Sounding Better!

Marine Asset Integrity Mapping Using Combined Multibeam Bathymetry, Topographic Laser Scanning & UAV Photogrammetry – An Example From Western Australia

Dr Peter Ramsay[1], David Murrell[1]& Darren Wilkinson[2]

(ramsay@marinegeosolutions.com, murrell@marinegeosolutions.com, & DWilkinson@landsurveys.net.au)

INTRODUCTION

Advances in marine & terrestrial scanning survey techniques together with precise inertial navigation sensors, multi-sensor acquisition system and cost-effective UAV photogrammetry allow hydrographic surveyors to undertake high precision marine asset integrity mapping. The benefit of this approach produces a very accurate three dimensional digital elevation model which could be used as a baseline comparative survey to determine the long term stability of sea walls and breakwater structures for engineering purposes.

Marine GeoSolutions have extensive experience in acquiring combined multibeam bathymetry & topographic laser scanning datasets and partnered with Land Surveys to demonstrate the viability of this technology over a test area along the Hillarys Boat Harbour breakwater in Perth, Western Australia.

FIGURE 1. Locality Map Showing the Breakwater at Hillarys Boat Harbour Demarcated by the Yellow Polygon.

1. Marine GeoSolutions, Unit 45, 110 Inspiration Drive, Wangara, WA 6065, Australia

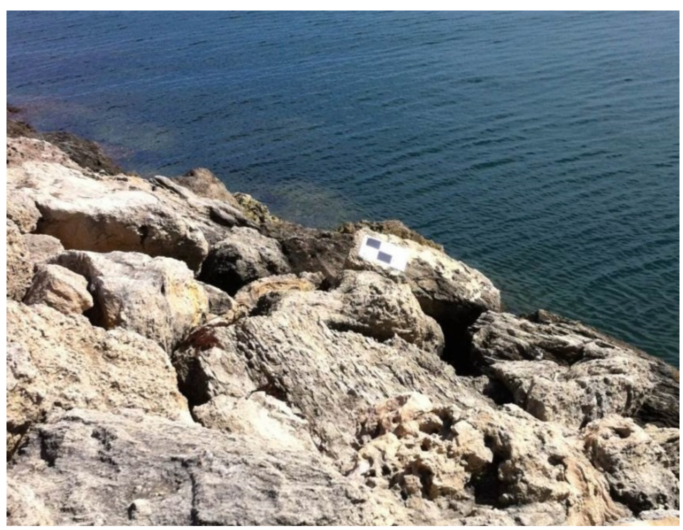
2. Land Surveys, 19 Brennan Way, Belmont, WA 6984, Australia

SURVEY METHODS

A Reson 7101ER-SV multibeam echosounder, Riegl VZ-1000 topographic laser scanner, POS MV 320 inertial navigation system and ASCTEC Falcon 8 UAV were used to acquire the datasets. A RTK GNSS base station was installed on a local survey monument within 500 m of the survey area. The survey instrumentation was installed on MGS's inshore survey vessel and the lever arm offsets accurately measured. Patch tests were conducted to determine misalignments between the multibeam sonar, topographic laser scanner and inertial RTK-aided navigation system. All the standard hydrographic survey calibrations were also performed. The multibeam sonar beam-forming was modified in the processor to ensure that the 511 equiangular-beams (EA) were generated and were able to extend beyond the water surface when the sonar transducer was rotated by up to 40°. Two sets of survey lines were run 5 m off the breakwater to simultaneously acquire multibeam bathymetry and topographic laser scanning datasets. The multibeam echosounder was set to a ping rate of 18 Hz at a 20 m range scale generating 511 beams per ping whilst the topographic laser scanner acquired 5,000 samples per ping. All inertial positioning, laser scanner & multibeam echosounder data acquisition, processing, system calibrations & most of the data visualisation were undertaken using HYPACK hydrographic software. Additional visualisation was performed in QPS Fledermaus.

A series of fifteen ground control points for the UAV photogrammetry were established on the breakwater using RTK GNSS positioning to enable the rectification of the photogrammetry imagery. A total of two 12-minute UAV flights over the breakwater produced forty-three photographs covering 100% of the breakwater.

