# Creating a GIS for the underwater research project "anaxum": The stella 1 shipwreck



Massimo Capulli
University of Udine

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Dante Bartoli[1], Massimo Capulli[2], Peter Holt[1]

[1]ProMare, Inc. 4 Water Street, P.O. Box 450, Chester, CT 06412 USA
[2] Università degli Studi di Udine, Dipartimento di Storia e Tutela dei Beni Culturali, Vicolo Florio, 2 - 33100 Udine, Italy
dante@promare.org; massimo.capulli@uniud.it; pete@promare.org

**Abstract.** In the summer of 2011 the archaeological site known as "Stella 1 shipwreck" underwent a new season of field work. This vessel, built at the beginning of the Roman Imperial Age, sunk in the Stella River carrying a cargo of Roman tiles and a few amphoras. An international research team conducted a full recording of the hull details and its construction technique, using a combination of direct measurements and trilateration from control points in order to measure all the ancient remains. Entering the data collected into a *Geographic Information System* (GIS) allowed to create a georeferenced database of the site, a powerful tool to visualize the ancient hull in its entirety and interact with its remains.

**Keywords:** Archaeological Remote Sensing, GIS, Shipwreck, Shipbuilding, Laced Construction, Stella River.

## 1 Introduction

The Anaxum[1] Project began in 2011 as a partnership between the Department of History and Preservation of Cultural Heritage at the University of Udine and the Superintendence for the Archaeological Heritage of Friuli Venezia-Giulia.[2] The main goal of the project is to reconstruct the history of the area, focusing on the relationship be-

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[1] Anaxum is the name the Romans gave to the Stella River, according to Pliny the Elder (NH, III, 126) [1].

[2] The international, multidisciplinary research team includes: Texas A&M University and ProMare Inc. (USA), highly-specialized Institutions in the field of underwater archaeology, the Department of Geophysics of the Università di Trieste, and the Istituto di Scienze Marine (ISMAR) of the Consiglio Nazionale delle Ricerche (CNR) of Bologna which carried out remote-sensing surveys. Macquarie University (Sydney, Australia) is currently executing aerial, remote-sensing investigations.

tween man and the landscape of the Stella River, the most important waterway in this area of the Friuli plain that provided access to the Mare Nostrum [2-3]. The Anaxum Project is based on an interdisciplinary research team that uses the Stella River as a laboratory for the training of underwater archaeologists in a challenging natural environment that preserves a wide range of ancient material remains. At the same time, the field of Riverine Archaeology benefits from the development of innovative and integrated geophysical techniques, which will be applied in the future to the study of other waterways. The main goal of the 2011 field season was to launch a campaign of underwater archaeology which had both research and teaching purposes. A specific study of naval archaeology was necessary to complete the work already begun by Serena Vitri and Francesca Bressan in 1998-1999 [4-5]. Furthermore, students from the University of Udine and Texas A&M University had the opportunity to learn "hands-on" the techniques of underwater excavation and documentation of a hull, which is extremely relevant due to its particular construction technique [6].

The Stella 1shipwreck site was discovered in 1981 by sports divers [7-8], and is located only 1,500 meters south of another important archaeological site: the remains of the bridge along the Via Annia [9], which was the focus of the 2012 field season.

The hull remains lie on the left margin of the river in approximately 5 m of water, where the river bottom is slightly inclined towards the center and tilted upstream. A layer of sand 5-10 cm thick helped to preserve the ancient wood in an anaerobic environment. An unknown number of artifacts were removed over the years before archaeologists were able to assess the site: Serena Vitri and Francesca Bressan directed two rescue excavations in 1998 and 1999. In 1998, an area of around 12 x 15 m was inspected and revealed a high concentration of artifacts; further exploration revealed that associated artifacts were distributed over an area at least 30 m long moving upstream of the site [1,2].That year, the team concentrated its efforts on the cargo still in place inside the vessel. The cargo found in situ consisted mainly of roof tiles, both embrici and coppi, which were stacked vertically on the flat bottom of the barge. A second campaign was carried out in 1999, lasting two weeks and aiming at the recording of the hull remains. After a complete recording of the wooden structure the hull was covered with several layers of geotextile and sand bags, and left in situ[3,4].

