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PROJECT MATERIAL PTY LTD
FULL SCALE TESTING OF ROCK BAG ARMOUR UNITS - FINAL

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Executive Summary

Project Material Pty Ltd, are promoting Rock Bags as an alternative to conventional rock armour to provide scour protection against wash generated by bow and stern propulsion units from ships and tug vessels. The Rock bags can be placed on the revetment and bottom of the berth pocket to prevent undermining of quay wall structures or scour around piles.

To date, only scale model testing of rock bag performance has been completed, such as *Super Cruise Vessel vs Rock Bags* from the Australasian Coasts and Ports 2019 Conference [1]. This study concluded that a revetement constructed of rock bags weighing 8 tonnes will fail when subjected to 8 m/s water velocities from a ship's thruster.

Project Material organised the use of Pacific Tug's Cape Mac tug located at their Brisbane Pacific Marine Base to conduct full-scale trials on the performance of the 4 t and 8 t Rock bags. The aim of the trial was to determine the point at which the Rock bags fail, or are dislodged, from the constructed revetment and base in the following configurations:

- Stability for the 4 t and 8 t rock bags on a 1V:2H slope
- Potential for uplift of the 4 t and 8 t rock bags on a flat surface when
    - The tug is located seaward of the bags
    - The tug is located above the bags
- Stability for the 8 t rock bags when stacked as an unsupported vertical wall

The trials were conducted on the 7th of October 2022, with the Cape Mac utilising both engines to thrust water towards the rock bags. The water velocities were measured at the revetment using an acoustic doppler velocimeter (ADV). However, during one of the runs, submerged debris impacted the ADV damaging the probe and eventually ceased to operate for the final configuration. As a result, the maximum water velocity from the tug was estimated at 5.3 m/s from data received from the damaged ADV.

During the testing, hydrographic surveys were conducted to measure the movement of the rock bags and surrounding riverbed. These scans showed that there was minimal movement for all cases and tug engine RPM, although a water velocity speed of 8 m/s was not measured to directly compare against [1]. However, the revetement was constructed of 4 t rock bags, compared to the 8 t rock bags in [1], and small 2 t rock bags used in the ground preparation and scour protection did not move under near maximum thrust from the tug.

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Introduction

Project Material Pty Ltd, are promoting Rock Bags as an alternative to conventional rock armour to provide scour protection against wash generated by bow and stern propulsion units from ships and tug vessels. The Rock bags can be placed on the revetment and bottom of the berth pocket to prevent undermining of quay wall structures or scour around piles. However, only model-scale testing has been completed to date on the stability of rock bags in this application, such as *Super Cruise Vessel vs Rock Bags* from the Australasian Coasts and Ports 2019 Conference [1].

Project Material organised the use of Pacific Tug's Cape Mac tug located at their Brisbane Pacific Marine Base, shown in Figure 2-1. The site features a permanently moored barge, Coochie, suitable for loading and installing the Rock bags onto an existing ramp via a mobile crane. The existing ramp was damaged during the 2022 Brisbane floods, as shown in Figure 2-2, but still retained a natural slope into the river similar to the required slope to be tested.

The aim of the trial was to determine the point at which the Rock bags fail, or are dislodged, when subject to thrust from a tug vessel, and compare the results to the conclusions made in [1].

Figure 2-1: Cape Mac moored alongside the barge Coochie

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Figure 2-2: Original condition of test area

Purpose

The purpose of this full-scale test, conducted on Friday the 7th of October, was to determine the following water velocity limitations of the Rock bags exposed wash from a tug, and compare the results to a previous scale model study investigating the stability of rock bags [1]:

- Stability for the 4 t and 8 t rock bags on a 1V:2H slope
- Potential for uplift of the 4 t and 8 t rock bags on a flat surface when
    - The tug is located seaward of the bags
    - The tug is located above the bags
- Stability for the 8 t rock bags when stacked as in an unsupported vertical wall

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Summary of *Super Cruise Vessel vs Rock Bags* Conference Proceedings [1]

Dan Messiter completed a study at the University of NSW Water Research Laboratory (WRL) investigating the stability of rock bags as scour protection from wash from cruise vessels [1]. The study involved physical model tests at a 1:20 scale of 4 t and 8 t rock bags on the slope and toe respectively, as shown in Figure 4-1.

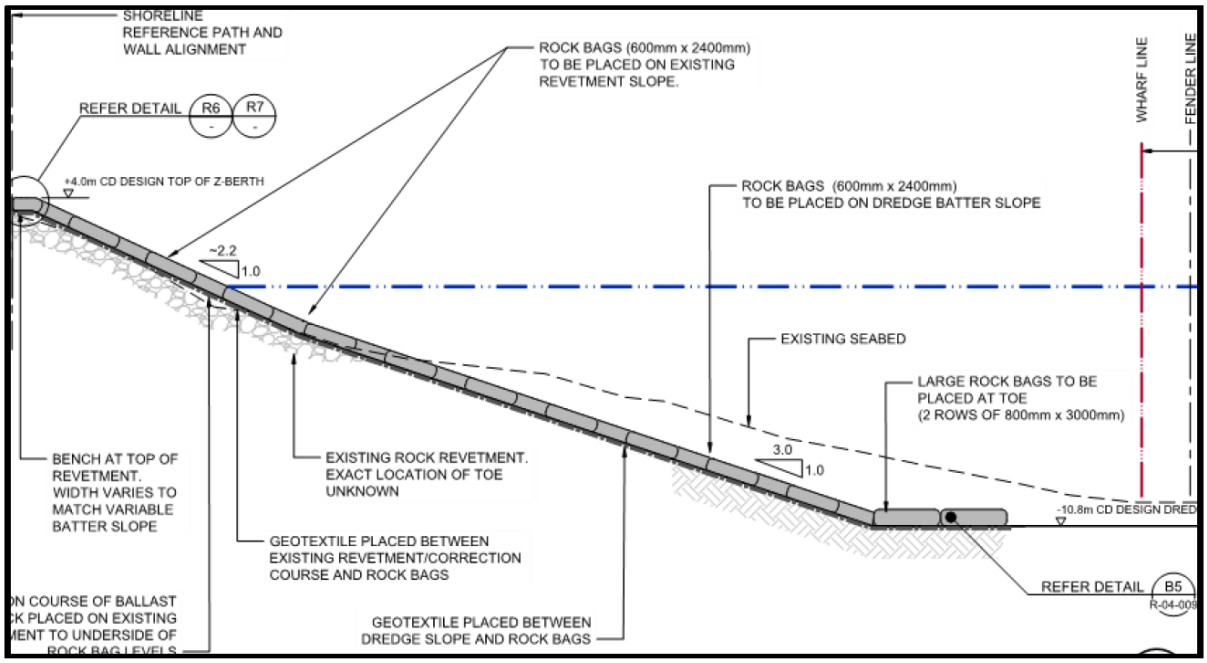

Figure 4-1: Revetment cross section [1]

The cruise ship bow thruster was replicated by a shrouded propeller to channel the thrust, as shown in Figure 4-2. The three full-scale water velocities tested were 4 m/s, 6 m/s, and 8 m/s for various offset distances from the revetment and water levels.

Figure 4-2: WRL basin showing the bow thruster tube, moveable bed, and rock bags [1]

During the testing, there was bag rock movement for Test 10 (8 m/s water velocity, 8 m from the berth line, lowest astronomical tide (LAT) water level) and full failure occurred for Test 6 (8 m/s water velocity, 3.5 m from the berth line, LAT water level) as shown in Figure 4-3.

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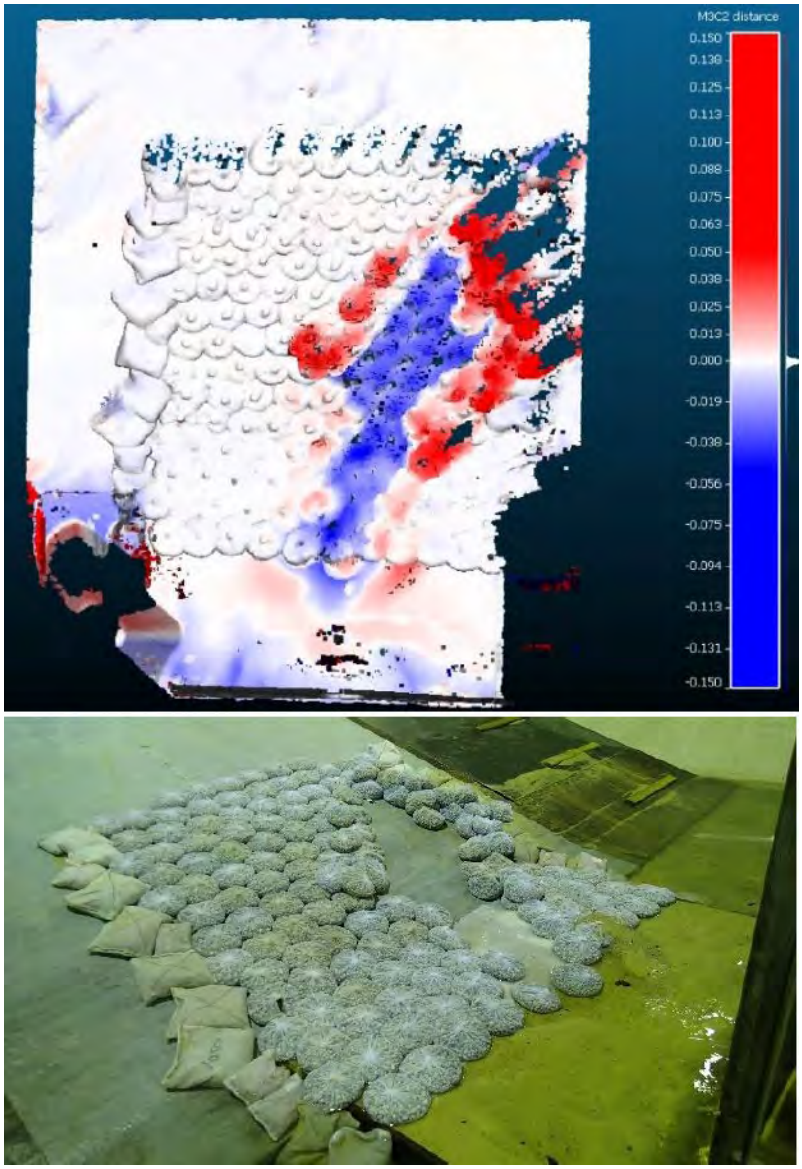

Figure 4-3: Image of the failed revetment and toe from Test 6 [1]

The paper summarised that the rock bags were stable when subjected to a 6 m/s bow thrust, which corresponds to standard operations. However, when the rock bags were subjected to the maximum bow thrust of 8 m/s, damage occurred with it being greater when closer to the berthing line and at lower water levels.

Methodology

1.1. Rock Bag Sizes

Small Rock Bag

The small rock bags are made from a warp knitted, double mesh of a polyester and polyolefin blend as shown in Figure 5-1. The mesh construction resembles that of a trawl net, such that if a strand breaks and causes a hole it does not propagate easily throughout the bag.

Figure 5-1: Small rock bag mesh and rock size

The small rock bags have a working maximum capacity of 2 t and typically have a 1.9-2.0 m diameter and 0.5-0.6 m height when installed, as shown in Figure 5-2 and Figure 5-3. The bags were filled to various capacities ranging from 0.9-2 t for different installation locations.

The rock used in the small bags was a 75-150 mm rock grade from river stone, therefore the rocks were more rounded which allowed for the bag to more easily conform in shape to the surrounding area. The average rock density was approximately 2.7 t/m^3.

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Figure 5-2: Small rock bag shape when stacked and filled to approximately 1.8 t

Figure 5-3: Small rock bag shape when being lifted, where it mostly retains the shape when removed from the filling jig

Medium Rock Bag

The medium rock bags were made from the same double mesh polyester and polyolefin blend as the small rock bags, as shown in Figure 5-4, but are larger in size.