FIGURE 2. Photogrammetry Ground Control Points Established on the Breakwater Using RTK GNSS Positioning.



RESULTS

The primary aims of this survey were to test the repeatability and accuracy of the acquired data on separate survey runs and to investigate the size of the data gap that exists between the topographic laser scanner data (above the water line) and multibeam bathymetry data below the water line on a single survey run. Initially the survey was run in a standard configuration with the multibeam transducer mounted vertically and the laser oriented to acquire data off the starboard side of the survey vessel. Preliminary survey results are shown below. NOTE the data gap that exists between the topographic laser scanner data and the multibeam bathymetry data (±1.5 m vertical data gap)

FIGURE 3. *3D Point Cloud Showing a Section of the Hillarys Breakwater and a Section of Floating Jetty. .*

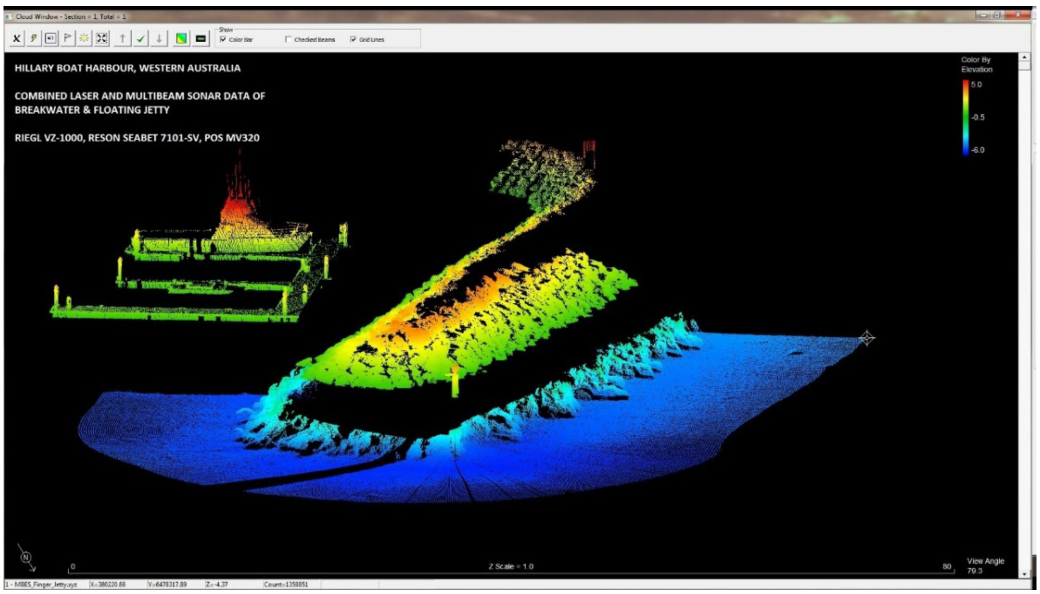
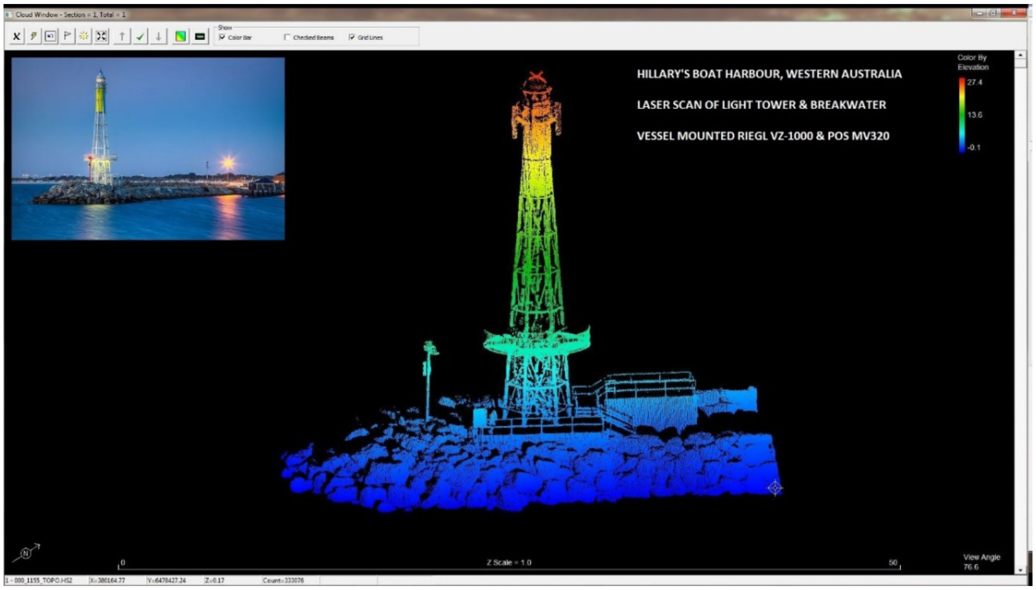