The Anaxum Project's team returned to the Stella River in 2011 to reassess the site and conduct a full recording of hull details and the construction technique. In order to access some of the timbers, it was necessary to use a water dredge to remove the sediment covering the shipwreck. All extant timbers were recorded and a corresponding timber catalog created. A combination of direct measurements and trilateration was used to map the site. All the data were entered into the GIS program, and were also drafted by hand; a model of the ship was drawn to scale on paper. The survey and excavation conducted during the 2011 field season resulted in the creation of a partial reconstruction of the shipwreck.

## 2 The GIS of the Stella 1 shipwreck

The creation of a GIS (Geographic Information System, also known in Italian as Sistema Informativo Territoriale or SIT) to study the Roman shipwreck sunk in the Stella River produced a powerful tool that has allowed researchers the ability not only to georeference the underwater site with all the artifacts that it contains, but also to plan, monitor, and visualize the progress of ongoing work and the results of the underwater excavation. In particular, there are three characteristics that made the GIS (in this case, Site Recorder 4 of 3H Consulting Ltd.), an extremely powerful and versatile tool:

1) Possibility to insert the location of each artifact on the bottom of the river by calculating the coordinates of the point of its location. Both the timbers of the hull, and the remains of roof tiles, amphoras, and pottery still present on the wreck site were individually mapped and georeferenced;

2) Easy management of the cartographic information of the area, such as aerial photographs and satellite data, bathymetric and river current charts, and topographic and geologic maps;

3) Unlimited detailed information that can be given to each artifact discovered during field work. The photos available, its size, depth of discovery and conservation status were recorded on customized datasheets that it is accessible on any computer by simply selecting the items in the system for which more information is needed (Fig.1). The creation of a GIS has provided a valuable system to quickly view the excavation area and the findings, making it easy to examine the site in its entirety. Furthermore, it is a geo-referenced electronic database, which can be expanded and updated constantly.

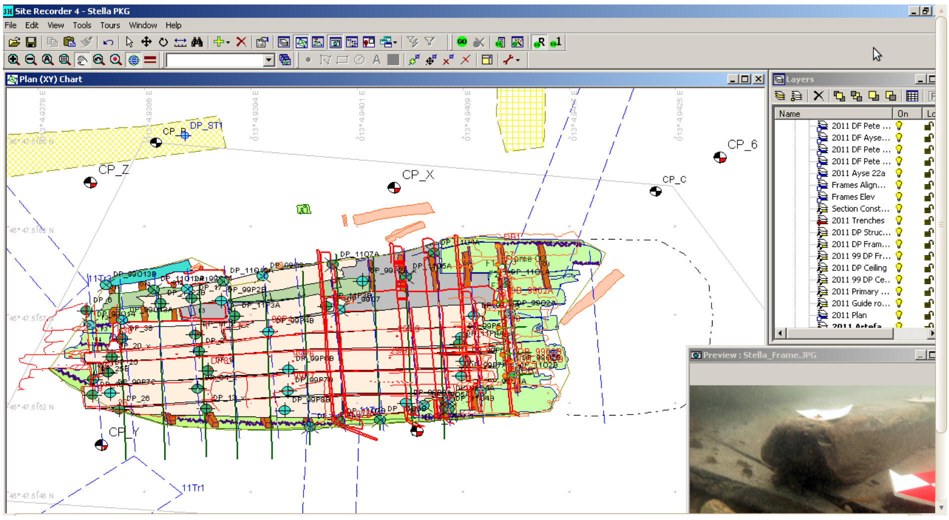



**Fig. 1.** Screenshot from *Site Recorder 4*.The GIS visualizes not only the Stella 1 shipwreck under excavation, but also extra information, images, and details.

## 3 Survey Methodology

First of all, the GIS program was used to position the Stella 1 shipwreck on a map of the surrounding area. The wreck lies 340 m north of the public square of the town of Precenicco, on the east side of the Stella River. The river is 28 m wide at the spot where the wreck is located. Site Recorder 4 also proved to be very useful to visualize the archaeological site within its wider geographical context, showing, for instance, the exact location of the wreck compared to the Roman bridge on the Via Annia (Fig. 2). Any other site discovered in the area can be added in the future, providing more and more information to complete the archaeological map of the region. The positions of four main reference points, already used in the campaigns of the late '90s, were taken as starting points for georeferencing the wreck in 2011. In Figure 3 it is possible to see the four original datum points. Vitri and Bressan left in situ (visible on the chart as CP_W, X, Y, Z), which were used as starting points to correlate all subsequent measurements. High accuracy data for the area were obtained for free from the Catalog of Environmental and Territorial Data of the Friuli-Venezia Giulia Region (http://irdat.regione.fvg.it/Consultatore/default.jsp), and then imported into the site plan.