Figure 5-4: Medium rock bag mesh size showing the larger and pointer rock inside the bag

The medium rock bags have a maximum working capacity of 4 t and typically have a 2.2 m diameter and 0.7-0.8 m in height when installed, as shown in Figure 5-6.

The rock used in the medium bags was larger compared to the small bags, consisting of a 150-300 mm rock grade from quarried rock. This provided larger and more jagged rock with an average rock density of approximately 2.7 t/m^3 compared to the recommended rock grades shown in Figure 5-5.

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The table below is a guide only; rock grading may vary the bag sizes by +/- 10%				
Average Weight	Rock Grading	Average Height	Average Diameter	Volume Cubic Metre
1 ton	50 — 100 mm	400 to 500 mm	1700 to 1900 mm	0.65
2 ton	75 — 150 mm	500 to 600 mm	1900 to 2100 mm	1.3
4 ton	75 — 150 mm	700 to 800 mm	2400 to 2700 mm	2.7
6 ton	100 — 200 mm	800 to 900 mm	2700 to 3000 mm	4.1
8 ton	150 — 250 mm	1000 to 11000 mm	3100 to 3400 mm	5.4

Figure 5-5: Rock Bag® rock grades for different bag dimensions [2]

This increase in rock size and type caused larger voids inside the bag as the rock could not easily move over each other. This also caused the bag to be slightly more rigid and not conform to the surrounding area as easily as the small bags. Additionally, the filled bags had an average mass of 3.3 t compared to the maximum of 4 t due to the number and size of the voids.

Figure 5-6: Medium rock bag prior to being placed in the water

Large Rock Bag

The large rock bags were made from a larger high-density polyethylene (HDPE) mesh and comprised of four layers, compared to the small and medium rock bags which has a smaller mesh and only two layers, as shown in Figure 5-7.

Figure 5-7: Large rock bag mesh size showing the four mesh layers

The large rock bags have a maximum working capacity of 8 t and typically have a 3.2-3.3 m diameter and 0.8-0.9 m in height when installed, as shown in Figure 5-8. The roc k placed inside these bags was the same as the medium bags which was a 150-300 mm rock grade from quarried rock. However, compared to the medium rock bag, the large bags contoured more to the surrounding terrain and had an average mass of 7.7 t.

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Figure 5-8: Large rock bag being lifted

1.2. Test Area Ground Preparation

A bathymetric and topographic survey were conducted to determine the existing topology of the site prior to the installation of any rock bags (Figure 5-9). From the survey, it was determined that the existing seabed slope to the shoreline and surrounding bathymetry were similar to the required design revetment slope and depth, therefore requiring no civil works beyond placement of small rock bags.

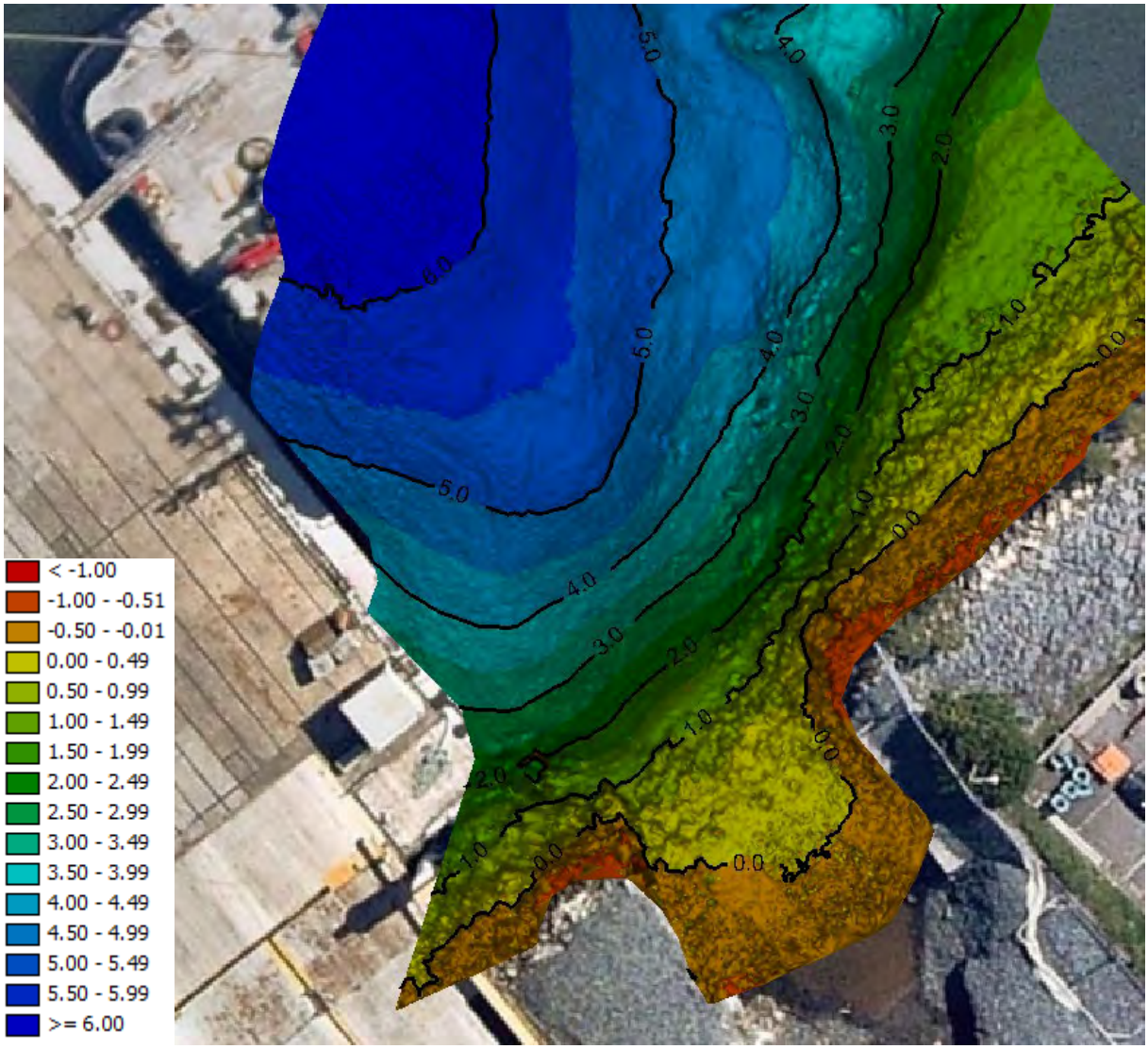

Figure 5-9: Bathymetric survey of the original riverbed [3]

However, there was a requirement to create a flat bed area to test the uplift stability of the bags. Therefore, the small rock bags were placed directly on the seabed with the aid of divers to create the required bathymetry, as shown in Figure 5-10.

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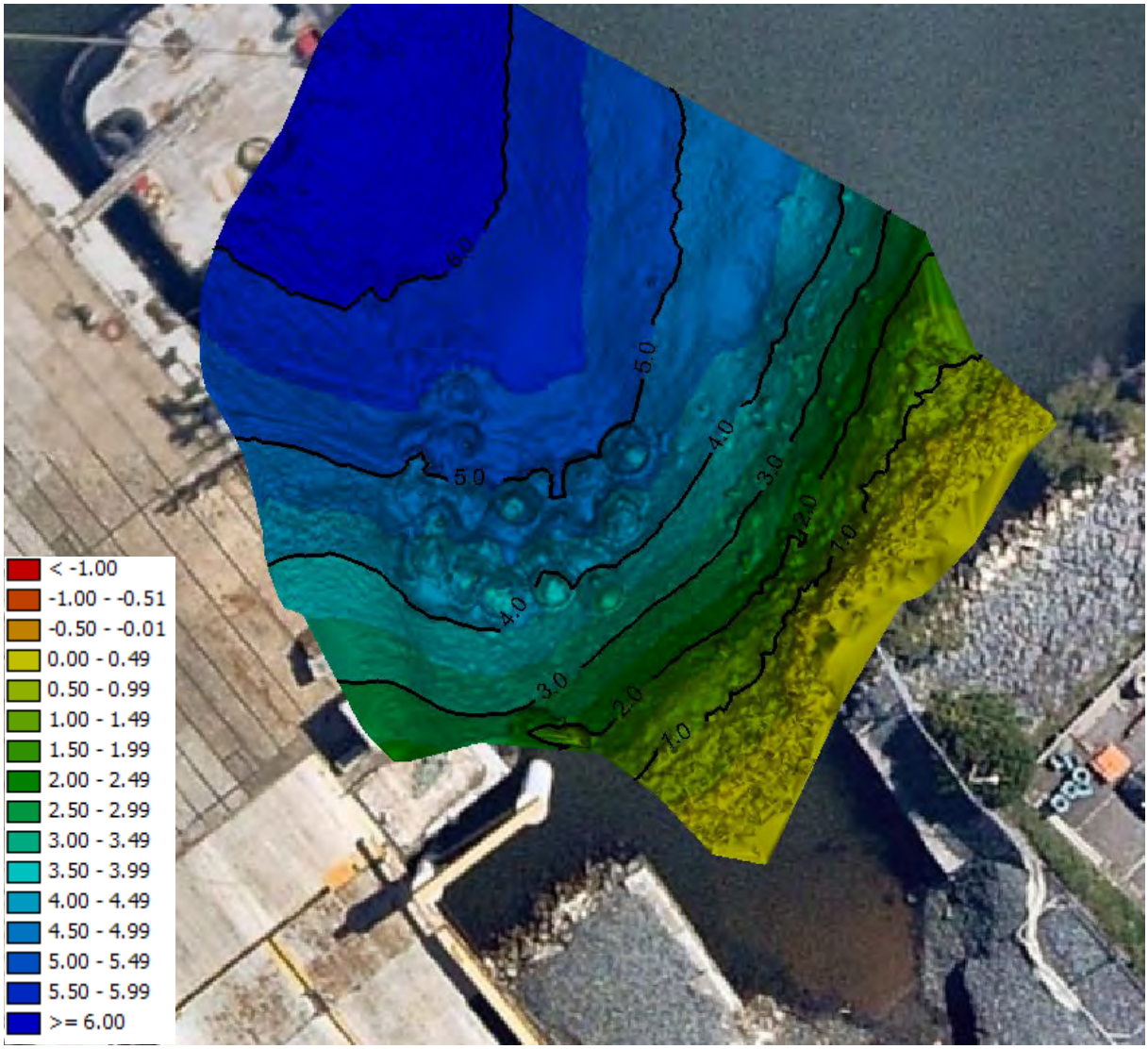

Figure 5-10: Bathymetric survey of the small rock bags installed prior to the installation of the geofabric [3]

Small rock bags were also placed around the barge mooring pile (Figure 5-11), and the existing rock revetment to prevent erosion from the testing outside of the prepared slope (Figure 5-12).

Figure 5-11: Small rock bags being installed around the barge mooring pile with the aid of a diver to prevent erosion during testing

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Figure 5-12: Small rock bags placed around the test area to reduce erosion

Once the small rock bags were placed, a 1200 GSM geofabric was placed down and held in place by small 1.8 t rock bags along the toe to prevent undermining as shown in Figure 5-13.

Figure 5-13: Installed geofabric being held in place by a small rock bag, with a second roll of geofabric yet to be installed

During the testing, the small rock bags were kept in place and the medium and large rock bags were relocated as required by crane and divers for the test schedule

1.3. Water Velocity Measurement

The water velocity from the tug wash was measured via a Nortek Vectrino which is a high-resolution acoustic doppler velocimeter (ADV). The device configuration and setup are detailed in [4].