FIGURE 4. A 3D Point Cloud Image of the Hillarys Light Tower and bReakwater Collected with the RIEGL VZ1000 Topographic Laser Scanner.



In order to minimize the data gap between the laser scanner data and the bathymetry data (Figure 5), the multibeam transducer was rotated by 40° to physically steer the "sweet spot" of the curved transducer array midway between horizontal and vertical to achieve better data coverage across the flanks of the submerged breakwater. The survey was then repeated and some of the survey results are shown below. Note there is no data gap between the two data sets.

FIGURE 5. A 2D section showing the topographic laser scanner data and multibeam echosounder data (MBES) with a superimposed horizontal white line representing the water surface at the time of the survey. .

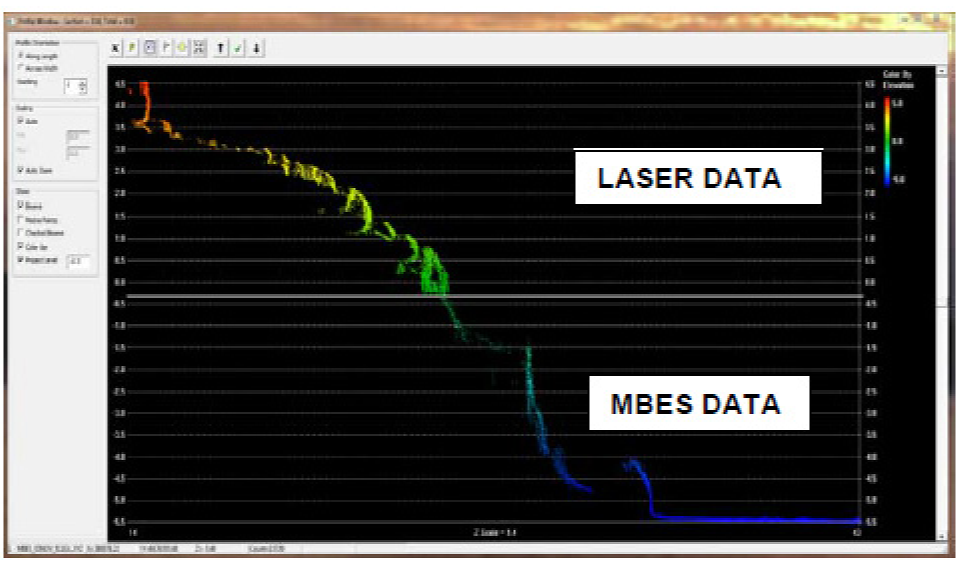


FIGURE 6. *UAV Aerial Image (top image) of the End of the Breakwater and Corresponding UAV Photogrammetry, Topographic Laser Scanning and Multibeam Bathymetry Merged Point Clouds (lower image).*

