets of the company.

IMPACT 3. Safeguarding of underwater cultural heritage
The work packages involving upscaling elements (WPs 3-6) saw the developments of numerous proofs of concept devices including an open water data logger, sediment profiler and vibracoring sediment sampling device (WP3). These were successfully trialled and tested and the results of the information gained from there use enabled a protocol for characterising of the burial environment and its effect on the preservation of organic archaeological material to be developed. The impact of the tools has been beneficial to the SMEs responsible for their development (above) and their use has furthered our knowledge into how the marine environment affects archaeological materials. A non-destructive wood tester (WP4) for use underwater (which can also be used on land) was developed, which will enable better management planning of excavations with archaeological wood present- i.e. excavation vs in situ preservation. Although this was developed for use underwater, planned future developments the SME AKUT will include a version that can be used on dry land and will be applicable to assessment of wood in non-archaeological situations (forestry, building industry etc.). Should it be deemed necessary to excavate a site various tools and methods were developed to improve the safe raising of fragile organic artefacts (WP5). This included a system to block lift consolidated sediments, innovative methods to consolidate sandy sediments containing artefacts in advance of lifting and supporting materials for raising excavated artefacts. All these methods will be of significant benefit to the archaeological / conservation community when faced with lifting irreplaceable cultural heritage. Should a site be preserved in situ and there is a risk of sediment erosion this can be used to our advantage with the final tool developed within the project- the artificial seagrass mats, which can effectively dissipate currents around sites and, as was seen in certain cases create an underwater burial mound.

Preservation of underwater cultural heritage this is not always viable due to either the nature of the site environment or the fact that, due to subsea development, sites have to be excavated. SASMAP addresses both these scenarios. Tools and new technologies will be developed to improve both the excavation and raising of fragile organic materials if it is not viable to preserve them in situ. If in situ preservation is an option, SASMAP will also see the development of new technologies to stabilise sites and monitor their effectiveness and also the effects these stabilisation materials have on the environment.
IMPACT 4: SASMAP is not just a European level project - Dissemination

SASMAP from the outset adopted a European rather than a national approach because the implications of the Treaty of Valletta affect all European nations with territorial waters and thus responsibility for dealing with underwater archaeology. However, the impacts of the project have reached far further afield and this is in no small part due to the international ethos of preserving underwater cultural heritage in situ through the ICOMOS Charter and UNESCO convention for the protection of underwater cultural heritage all of which advocate this unique heritage should preferably be preserved in situ.

The results of the project have been disseminated on several levels. The project home page has been frequently updated and includes numerous small film clips of the use of the various tools developed. The project has been showcased and presented at over 30 scientific conferences and exhibitions at an international level with presentations in Australia, Belgium, Croatia, Estonia, Denmark, Germany, Greece, Italy, Japan, Korea, the Netherlands, Norway, Spain, Sweden, Taiwan, UK and the USA. Where possible any resulting conference proceedings have been published as open access and these have been made available on the project home page. The project held its own conference and workshop which attracted 53 participants (Figure 27) from Australia, Denmark, Germany, Greece, Ireland, Italy, the Netherlands, Poland, Sweden, Switzerland and the UK. The delegates represented developers, cultural resource managers, representatives from European heritage agencies and practitioners such as archaeologists, conservators, geologists and geophysicists. The two-day event included lectures on all themes of the project on day one with practical demonstrations and hands-on experience of working with the developed tools on day two. Although 53 participants attended there was interest from over 300 scientists worldwide, all of whom were not able to attend. As a response to this interest, all lectures were filmed and a short film of the overall event were made and uploaded on the home page (www.sasmap.eu) as a record of the event.

The conference was also used as an opportunity to obtain feedback from delegates about the overall objectives and strategy of SASMAP. This feedback was implemented into the main planned published output of the project – two best practice Guidelines. Guideline Manual 1: Guidelines to the process of underwater archaeological research (Figure 28) was aimed at giving an overview and explanation of the various steps of the development led archaeological process to stakeholders that are not necessarily underwater archaeologists, cultural historians or aware of the various natural scientific methods that are currently available to assess underwater archaeological sites. Guideline Manual 2: Best practices for locating, surveying, assessing, monitoring and preserving underwater archaeological sites (Figure 29) illustrates the product of carrying out these processes. It draws heavily upon the downscaling and upscaling approach that the SASMAP project has taken to the various phases detailed in Guideline 1 and draws upon the experiences gained from WP1-6. Guideline 2 discusses currently used methods and their principles and summarises the key results from the various elements of the SASMAP project. The guidelines are aimed at stakeholders and managers of underwater cultural heritage so as to improve the decision-making process in the management of the underwater cultural heritage. They will be available as a limited print run to send physically to stakeholders that were present at the conference and also as downloadable PDF files on the project homepage; www.sasmap.eu. On a final note as to the overall impact of the project, the coordinator presented the project on behalf of the consortium at the European Parliament at special EU-UNESCO meeting on the protection of Europe's Underwater Cultural Heritage in October 2015. The well-attended meeting with ca. 80 participants of which 40 were MEPs and representatives of the European Marine Board which “provides a platform for its member organizations to develop common priorities, to advance marine research and to bridge the gap between science and policy, in order to meet future marine science challenges and opportunities” (http://www.marineboard.eu/) and it is aimed that the Guidelines will contribute to shaping future European Policy on the protection of underwater cultural heritage.

Future dissemination of the project will be carried out by the coordinating institution include continual updates of the project home page when further results become available. All partners are interested in further collaboration and in the first instance this will be through scientific publication of the results in peer-reviewed journals and industrial magazines relevant to the SME. The coordinator and consortium are currently reviewing the possibilities of publishing open access articles or a monograph, taking advantage of the opportunities provided by the EUs OpenAIRE publication scheme which facilitates the open access publication of completed European level research projects.
Figure 27. Delegates at the SASMAP final conference and workshop
Figure 28. Cover of Guideline Manual 1: Guidelines to the process of underwater archaeological research
Figure 29. Cover of Guideline Manual 2: Best practices for locating, surveying, assessing, monitoring and preserving underwater archaeological sites.

List of Websites:
SASMAP public website (and intranet for partners) www.sasmap.eu Contact details in attachment.

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