Live water velocity readings were observed to estimate the water velocity from the tug to determine if more or less tug engine RPM was required.

1.4. Tug Particulars

The tug used in the test was the Cape Mac; a twin azimuth stern drive (ASD) towage vessel with the main particulars listed in Table 5-1 and shown in Figure 5-14. For the testing, the Cape Mac was moored to the barge Coochie with both ASD units operated to specified RPM.

Table 5-1: Cape Mac tug particulars

Particular	Value	Unit
Length Overall (LOA)	28.00	m
Length Between Perpendiculars (LBP)	22.94	m
Beam	9.80	m
Aft Draught (During Testing)	3.85	m
Maximum Thrust per ASD	20	t
Maximum Volumetric Flow Rate	8,000	L/s
Maximum Bollard Pull (BP)	42	t

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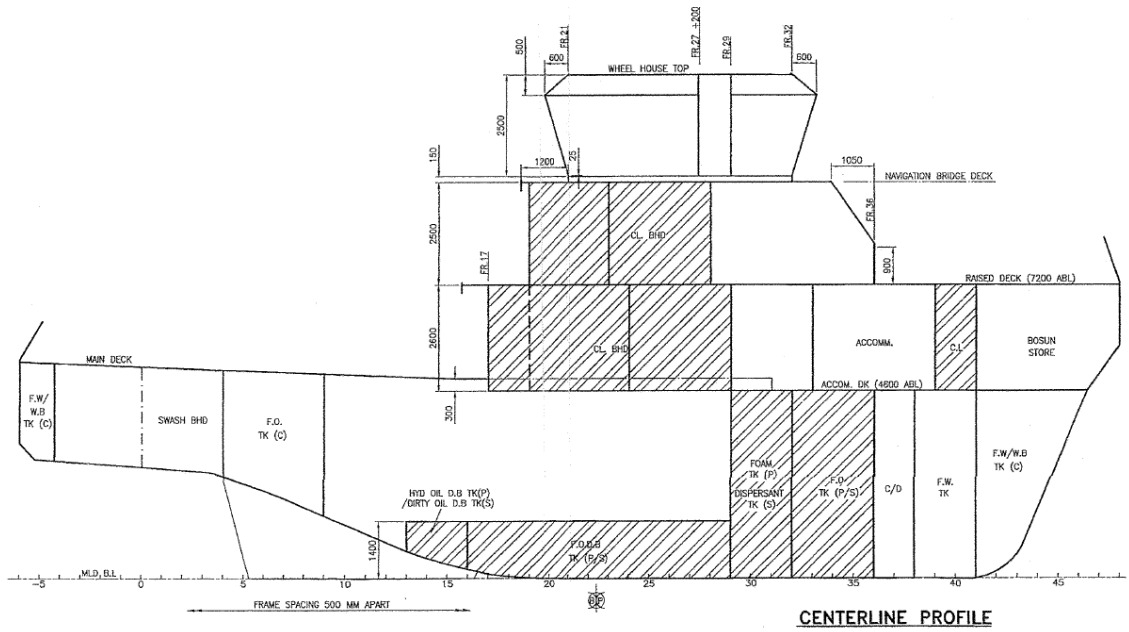

Figure 5-14: Profile of the Cape Mac tug

Table 5-2 outlines the estimated Cape Mac tug engine output for a given throttle/engine RPM input.

Table 5-2: Cape Mac tug engine throttle details

Tug Engine RPM	Estimated Tug Engine Throttle	Estimated Equivalent BP [t]
400	Idle	11
600	50%	21
650	63%	26
675	69%	29
700	75%	32
800	+100%	42
900	Maximum Engine Capacity	-

For each run, the tug engaged the propellers while the ASDs were orientated in the neutral position (Figure 5-15), and then rotated toward the rock bags and increased the RPM to the required value.

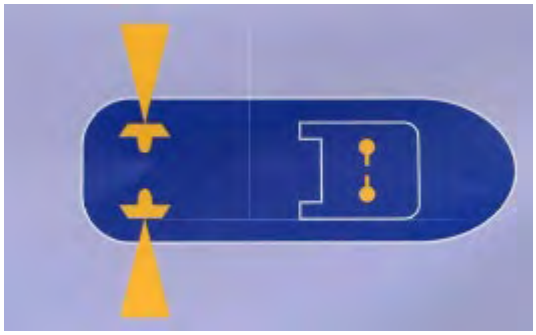

Figure 5-15: Station keeping - Thrusters in neutral position, both engines running at the same power [5]

1.5. Project Set-Up

Testing Configurations

There were three different configurations tested on Friday the 7th of October 2022 which are listed in Table 5-3, with references to the drawings illustrating the configuration. These three cases were developed to try and replicate the model-scale testing outlined in [1].

Table 5-3: Case configuration for testing

Case	Configuration	Water Velocity Range [m/s]	Figure
A	- 4 t rock bags on revetment - 8 t rock bags on bottom - Tug located over scour protection bags	3-8	Appendix A Figure 5-16
B	- 4 t rock bags on revetment - 8 t rock bags on bottom - Tug located 8 m away from revetment	4-6	Appendix B Figure 5-17
C	- 8 t rock bags on revetment - 4 t rock bags on bottom - Tug located 8 m away from revetment	6-8	Appendix C Figure 5-18

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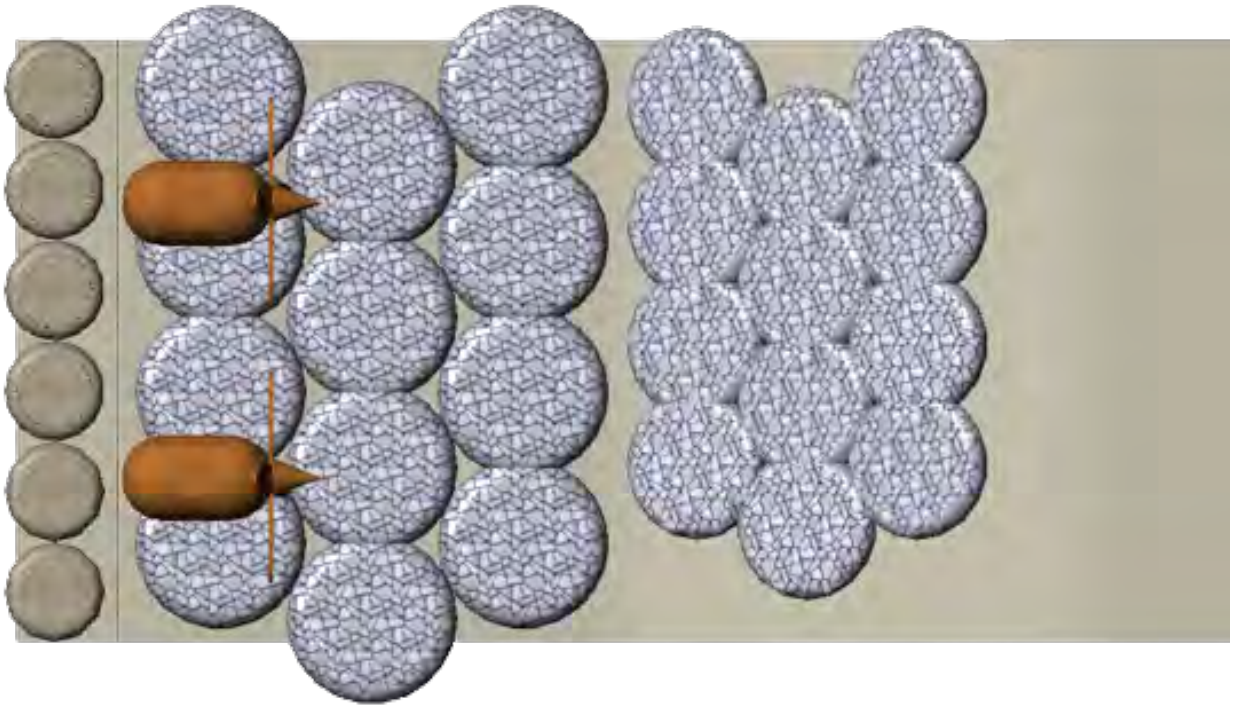

Figure 5-16: Provided sketch of the rock bag and tug positioning for Case A

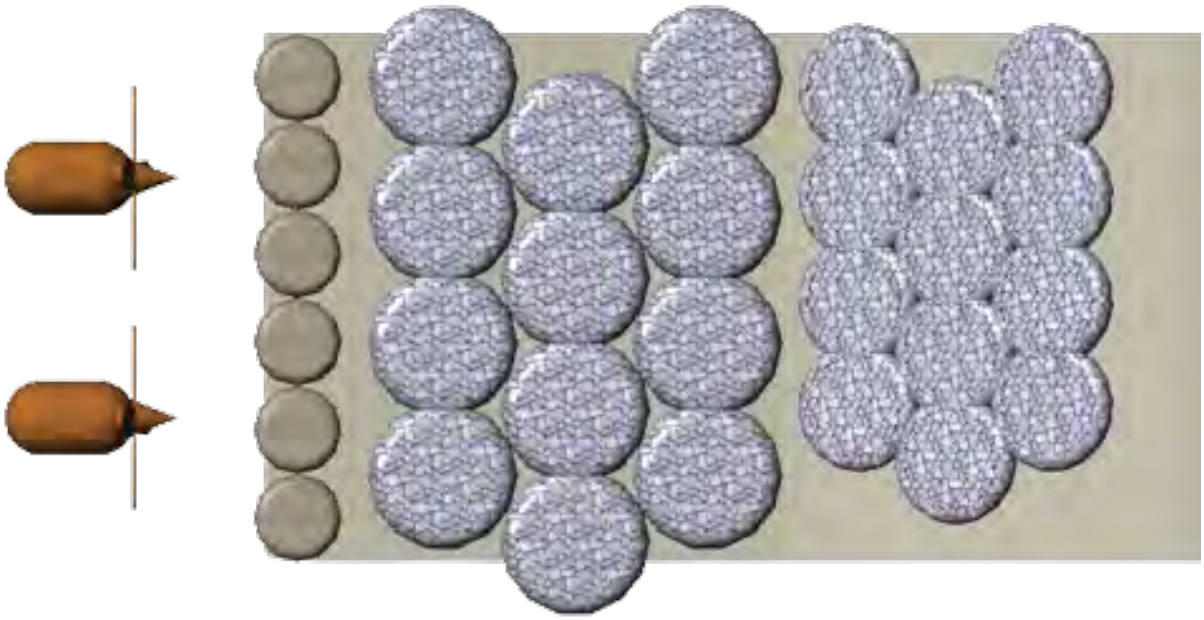

Figure 5-17: Provided sketch of the rock bag and tug positioning for Case B

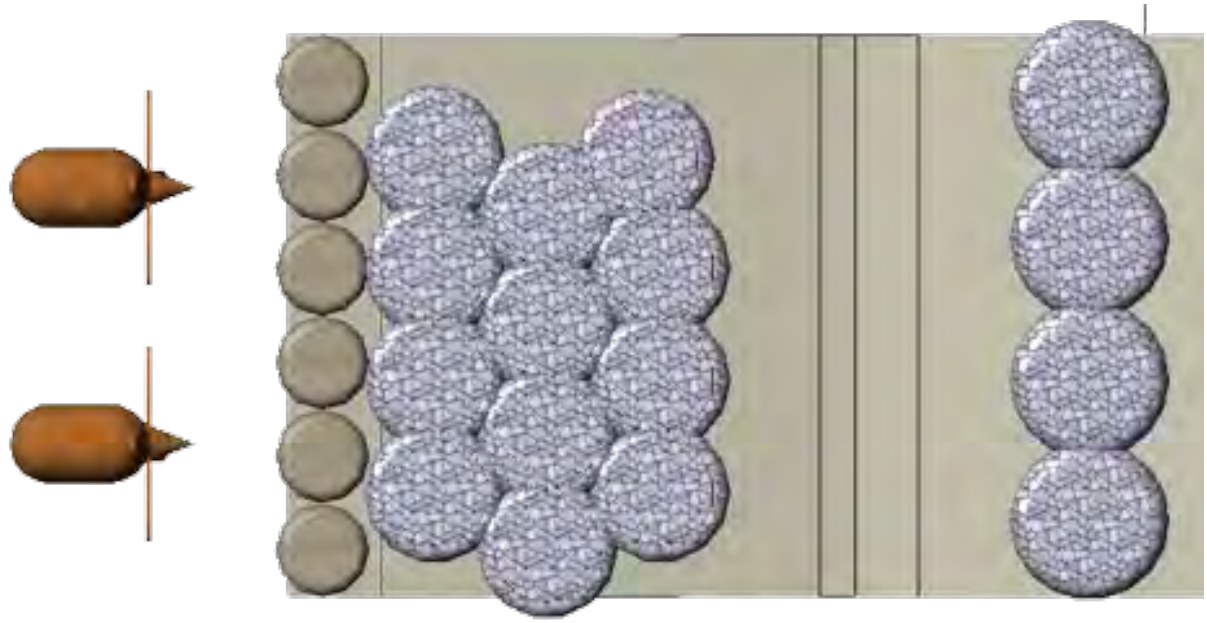

Figure 5-18: Provided sketch of the rock bag and tug positioning for Case C

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Results and Analysis

1.6. Water Levels

Figure 6-1 shows the measured and predicted water level for the 7th of October 2022 located at the Port of Brisbane Operations Base at Brisbane Bar (Whyte Island) [6].

