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The State of the Art and Science of Coastal Engineering

Physical Modelling of Propeller Scour on an Armoured Slope

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Topics

1. Overview
2. Physical model
3. Velocity profile
4. Test results
5. Site observations
6. Conclusions

Sino Iron Project – Cape Preston, WA

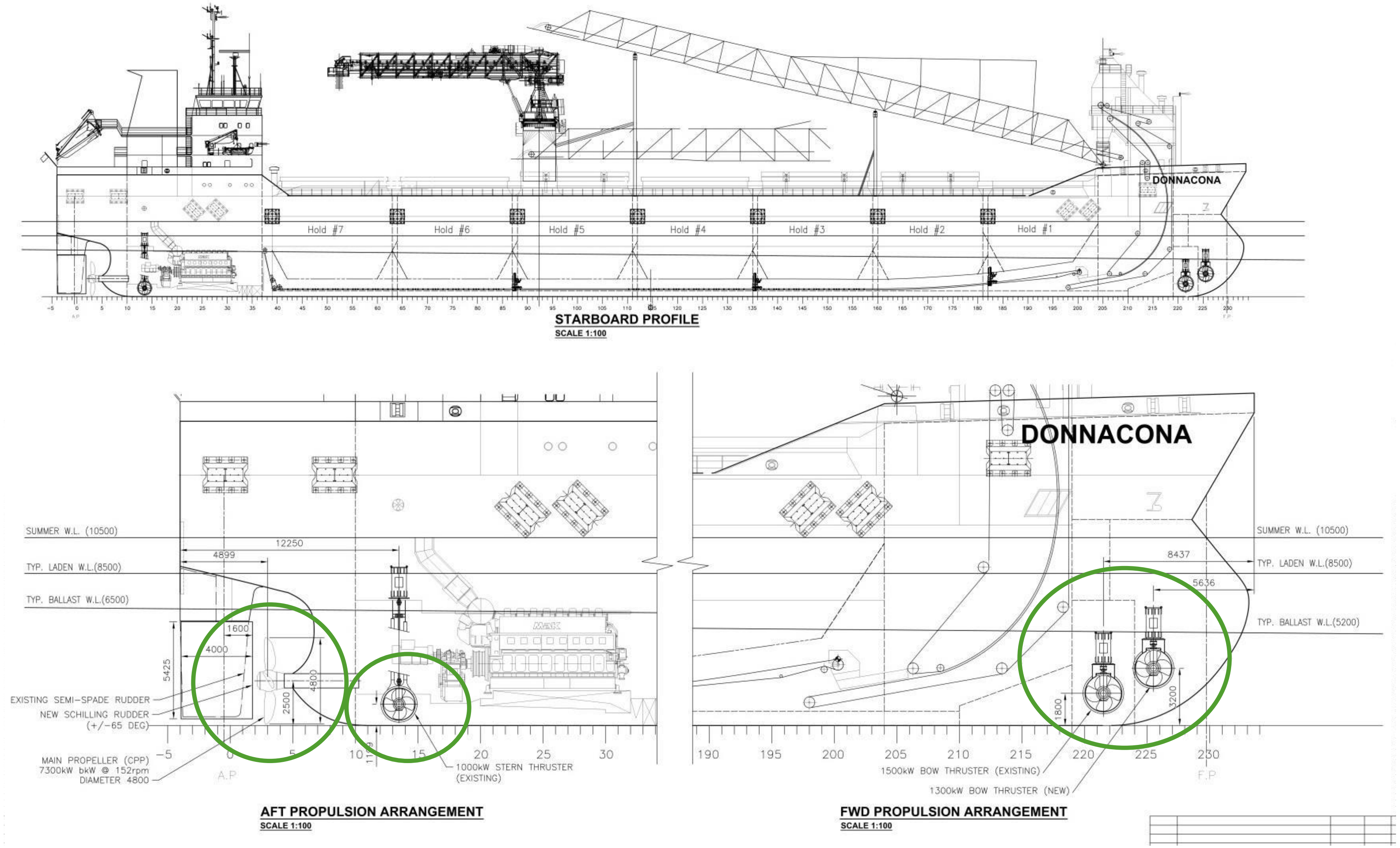
- CITIC Pacific Mining
- 100 km SW of Karratha in Pilbara region
- Largest magnetite mining and processing operation in Australia