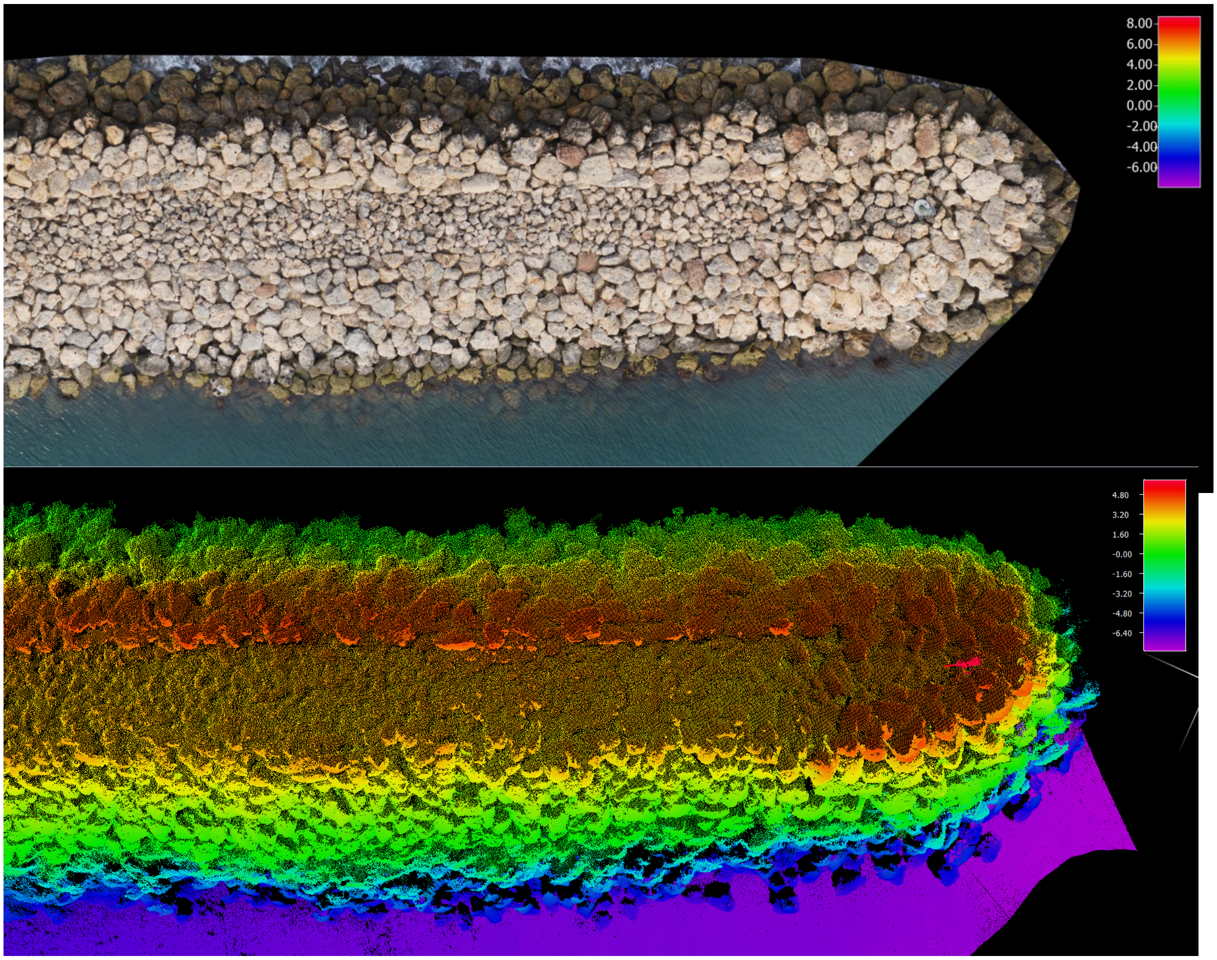


FIGURE 7. *An oblique 3D point cloud of topographic laser scanner and multibeam bathymetry data collected on a single pass along the Hillarys breakwater. Note there is no data gap between the topographic laser scanner data and the multibeam bathymetry data.*