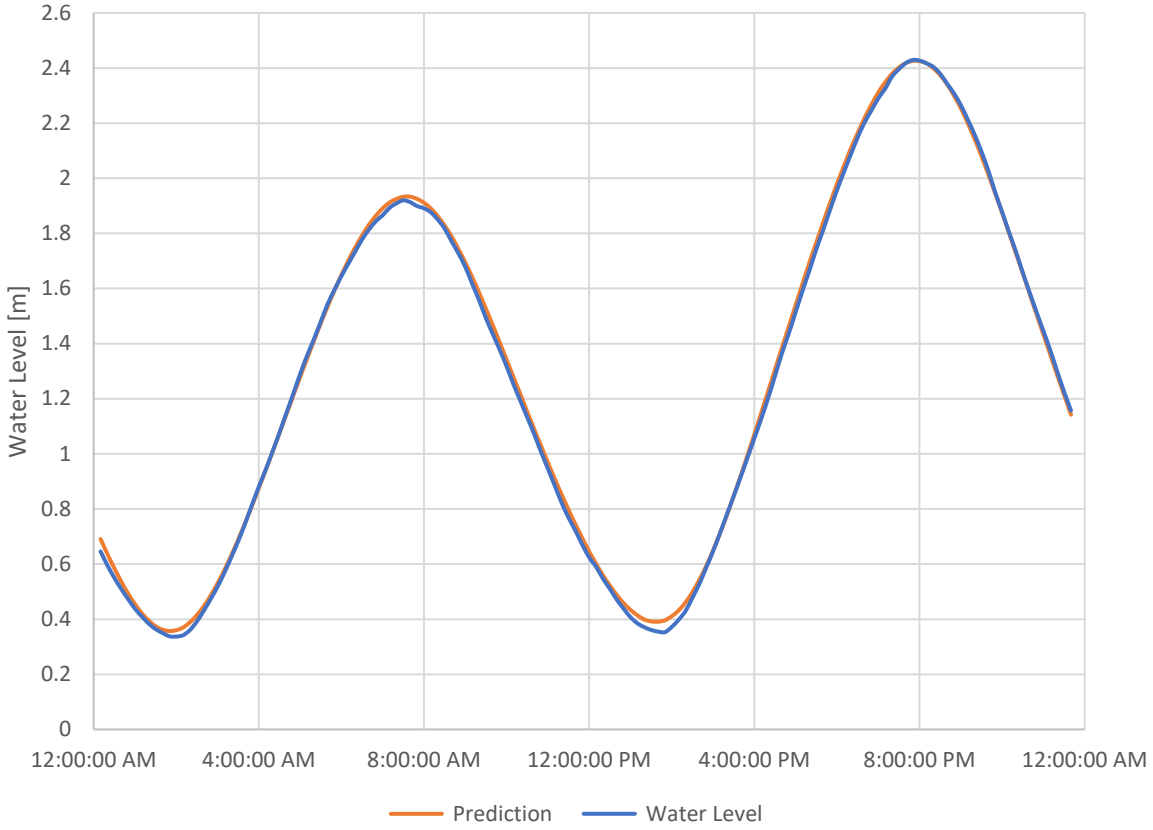

Figure 6-1: Predicted and actual water levels at the Brisbane Bar (Whyte Island) for the 7th of October 2022 [6]

1.7. Test Schedule

Table 6-1 outlines the conducted tests for the different tug RPM and rock bag placement, with Figure 6-2 showing the test times against the water level. After each case, a bathymetric survey was conducted to determine if any of the bags had dislodged and/or moved. During this time, the water was able to settle.

The large gap in testing time between Cases B and C was due to the relocation of the bags taking longer than expected as a result of poor visibility for the diver.

Table 6-1: Completed testing schedule and water level during test [4] [6]

Case	Configuration	Engine RPM	Run Time [min]	Estimated Peak Water Velocity [m/s] [4]	End Time	Water Level [m]
A.1	4t Revetment - tug over 8t	400 RPM	5	2.8	0902	1.68
A.1 - Repeat		400 RPM	5	2.8	0923	1.56
A.2		600 RPM	10	2.8	0934	1.49
Tug moved 8 m from revetment						
B.1	Bottom unit lift - 8t	400 RPM	10	4.4	1007	1.25
B.2		600 RPM	10	4.4	1039	1.07
B.2 - Repeat		600 RPM	10	4.8*	1109	0.88
B.3		650 RPM	10	5.1*	1123	0.82
B.4		675 RPM	10	5.2*	1206	0.59
B.5		700 RPM	5	5.3*	1230	0.51
B.5 - Repeat		700 RPM	5	5.1*	1237	0.47
4 t bags moved to bed and 8 t bags stacked into a wall behind the 4 t bags						
C.1	8t wall and 4t uplift	600 RPM	5	4.6**	1735	1.81
C.2		650 RPM	5	5.1**	1755	1.96
C.3		700 RPM	5	5.2**	1810	2.02

* Note: ADP Instrument was damaged for these measurements
** Note: Water velocity assumed equal to the recorded velocities in Case B

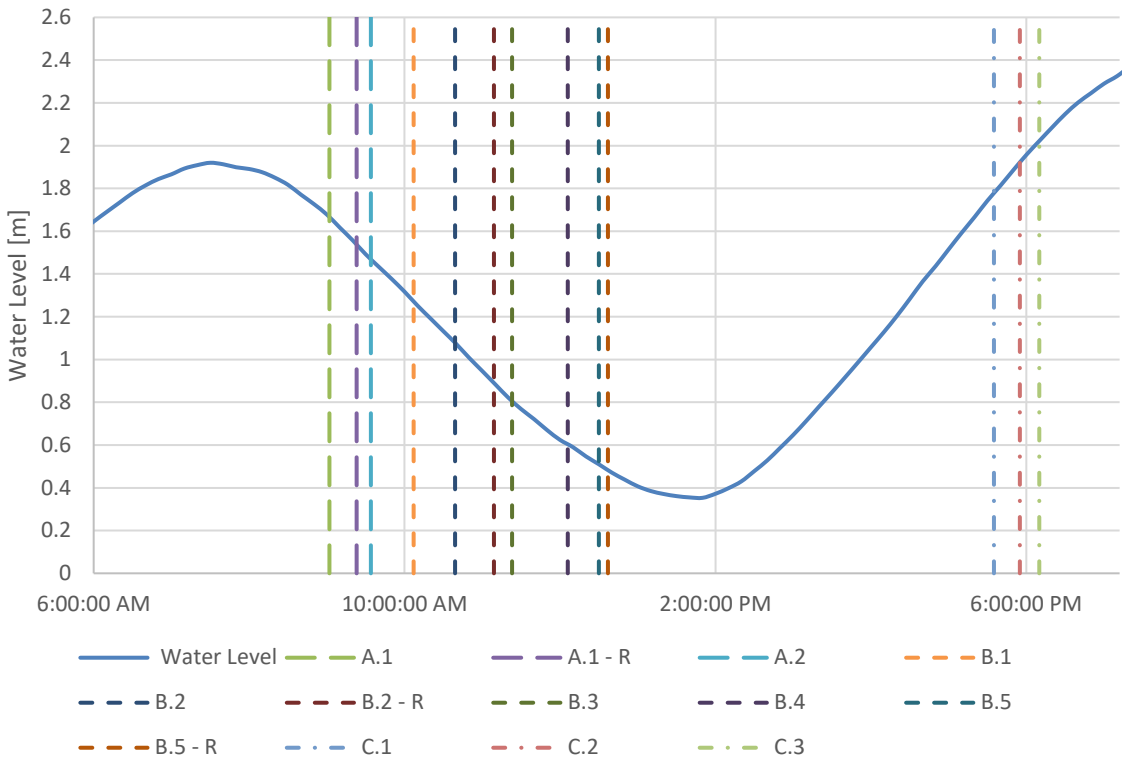

Figure 6-2: Actual water levels at the Brisbane Bar (Whyte Island) [6] with the test completion times shown in dashed lines

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1.8. Rock Bag Installation

The rock bags were installed via a mobile crane and positioned via divers into the correct positions as shown in Figure 6-3. A bathymetric survey was conducted at several stages during the installation to ensure that the rock bags were installed in the correct location.

Figure 6-3: Photo of a large rock bag being craned into position with a diver on standby

All the rock bags were filled on site with the rock delivered by truck as shown in Figure 6-4. Each of the three sized bags had their own jig for filling which prevented the bag from being overfilled. The filling of the bags took between 10-15 mins each with an excavator and bobcat.

Figure 6-4: Quarry rock being delivered to fill the medium and large rock bags with the small bags in the foreground

Placement of the small rock bags and the geofabric occurred between the 29th of September and the 6th of October. The placement of the bags was slowed down by the limited visibility and the sliding of three bags down the bank into an existing scour hole which needed to be found and replaced (Figure 6-5). It was determined to leave the bags in that location to prevent additional bags sliding down.