The hull planks and frames appeared to be in remarkably good condition, thanks to the geotextile and sand bags which were used to protect them at the end of the 1999 excavation. The frames are still firmly connected to the hull planking, which is still laced together with vegetable fibers. The ceiling planking, which the Romans laid onto the framing loosely rather than affixing it to the framing, was sitting on top of the frames but had likely shifted position in the 2,000 years since the wrecking event. Considering that the Stella shipwreck can be displayed, in a very basic way, as a single and compact structure (a "rectangular box"), it was possible to use measurements taken with three fiberglass tapes, a meter, and a goniometer, to map the position of the various components of the hull. Using triangulation, three distances and the depth for each desired point were taken, and then everything was plotted into the GIS software.

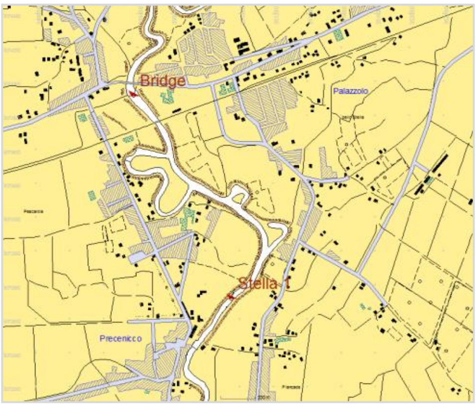



**Fig. 2.** General overview of the area: the Stella 1 shipwreck, Precenicco, Palazzolo, and the Roman bridge on the via Annia.

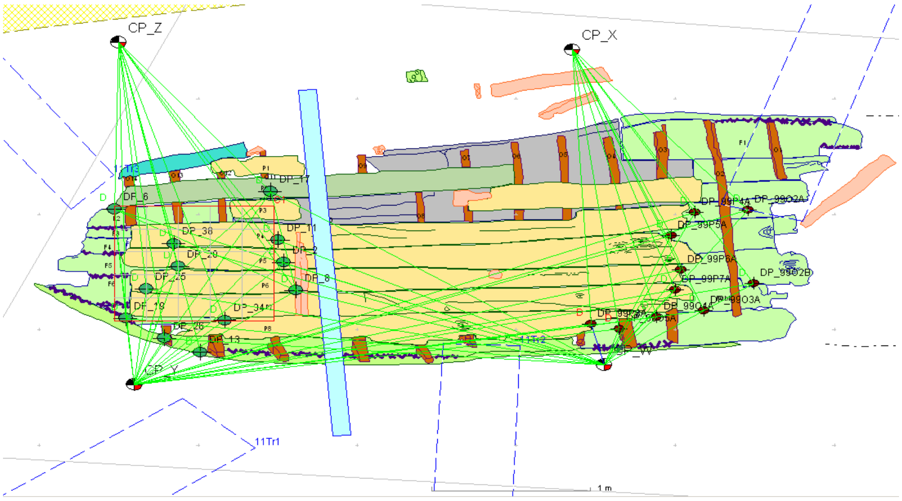
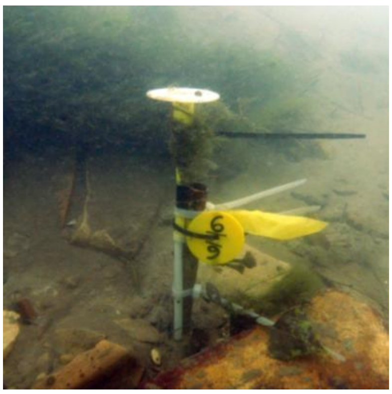



**Fig. 3.** Four basic control points as "cornerstones" to georeference other points and the wreck.

### 3.1 Horizontal control points

Horizontal control points were provided by a network of unmovable data points fixed inside and around the site. The control points - CP_W, CP_X, CP_Y, CP_Z - that were installed during the previous excavations were restored, adding new plastic rods fixed to the top of each original datum, and were made more visible by covering this tip with yellow and black stripes of electrical tape (Fig. 4).Additional control points, numbered as CP_1 to CP_5, were added in 2011, using helical screws made of galvanized steel fastened into the bottom of the river around the hull structure (Fig. 5).Each control point was clearly marked with a yellow disk and flagging tape to make it easier to identify them under limited visibility conditions. Measurements were made between the points using a conventional fiberglass tape measure.