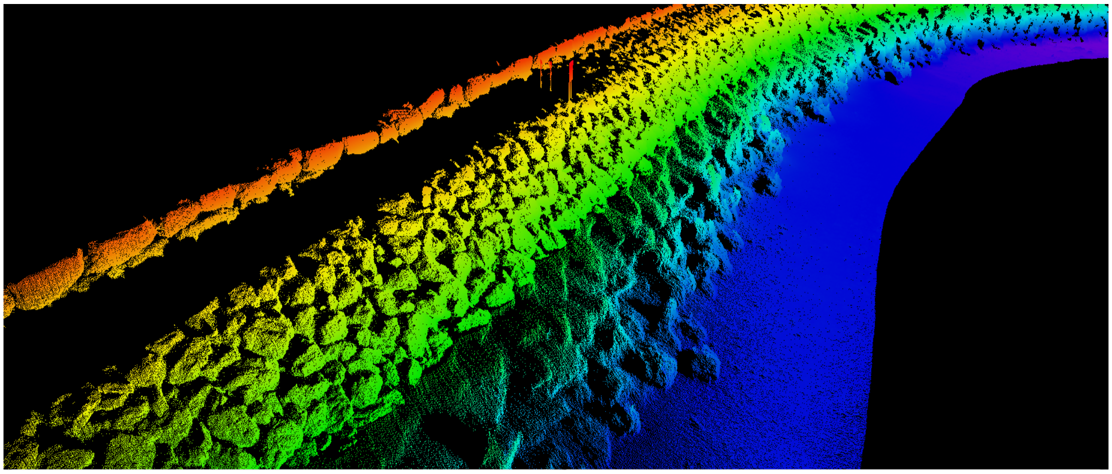
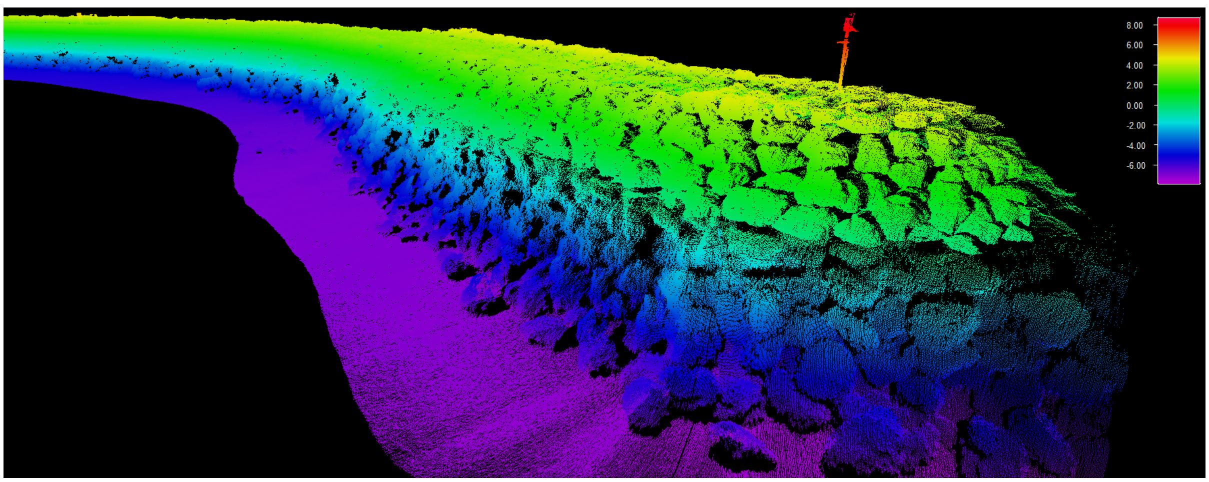
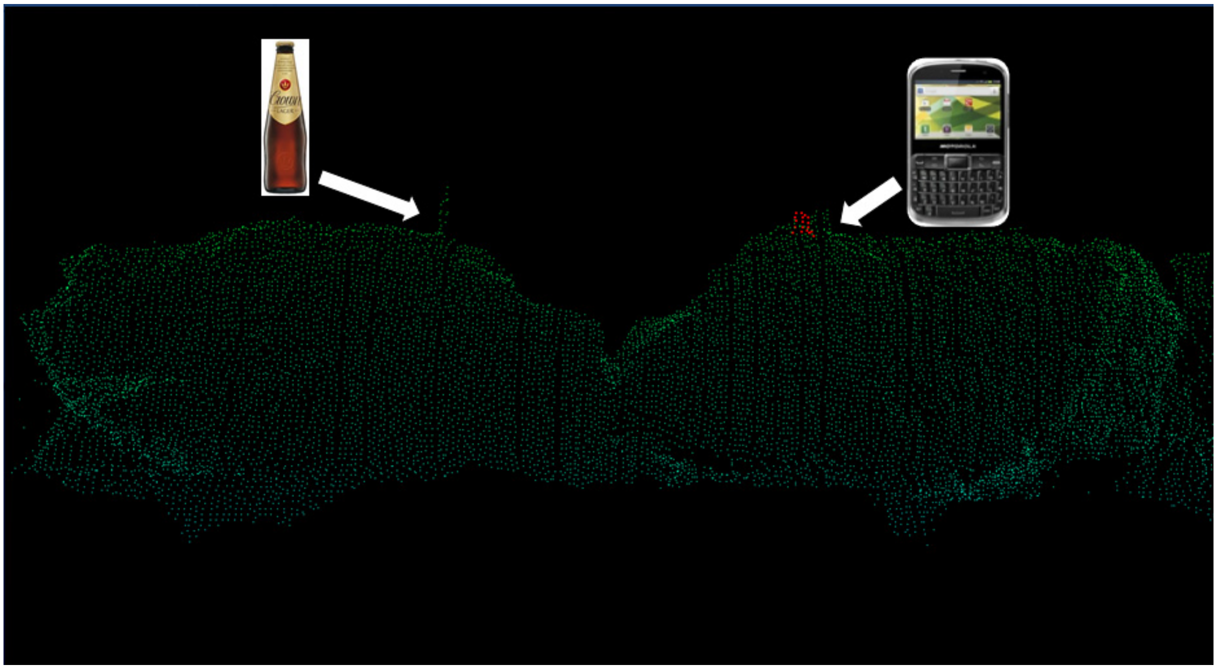