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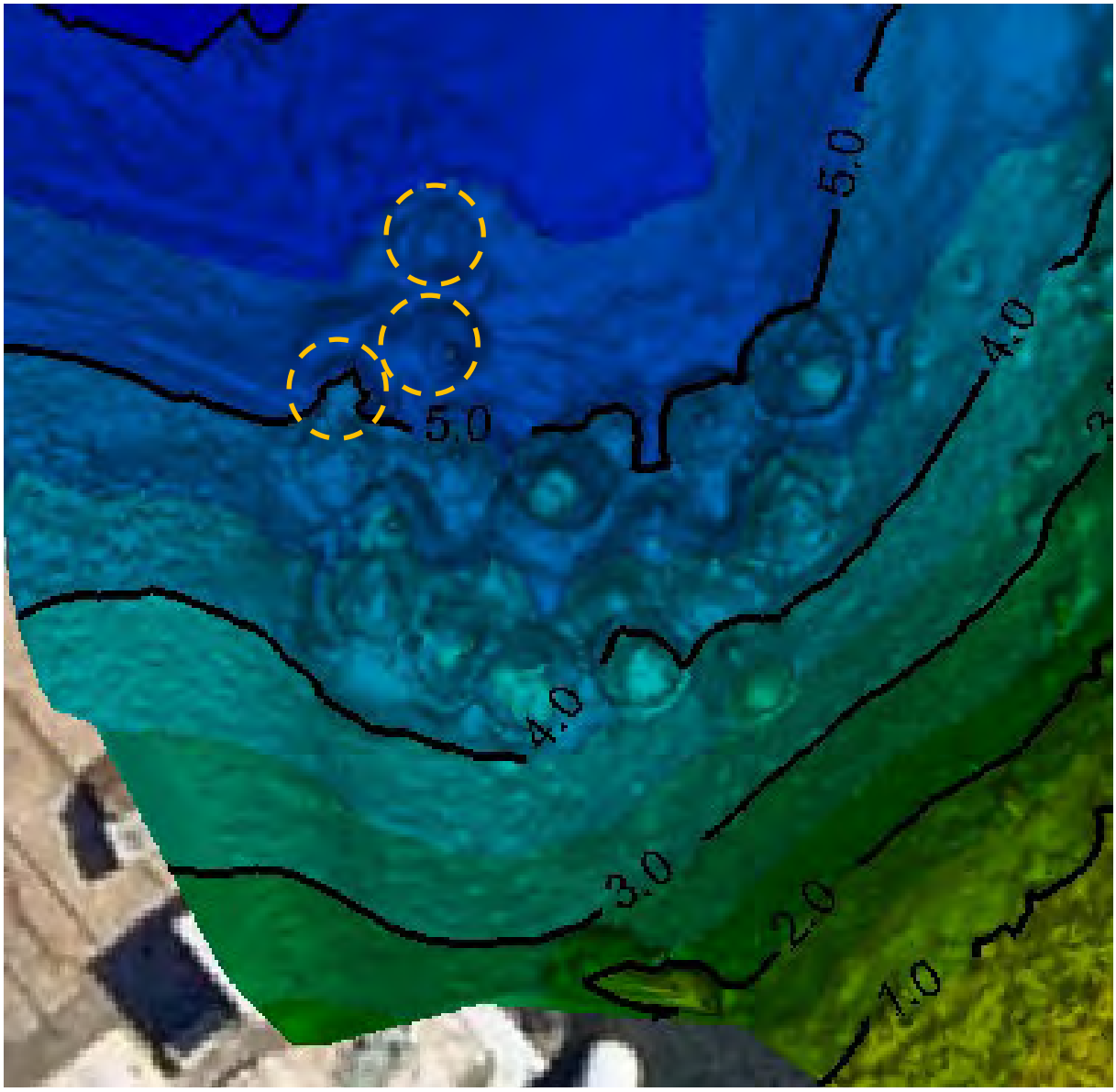

Figure 6-5: Cropped bathymetric survey of the small rock bag installation prior to the geofabric installation highlighting the three small rock bags that slipped during installation [3]

Once the small bags were in position, the geofabric was installed to prevent undermining. The geofabric extended over the toe of the revetment of small bags and was held down by an additional 6 small bags as shown in Figure 5-13 and Figure 6-6. The medium and large rock bags were placed on top of the geofabric on the 6th of October.

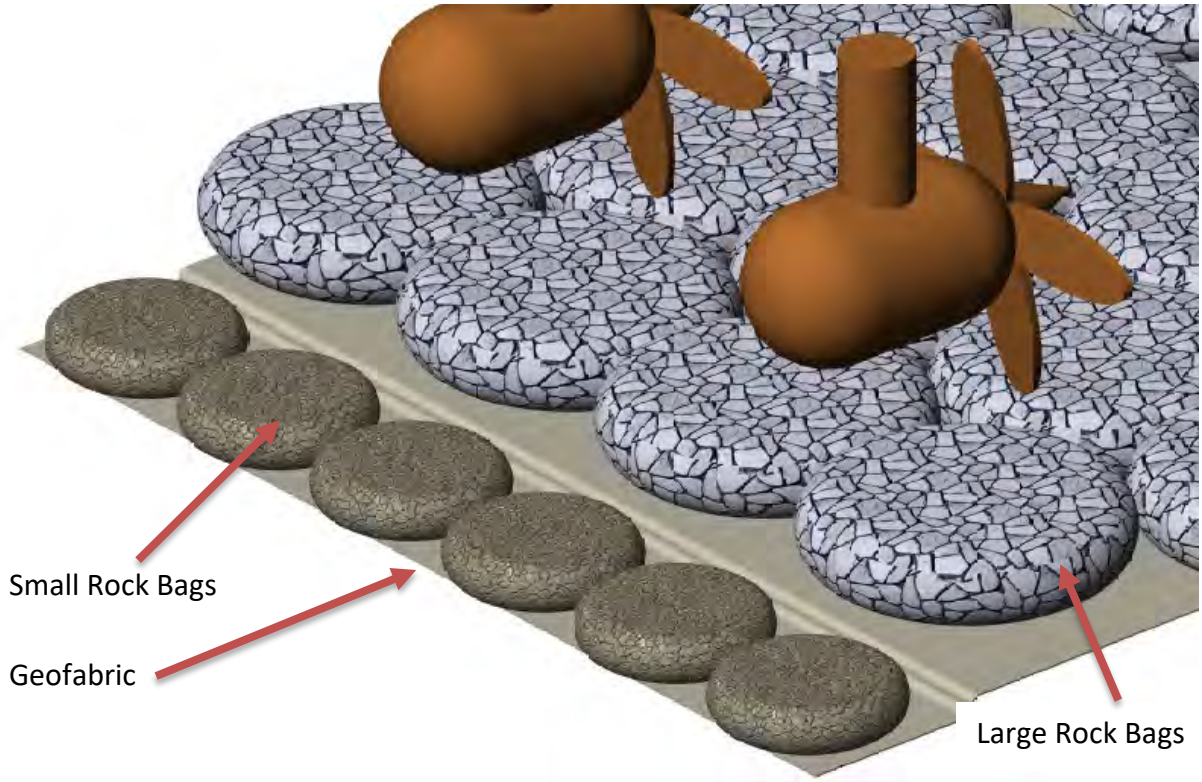

Figure 6-6: Render of the small and large rock bags placed over the geofabric, with the small bags securing the toe

The remainder of the small rock bags were placed around the test area to reduce the erosion and scour during the testing in the morning of the 7th of October. Once all the bags were installed, the ADP sensor placed, divers out of the water, and a hydrographic survey conducted, the testing commenced.

1.9. Case A

Due to unforeseen delays in placing the rock bags over the previous days, additional small bags were installed on Friday the 7th prior to testing commencing. This meant that testing could not start at 6am as planned to maximise the high water, and therefore there were underkeel clearance concerns which is why only three cases could be assessed for this tug location.

The Case A runs had the tug propeller located above the large rock bags and impacting the medium bags on the revetment while also subjecting the large rock bags to uplift due to lower pressure. The rock bag placement can be seen in Figure 6-7.

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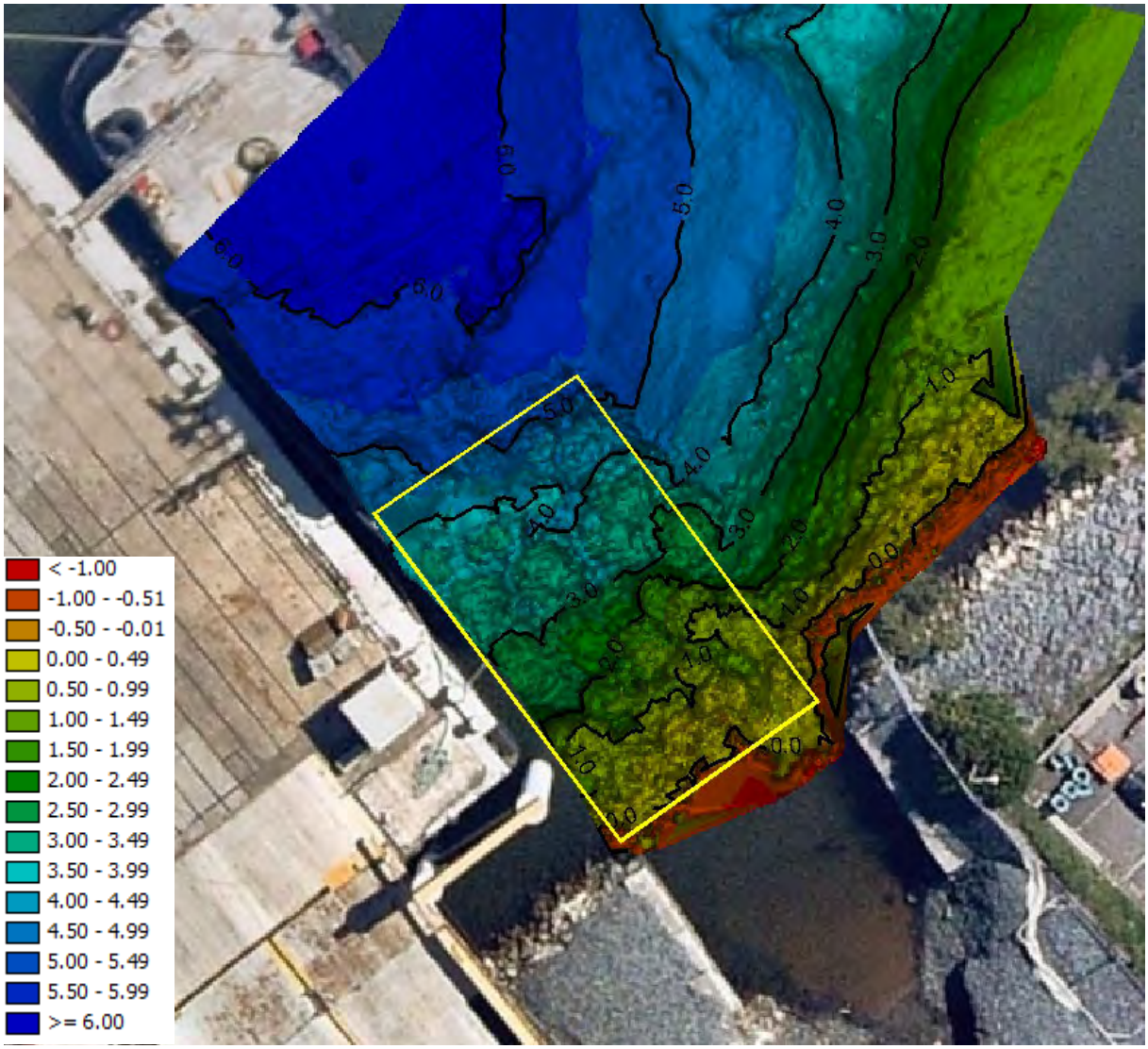

Figure 6-7: Medium and Large rock bag placement along the revetment and base respectively [3]

During the tests, it was observed that the water from the tug thrust was severely turbulent with variable flow directions as it hit the rock bags and upwelled as shown in Figure 6-8. Also, as the water level decreased, the surface water became more turbulent, as described in [4]. This is due to the short distance between the propeller and the revetment not allowing the thrust sufficient distance to disperse. It was also observed that large volumes of water were flowing parallel to the shoreline away from the testing site which became more visible for the lower water levels.

Figure 6-8: Run A.1 – Repeat where significant turbulence and upwelling can be seen

Figure 6-9 is a Delta Z bathymetric plot which shows the change height between two surveys. This plot type was used during the trial to estimate quickly if any of the rock bags had moved compared to the previous case. Figure 6-9 shows the change in bathymetry between pre-Case A and post-Case A, which shows that there is minimal movement of any of the rock bags, including the small rock bags placed at the toe and around the revetment. However, minor scour of the riverbed to the east (right of page) of the geofabric and small rock bags can be seen.