Cape Preston, WA

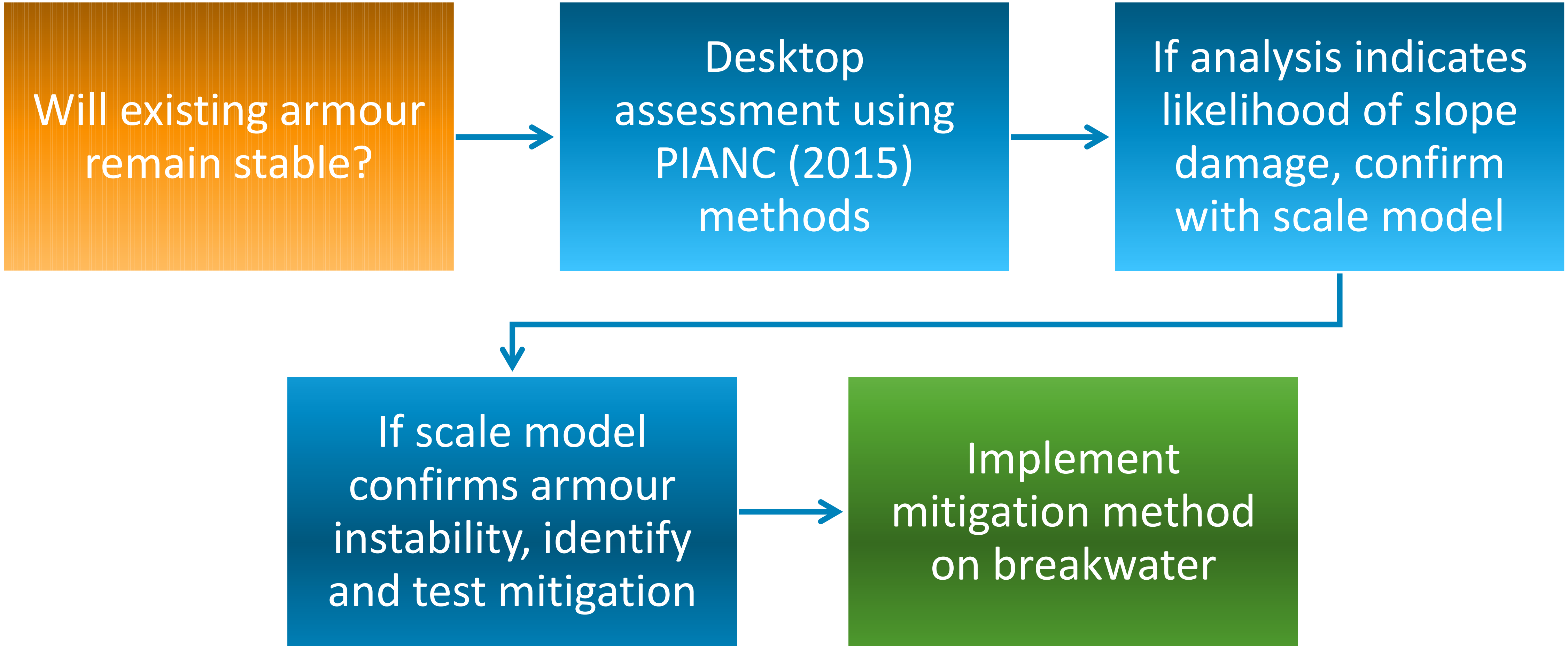
Barges (no propulsion)

Transhipment Vessel (TSV)