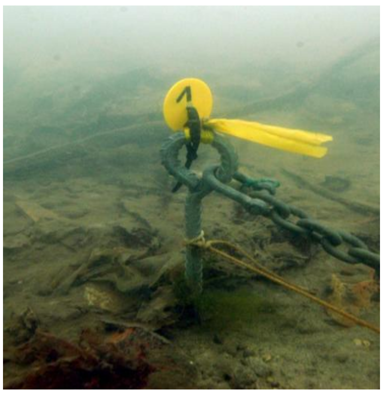


**Fig. 4 -5**. Control point of the 1998-1999 campaign restored (left), and a new one (right).

### 3.2 Vertical control points

The vertical measurements (depths) were taken using a single dive computer for all measurements (Suunto Vyper), in order to eliminate any possible variation of depth caused by differences between different instruments. Obviously, there was also a need to take into account the variation in depth due to daily tidal excursion, which was calculated by keeping track of the time of day when diving started and ended. Unfortunately, it was noted that the depths provided by the dive computer were not sufficiently detailed and accurate to calculate the 3D positions of the data, as the dive computer only reports depth to a resolution of 100mm which limits the precision of the measurements. The only option available in the field was to build a bubble level and to measure the depths by hand; this device, used in antiquity, uses a bubble of air to accurately transfer a known level from one point on the site to other points on the site. The bubble level was constructed using materials at hand and available at a local builder’s retailer. A 7m length of 10mm diameter clear plastic tube, normally used for winemaking, was employed to contain the bubble. The top of a plastic drink bottle was attached to the hose at the fixed, or reference, end so the hose could be filled with air underwater from a diver’s regulator. The free end of the plastic hose was attached to an aluminum scale bar and weighted with a small lead weight so the free end would fall to the seabed if dropped and not let the air in the tube escape. While in use, the bubble level was attached to the shallowest control point so that all measurements were made below this level. The plastic tube was filled completely full of air and the difference in height was noted between the control point reference and the lower level of the air bubble at the fixed end of the tube. The free end of the tube was then moved around the site by a pair of divers and for each control and detail point the relative height of the bubble above the point was measured with a 1m plastic rule to a resolution of 1mm. A number of points were recorded, both at the beginning and end of each leveling run, as a confidence check to ensure that no air had escaped from the tube during the recording process. Closed loop tests on the depths measured by the bubble gauge showed repeatability in measurements of between 0 and 10mm.

### 3.3 Detail points, creation of the digital model

Measurements from the primary control point network were used to position detail survey points on the hull and on other objects around the site. Detail points had been added to the hull timbers during the 1999 survey and a number of these points still remained attached to the hull; additional points (small nails passing through plastic tags) were also placed on the ceiling planks and frames in 2011 to provide reference points for the timber recording. The positions of the primary survey control points were calculated by combining the distance, depth, and surface position measurements using Site Recorder 4. Any measurements that were found to be in error were re-measured and the point positions recalculated. The 51 detail points were positioned using 235 manual measurements (Fig. 6). The majority of points were positioned using four or more distance measurements plus a depth measurement; however, some points that did not survive for long were only positioned with two or three measurements so their positions are less reliable.