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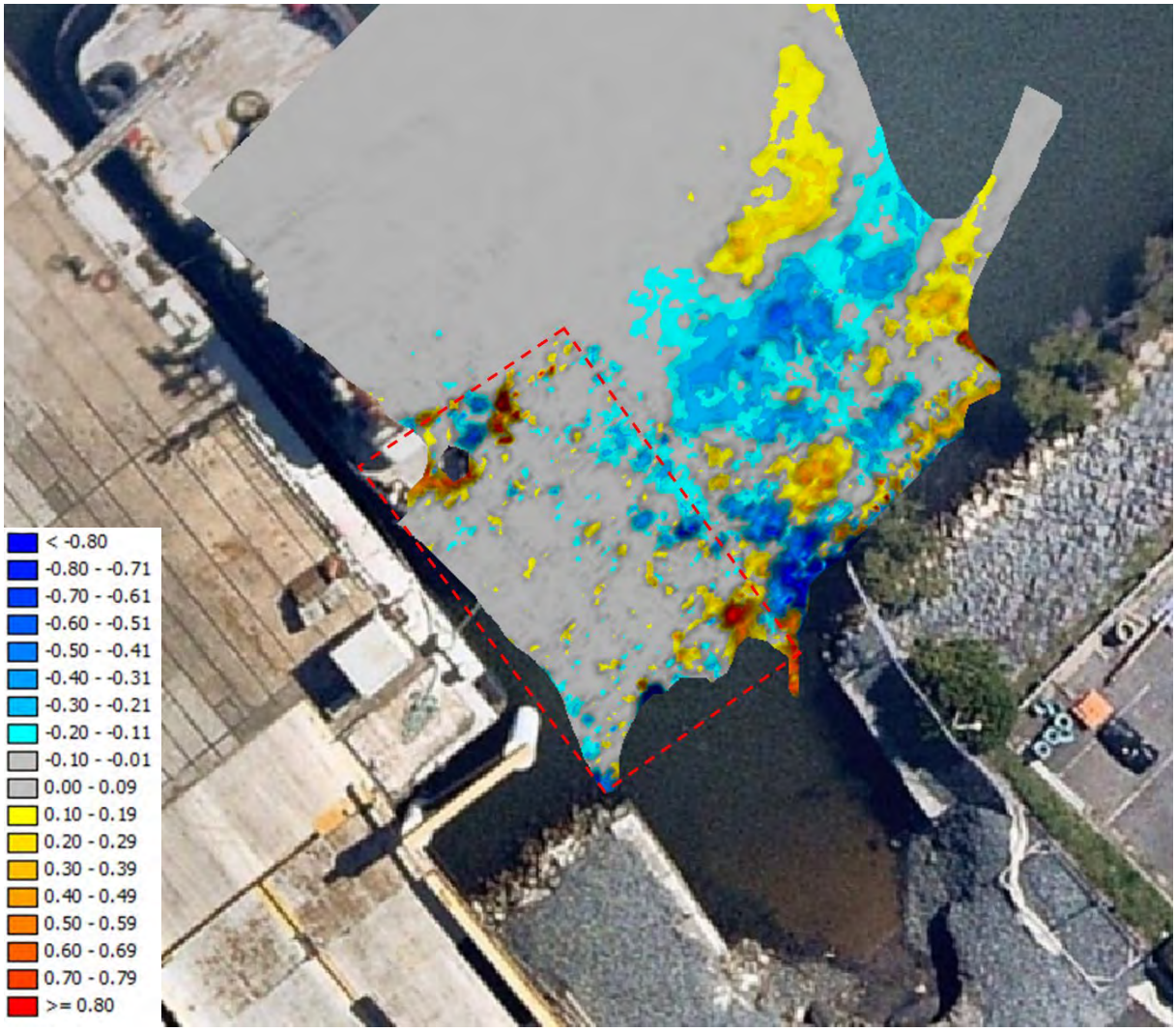

Figure 6-9: Delta Z colourmap showing where there are changes in surface levels after the Case A runs compared to the pre-trial bathymetry with the approximate location of the geofabric outlined [3]

1.10. Case B

The Case B runs required moving the tug 8 m along the barge away from the revetment to test the uplift of the large rock bags and the medium rock bags on the revetment. These tests occurred at lower water levels as shown in Figure 6-2 compared to Case A.

During the test, it was observed that the water was not as turbulent compared to Case A and that more surface flow could be seen impacting the revetment. There was also more noticeable surface flow parallel to the shoreline in both directions at an estimated 3-5 m/s, as shown in Figure 6-10, which caused erosion along the banks where no rock bag protection was installed. The boiling and upwelling of the water also pulsated which was both observed and measured [4] and was assumed to be as a result of the tug engine hunting around the set engine RPM.

Figure 6-10: Run B.4 where significant water flow parallel to the shore can be seen circled, with the solid line showing the water uplift due to the presence of the medium rock bag, and the large current around the barge mooring pile shown in the dashed circle.

For Case B.5, the tug engine RPM was gradually ramped up to a maximum of 700 RPM which was the limit the tug master was comfortable running due to the strain on the barge and tug mooring lines. This engine speed is approximately equivalent to 75% of the tug's 42 t BP and produced a measured maximum water velocity of 5.2 m/s past the rock bags.

Similar to Case A, a bathymetric survey was conducted after each run where it was determined that there was minimal movement of any of the bags post Case B.5 – Repeat compared to pre-trial, as shown in Figure 6-11. However, the scour hole to the east of the rock bags and geofabric became deeper and widespread compared to the end of the Case A testing, with accretion on the northeast corner of the geofabric and rock bags as shown in Figure 6-12.

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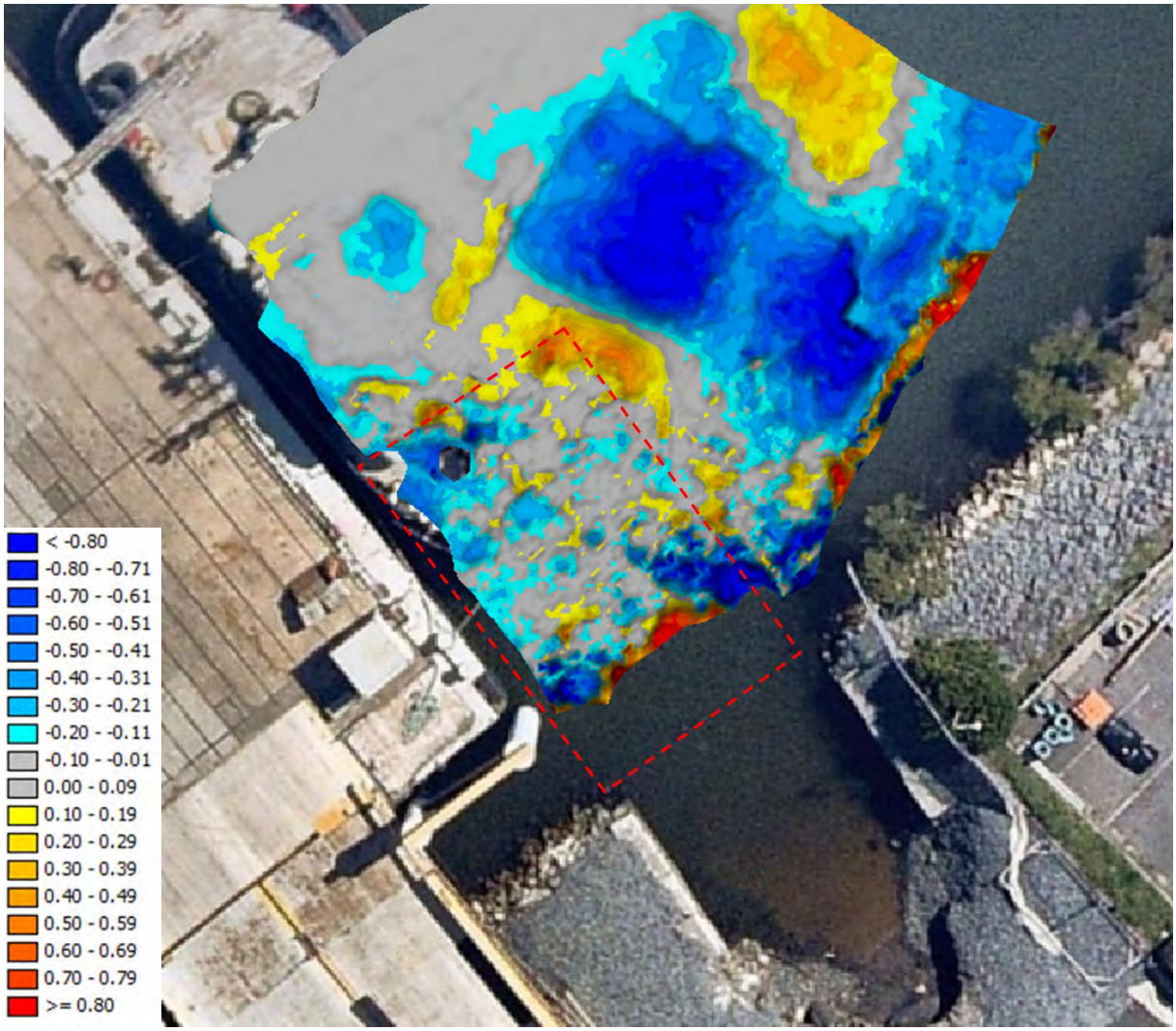

Figure 6-11: Delta Z colourmap showing where there are changes in surface levels after the Case B runs compared to the pre-trial bathymetry with the approximate location of the geofabric outlined [3]

