Case study for the application of the SES-2000 *quattro* system during marine archaeological investigation near Ostend, Belgium (2015)

**Study Site**

The study site is a coastal stretch of c. 3 km x 1 km, located offshore Raversijde, near Ostend, Belgium (Fig. 1). During the Late Holocene the sub-tidal and intertidal zone was dominated by a tidal flat and marsh environment cut by tidal gullies. This environment formed alternating peat, clay and sand layers with a high lateral variability. During the Early Middle Ages land reclamation and dyke building started with later evidence of a medieval settlement, called Walraversijde. Archaeological finds at the site include remains of Roman dykes, remains of medieval houses, peat digging pits, salt pans, trenches, log roads and wooden tools. Some of these structures were visible on the beach until the 1970s, when the construction of new breakwaters caused the coverage of the site with 1 to 2 meters of sand (Figs. 2 and 3).

![Figure 1](image.png)

**Figure 1** Study site offshore Raversijde, Belgium

Today’s marine archaeological questions and study goals include the understanding of the recent geological evolution over the last 5000 years, the mapping of the former coastline and tidal channel network, the identification of archaeological layers and the detection and mapping of buried artefacts and relics of human occupation and activities, such as Roman and medieval houses, peat digging and salt exploitation structures (Fig. 2). Previous work included 2D seismic investigation, an
EMI survey and ground truth data collection with cores and CPT. However, the sub-seabed morphology has shown a high complexity and the mapping of peat layers and tidal gullies was rather difficult with the required detail for the above mentioned marine archaeological purposes. A full paleo-channel network could not be established and artificial features were not detected or interpreted at all. It must be noted that survey conditions at the site are very demanding with a tidal range of 4 to 5 meters, often high wave action and shallow water depths between 0 and 10 metres.

![Figure 2](image2.jpg)  
**Figure 2**  Aerial Image of the site before the construction of the breakwaters (Photo: E. Cools)

### System Setup and Methods

In summer 2015 a survey with the new developed SES-2000 quattro multi-transducer parametric sub-bottom profiler was performed by the University of Ghent. On a small survey boat of c. 8 m length equipped with RTK positioning, true heading sensor, high-accuracy motion sensor and a simultaneously operated multi-beam system the over-the-side mounted SES-2000 quattro multi-transducer array was easily mobilized. The array involved four transducers in a line of 1 m spread across the survey direction.

An area of 220 m x 80 m within the intertidal zone was surveyed over two days with a total recording time of c. 6 hours due to time constraints given by the tide. A line spacing of 1 meter was chosen. However, small gaps remained within the acquired data set (Fig. 3) since navigational and time limits did not allow for enough infill lines in order to achieve full coverage. The system was operated with a low frequency of 10 kHz and a pulse length of 100 µs with a resulting vertical layer to layer resolution of better than 10 cm (Fig. 4). A recording window of 7 meters was used and each of the individual transducers was operated with c. 17 pings per second. All data were motion compensated during acquisition.
During offline data processing positional offsets were corrected by using the RTK data and true heading sensor data. Tidal corrections were applied as well. All scattered soundings were transformed into a uniform lattice with a grid cell size of 25 cm x 25 cm x 1 cm. The uniform lattice was visualized in 3D with a volume renderer by using an opacity and colour map transfer function. Clipping planes were applied in order to visualize buried sections and time slices below the sediment floor.

**Results**

The seabed is gently sloping towards the sea and water depths are getting slightly shallower towards the two bounding breakwaters (Fig. 3). No exposed features were observed in the entire area, also not within the simultaneously acquired multi-beam data set. The complexity of the sub-seabed morphology is already visible when neighbouring seismic sections of the transducers within the array are compared (Fig. 4). Horizontal and slightly rotated time slices at different depths revealed numerous artificial features and a tidal gully (Figs. 5, 6 and 7). They are quite comparable to visible surface features on existing photographs from the time before burial. Dimensions of the sub-surface features vary between 1 m and up to 50 m length (Fig. 5). The peat layer distribution is recognizable by a distinct amplitude level of the acoustical signals (Figs. 4 and 5). Furthermore, several circular explosion pits with different diameters between c. 5 to 15 meters were identified within the entire area of the survey site (Fig. 8). These are related to the 2nd World War when the coastal defence structures were attacked by Allied forces as well as controlled explosions of ordnance on the beach after the war.

Further processing and interpretation of the acquired data set is ongoing and results are expected to be published later.
Figure 4  Morphological differences between two seismic sections with a distance of 75 cm

Figure 5  Time slice through the 3D volume with artificial features and aerial photograph
Figure 6  Time slice through the 3D volume with artificial features and beach photograph

Figure 7  Time slice through the 3D volume with paleo tidal gully
Acknowledgements

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