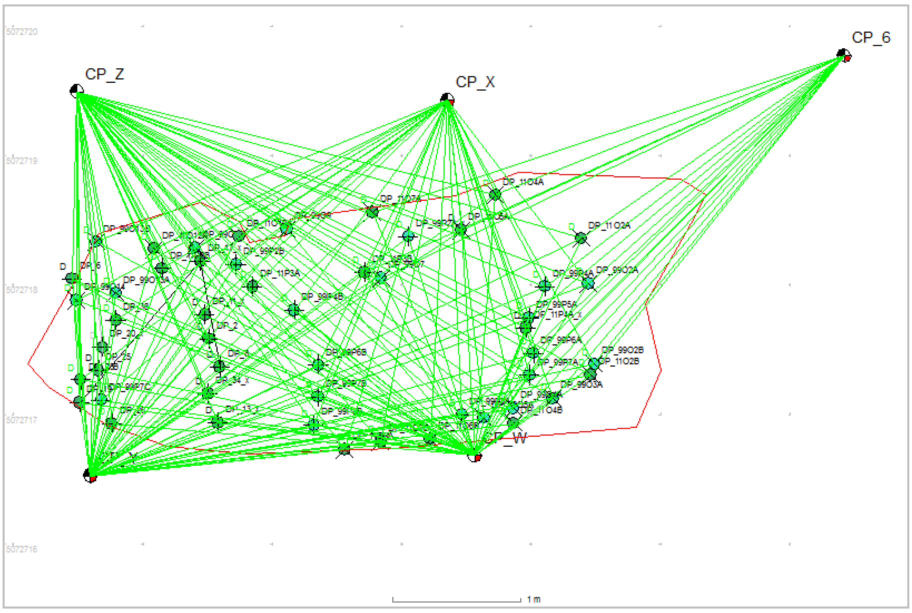



**Fig.** 6. Detail points measurements at the end of the field season.

## 4 Conclusions

At the end of the 2011 field season it has been possible, thanks to measurements taken and to some extra sketches made by hand, to draw all the archaeological features visible on the riverbed, including the entire hull and its details. The dimensions of all the wooden elements of the ship and the positions of the treenails, limber holes, and grooves for the ligatures have been mapped in each frame, along with ancient repairs visible in several bottom planks. This information, along with information regarding the spacing of the frames, has been used to reconstruct the entire shipwreck. In this way it has been possible to create a digital reconstruction of the Stella 1 shipwreck, which is completely georeferenced, and also to relocate the cargo of roof tiles as it appeared in 1998-1999, based on the data Vitri and Bressan recorded (Fig. 7).

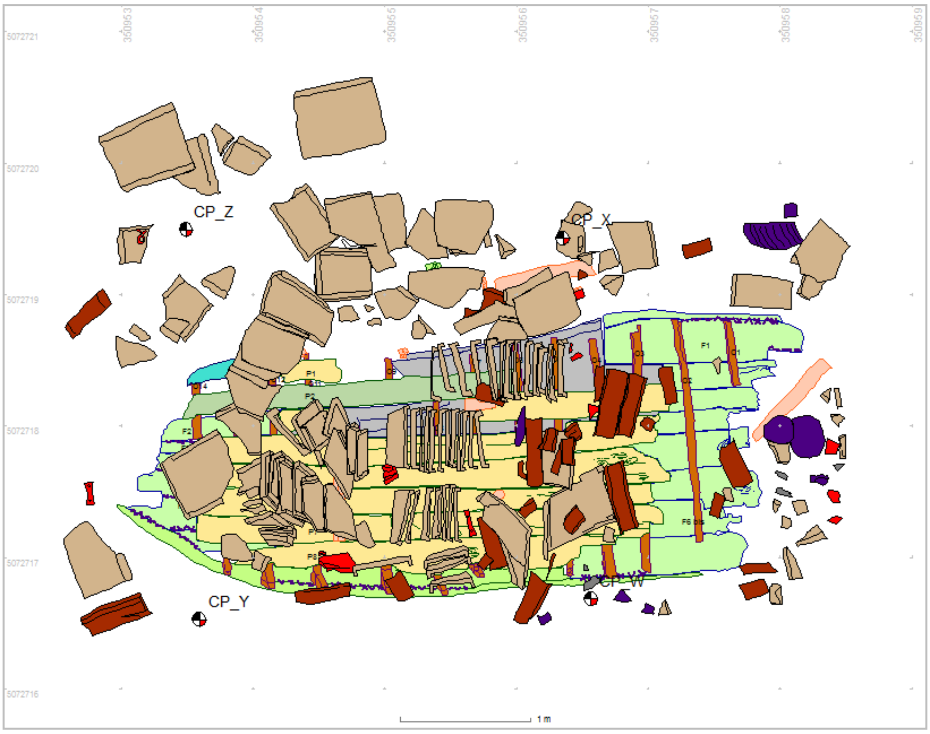



**Fig. 5.** The Stella 1 shipwreck at the end of the 2011 field work. The tiles visible in 1998 and 1999 have been virtually relocated on the hull.

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