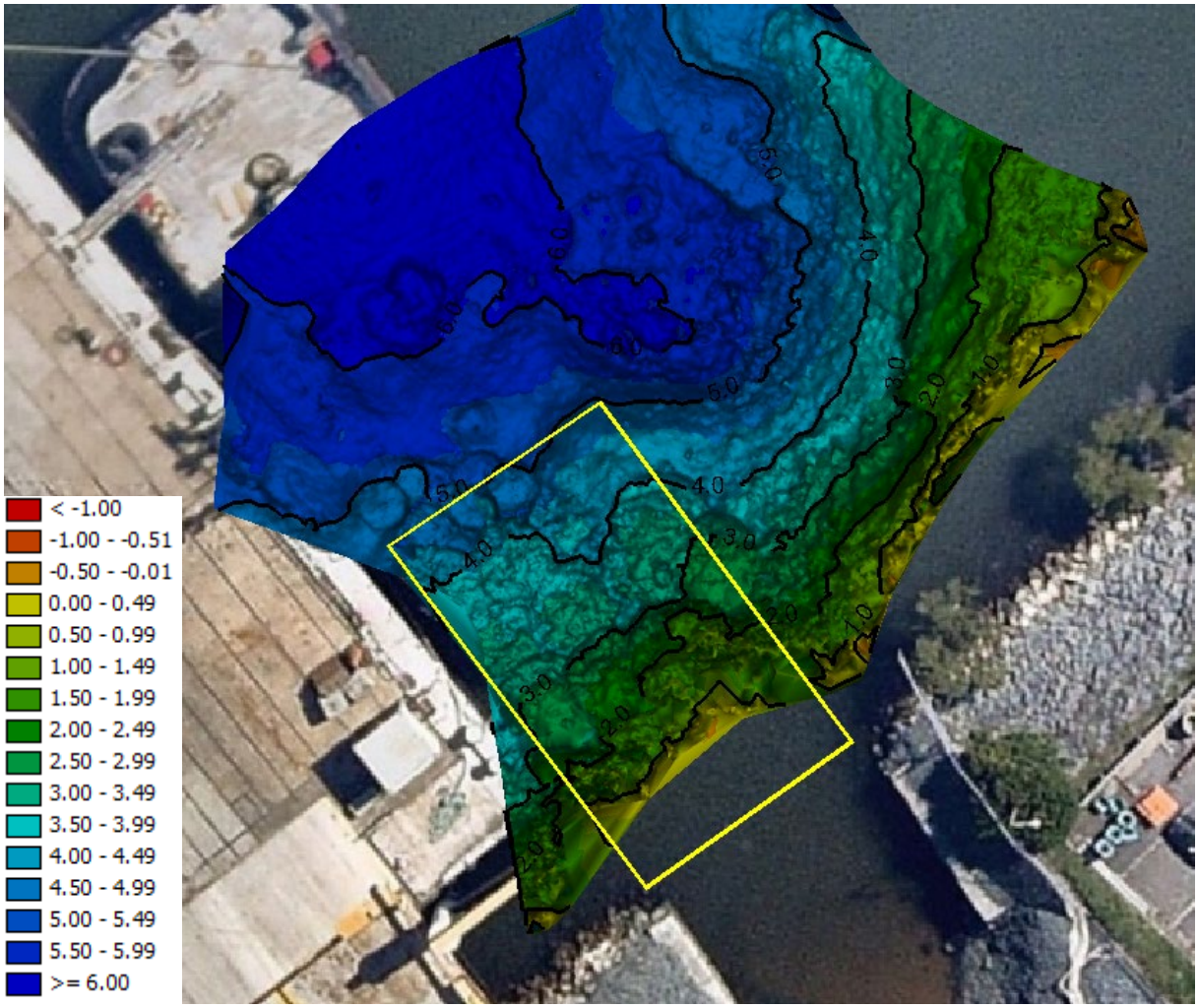

Figure 6-12: Bathymetric survey post Case B.5 – Repeat

During Case B.2 – Repeat, an unknown underwater debris struck the ADP instrument and bent the probe as shown in Figure 6-13 and discussed in [4]. This resulted in inaccurate readings for the remainder of the cases with the instrument failing to respond when redeployed prior to commencing Case C. Additional post processing methods were conducted on the recordings to estimate the velocities, as discussed in [4].

Figure 6-13: The ADP instrument with the bent probe after being struck by underwater debris during Case B.2 – Repeat

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1.11. Case C

Case C required moving the medium rock bags to the base with the large rock bags being placed in a freestanding wall configuration behind the medium bags, as shown in Figure 6-14. This movement required more time than expected with testing commencing at approximately 1730 on the 7th of October. Additionally, as the ADP instrument was not operational for Case C, the run time was reduced from 10 min to 5 min with no repeats due to time constraints and no data recording requirements.

Due to the water level at the time when the pre-test survey (Figure 6-14) was conducted, only limited datapoints could be captured on the top and front of the large rock bag wall. Due to the limited data points, the survey required interpolating large areas between survey points which lead to artificial changes bathymetry, as shown in the red circle in Figure 6-14.

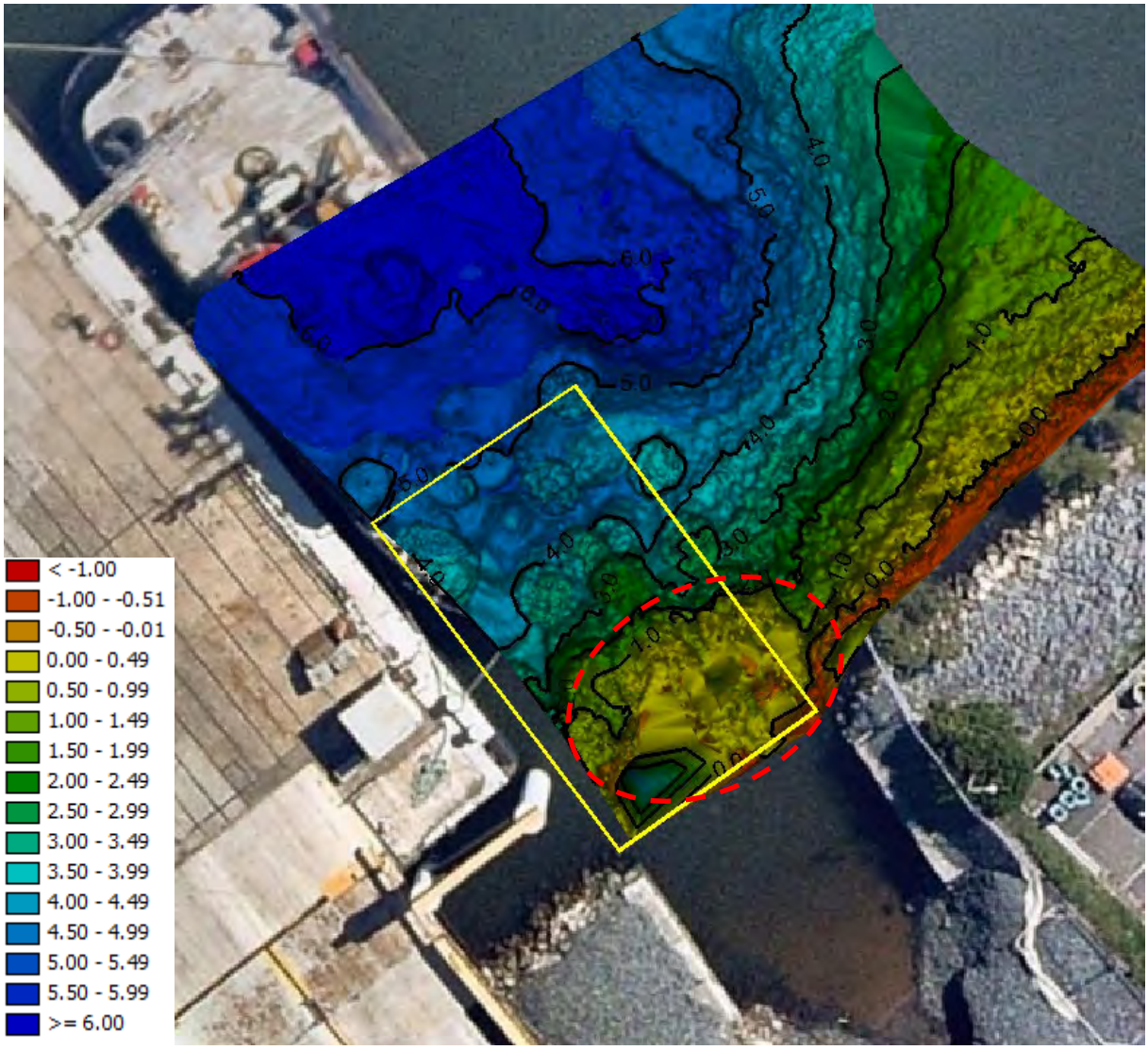

Figure 6-14: Medium and Large rock bag placement along the base and stacked into a wall respectively [3]

During the tests, significant upwelling was observed approximately where the large rock bag wall was located, as shown circled in Figure 6-15. Strong water flows were also observed flowing along the wall and parallel to the shoreline, similar to Case B. The water level was also higher for these runs compared to Case A and B reducing the surface level turbulence.

Figure 6-15: Case C.3 where upwelling at the large rock bag wall can be observed (circled) with strong flows parallel to the shoreline

Figure 6-16 shows the change in bathymetry from the pre-Case C runs to the post-Case C runs, where significant positive and negative changes can be seen in the location of the rock bags. However, when overlaid with the bathymetric survey, as shown in Figure 6-17, the below can be observed:

- the accretion is located at the base of the large rock bag wall with minimal change in the contours along the front of the wall (red), and
- the loss is located on top of the large rock bag wall, and in between the medium rock bags located near the barge (blue).

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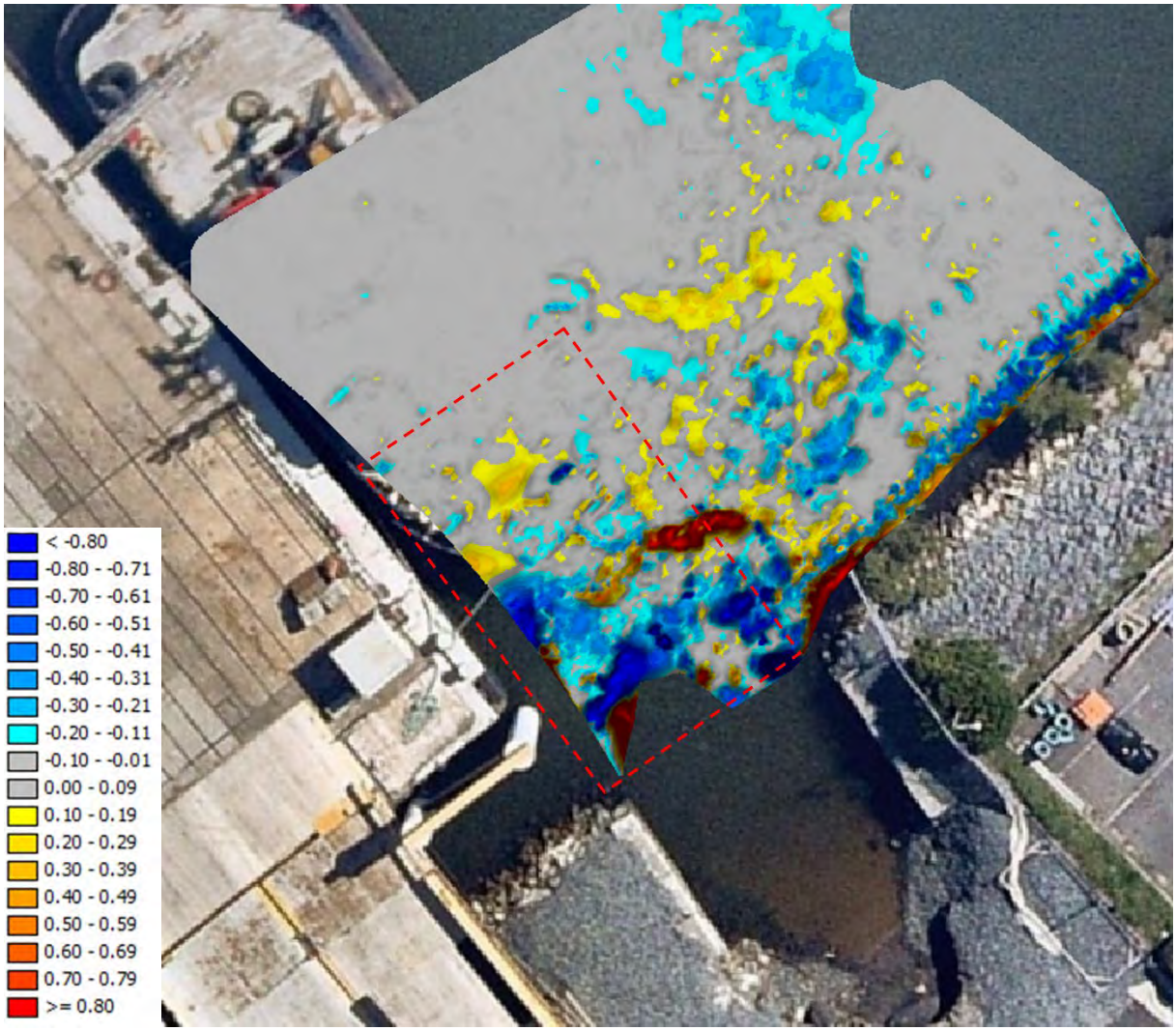

Figure 6-16: Delta Z colourmap showing where there are changes in surface levels after the Case C runs compared to the pre-Case C bathymetry with the approximate location of the geofabric outlined [3]