FIGURE 8. *Figure 8. A low angle 3D point cloud showing the seamless merged topographic laser scanning data (red, yellow & green hues) and the multibeam bathymetry data (blue & purple hues).*



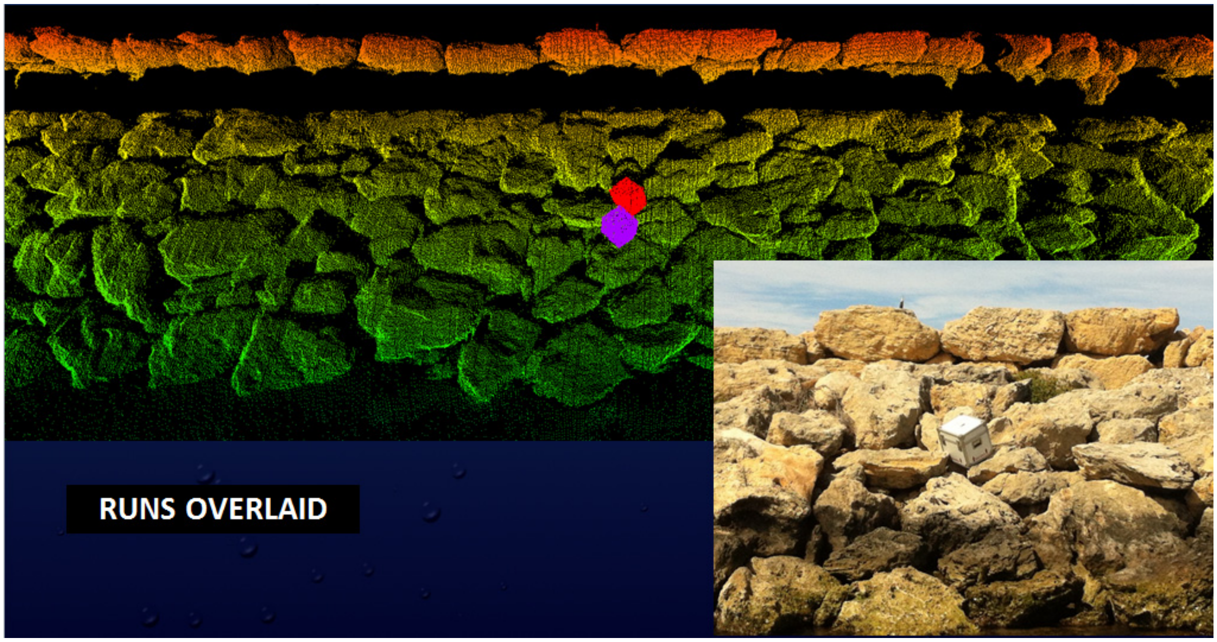
In order to test the accuracy & repeatability of the topographic laser scanning and the positioning system, two small objects were placed along the skyline of the Hillarys breakwater to investigate if these items could be mapped with the laser system. One of the items (a Crown beer bottle) was left stationary on the breakwater for two separate survey runs, and a second item (a Blackberry phone) was moved a small distance (0.070 m) between the two survey runs. Comparisons of the skyline laser data between the two survey runs revealed an agreement of ± 0.01 m for the centre-point of the stationary Crown beer bottle position, while the two recorded positions of the Blackberry phone confirmed that the phone had been moved one phone width (0.075 m) between the two survey runs; the actual phone width is 0.070 m. The results of this test are shown in Figure 9.