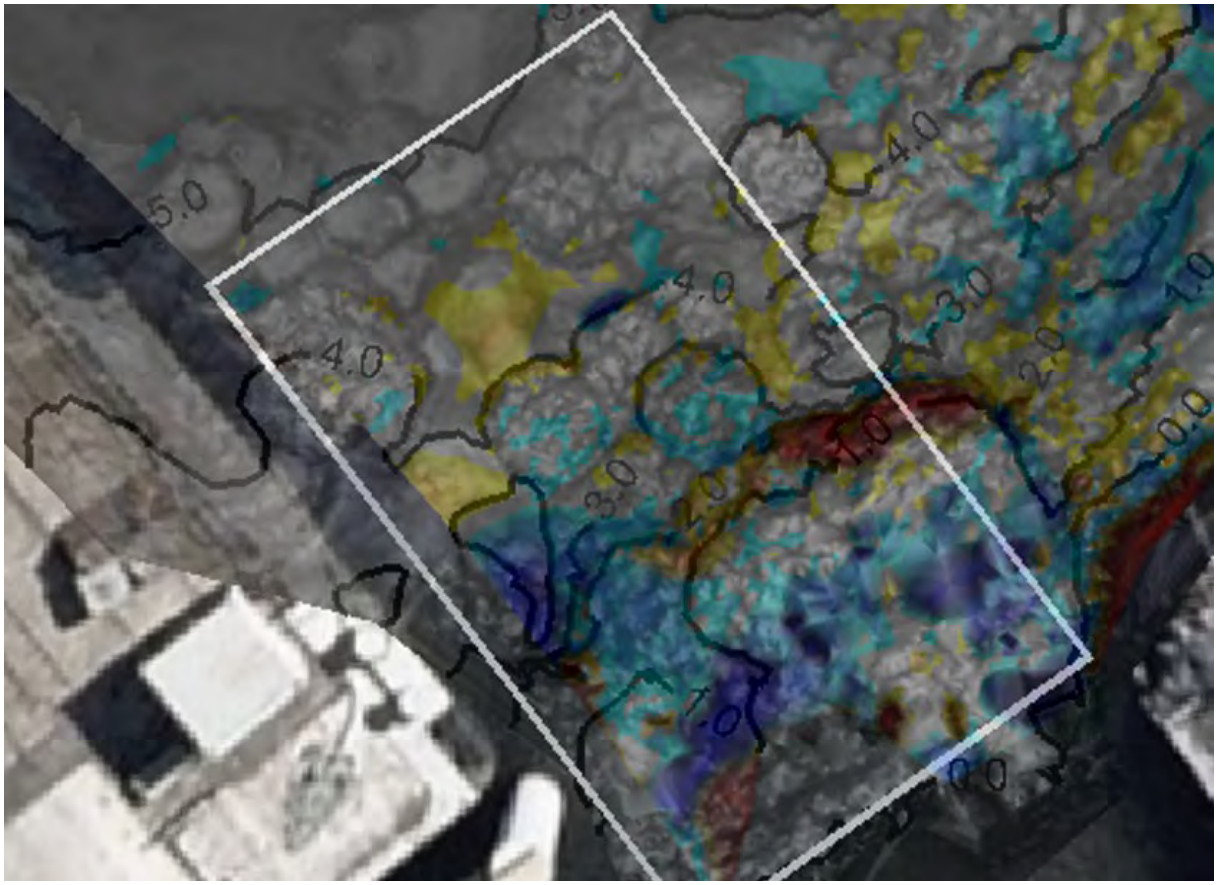

Figure 6-17: Cropped post Case C.3 bathymetric survey (greyscale) overlaid on the Delta Z colourmap showing the areas of greatest change

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Discussion and Conclusions

From the analysed ADP instrument data, the measured maximum water velocity of 5.3 m/s was lower than required 8 m/s for the test. However, as the ADP instrument was damaged during Case B.2 – Repeat, which was prior to the maximum tested RPM, this could have lowered the recorded velocities. Additionally, as the water flow from the ASD was severely turbulent, this may have further provided lower readings from the sensor, as evident between the difference in measured velocities in Case A and Case B. Although the maximum required velocity was not measured, a significant volume of water was thrust at the rock bag structure for an extended duration, as observed in the figures, and resulted in minimal movement of any rock bags.

The bathymetric surveys showed that there was minimal movement of the medium and large rock bags on the revetment and base respectively for Cases A and B. Additionally, the small rock bags that were installed at the toe, around the revetment, and at the base of barge mooring pile had minimal movement even though erosion along the riverbank either side of the revetment was observed. There was also a significant scour hole developed to at the northeast corner of the geofabric and small rock bags, however no small rock bags slipped into the hole. This highlights the stability of interconnected rock bags compared to single rock bags, as during construction three small rock bags slid into an existing scour hole.

However, for Case C, the Delta Z plot showed that there was significant movement on and in front of the large rock bag wall. From Figure 6-17, it could be seen that:

- majority of the loss areas are due to interpolation errors on the top of the large rock bag wall as the survey vessel could not travel over or around the large rock bag wall due to low water levels,
- loss occurred where the rock bags were not located, therefore could be attributed to the geofabric and/or sediments shifting, and
- loss and accretion occurred where the bags may have settled after being relocated and subjected to the tug thrust.

Additionally, based off the bathymetric survey there was no indication that any of the rock bags had significantly moved, or the large rock bag wall had collapsed.

In comparing the outcomes from this trial to [1], similar conclusions can be drawn as there was no movement of the bags for water velocities less than 6 m/s in both studies. However, the scale model had the large rock bags placed on the revetment whereas this study had the medium rock bags installed and still achieved minimal movement.

The measured water velocities were lower than the speeds tested in [1]. This difference may be attributed to the below factors:

- The Cape Mac tug vessel bollard pull/engine size is less than the Oasis class cruise vessel bow thrusters and ASD, and therefore cannot achieve those larger water velocities
- The model-scale thruster was located inside a tunnel, to replicate a bow thruster, which channels the flow providing a less turbulent stream compared to an open ASD

- The tug thrust was pulsing, most likely due to the engine hunting around the set RPM, compared to the steady RPM of a small electric motor for the model-scale tests
- At the model-scale, the water velocities were approximately 4.5 times less than the full-scale which would provide a less turbulent flow compared to the full-scale ASD tug
- The ADP sensor was located at the exit of the tunnel for the model-scale, whereas it was installed near to the toe of the revetment for the full-scale trial due to the significant turbulence at the stern of the tug
- There were varying water levels at the full-scale trial location which altered the surface level water flow around the rock bags which was controlled in the model-scale
- There were tidal currents acting perpendicular to the tug and thrust which was not present in the model-scale
- The ADP instrument was damaged during the full-scale trials before the higher speed runs were completed

In summary, the rock bags in the three test configurations had no movement from the direct and indirect tug wash in velocities up to an estimated 5.3 m/s, which was the maximum the tug could safely deliver, similar to [1]. Therefore, this test showed that the Rock Bag units are suitable to be installed as scour protection in a berth pocket, around piles and on revetments, as well as revetment armour units in water velocities up to 5.3 m/s with minimal movement. Due to the large tidal range at the time of the test, it was not practical to test each rock bag configuration (Case A, B, and C) for a range of water levels and tug positions.

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References

[1] D. Messiter, B. Miller, J. H. Simpson and G. Lumiatti, "Super Cruise Vessel vs Rock Bags," in *Australasian Coasts and Ports 2019 Conference*, Hobart, 2019.

[2] Internationale Geotextil GmbH, *AquaRockBag® - The flexible Polymer Net Bag,* Twistringen.

[3] Total Hydrographic, "Norbit Winghead i77h Mobilisation Report," Total Hydrographic, Sunshine West, 2022.

[4] Bluecoast Consulting Engineers, "Rock bag field trial current measurements – 7 October 2022," Bluecoast Consulting Engineers, Burleigh Heads, 2022.

[5] Calon Captain, "Overview of ASD (Azimuth Stern Drive) and its motion on a tug boat," [Online]. Available: https://caloncaptain.blogspot.com/2019/06/gambaran-umum-tentang-asd-azimuth-stern.html.

[6] Queensland Government, "Coastal Data System - Tide Data (7 Day)," Queensland Government Open Data Portal, 11 October 2022. [Online]. Available: https://www.data.qld.gov.au/dataset/coastal-data-system-tide-data/resource/1311fc19-1e60-444f-b5cf-24687f1c15a7.

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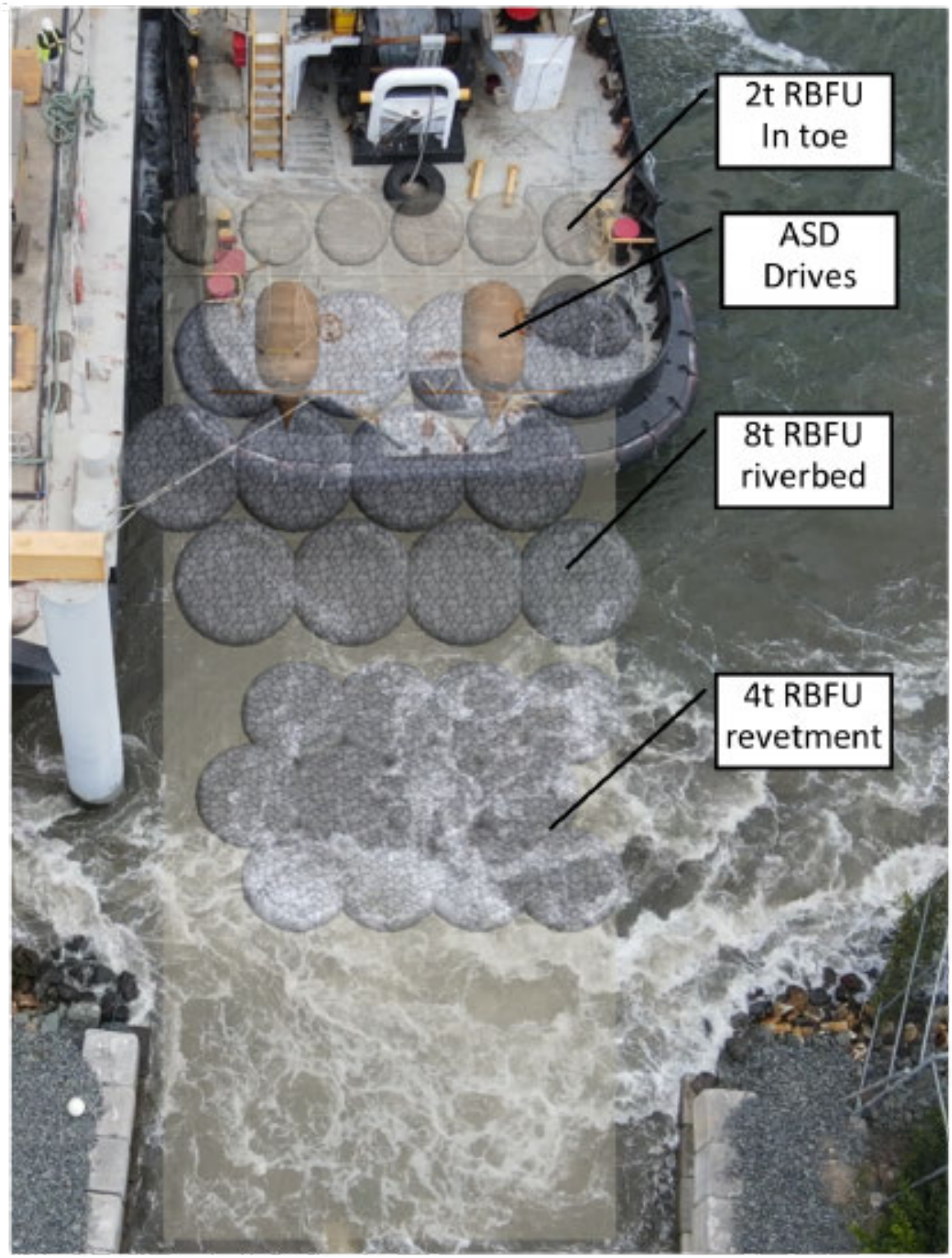
Case A Overlay



Case B Overlay

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