FIGURE 9. *Figure 9. Topographic laser point cloud showing the beer bottle and Blackberry phone along the skyline of the Hillarys Breakwater imaged from a distance of 30 m.*



A second test was performed to simulate a rock displacement on the breakwater with could affect the structural integrity of the structure. A 0.5 m^3 box was used to model the rock displacement and was repositioned on a subsequent survey run. The results indicate that the displacement of a small rock could be easily detected using this technology.

FIGURE 10. Topographic laser scanner point cloud showing the 0.5 ³ box on the first survey run (red box) and after being moved (purple box) for second run. The inset photograph shows the white box used to simulate rock displacement.



To quantify the expected levels of accuracy achievable using the combined multibeam bathymetry and topographic laser scanning, the positions and elevation of the ground control points (GCP) where compared to the laser point cloud data. In general, the XYZ positions were in the centrimetric scale (Table 1).

TABLE 1. Tabulated differences between the GCP's and the topographic scanning laser point cloud data.

GCP Station ID	RTK Survey Control Elevation (m)	Laser Elevation (m)	Position Difference		Elevation Difference (m)
			dE (m)	dN (m)	
9001	4.479	4.470	0.025	0.022	0.009
9004	3.931	3.940	0.021	0.303	-0.009
9005	1.736	1.730	0.036	0.023	0.006
9006	2.806	2.820	0.090	0.134	-0.014
9007	1.209	1.210	0.020	0.111	-0.001
9010	0.689	0.700	0.051	0.018	-0.011
9014	0.724	0.740	0.012	0.100	-0.016
9015	1.013	1.020	0.000	0.070	-0.007
Mean Elevation Difference					0.009

The photogrammetric reprojection error for the UAV aerial imagery was less than 0.008 m when processed using the ground control points.

CONCLUSIONS

This paper demonstrates that the combined use of a topographic laser scanner, multibeam echosounder and UAV photogrammetry together with precise inertial navigation and robust calibrations yield centrimetric accuracy for high precision marine asset integrity mapping. As these datasets are acquired from various different incident angles, this produces a seamless digital elevation model (DEM) with very few, if any, areas which have not been insonified or imaged. The repeatability of this technique is very good, with multiple runs of the same survey line showing overall errors of less than 0.010 m between all sensors. The modular design of the system means that surveys can be conducted simultaneously and on the same day for small areas.

The benefit of this approach produces a very accurate three dimensional digital elevation model which could be used as a baseline comparative survey to determine the long term stability of sea walls and breakwater structures for engineering purposes. It is postulated that marine structure subsidence can be monitored to better than 0.020 m.