The CSL Donnaconna

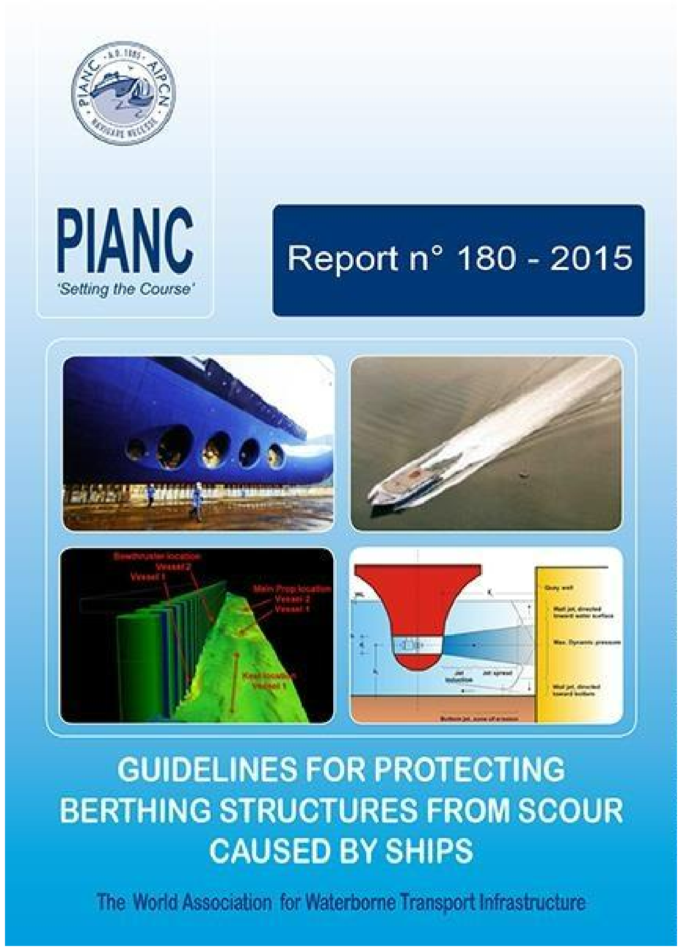


Seeking a Solution



Desktop Assessment of Propwash Effects

- PIANC 180 (2015) provides the latest guidance on propeller induced scour
- Three methods described to calculate the minimum stable rock size:
  - Dutch/Izbash
  - Dutch/Pilarczyk
  - German
- All methods agree that bow thruster wash would cause slope instability (W_{50} = 0.5 t), but differed for the lower velocity main propeller wash
- A physical model study was recommended



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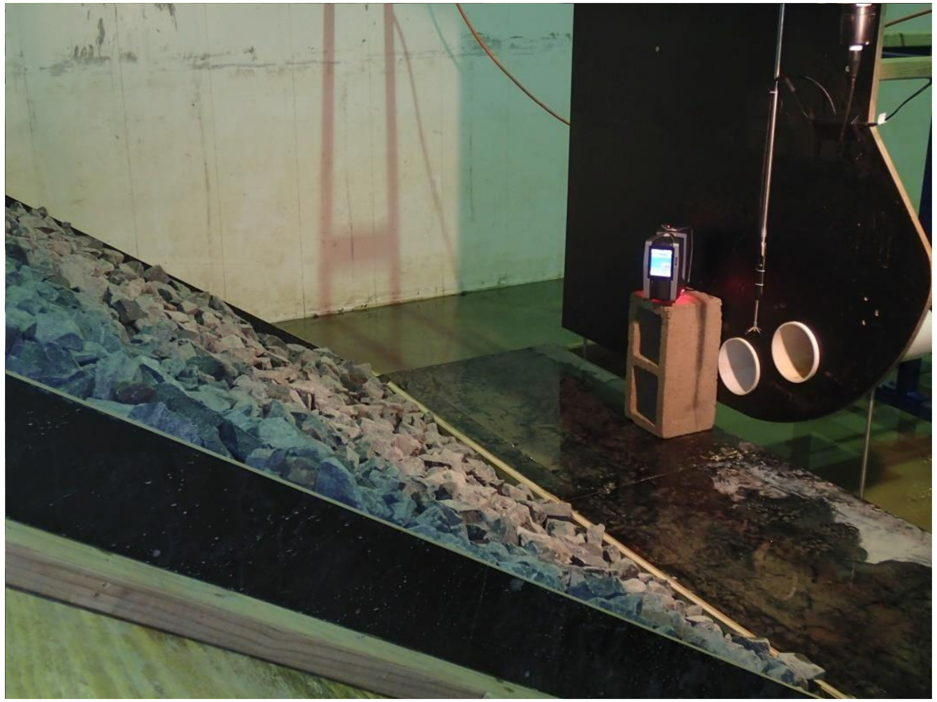
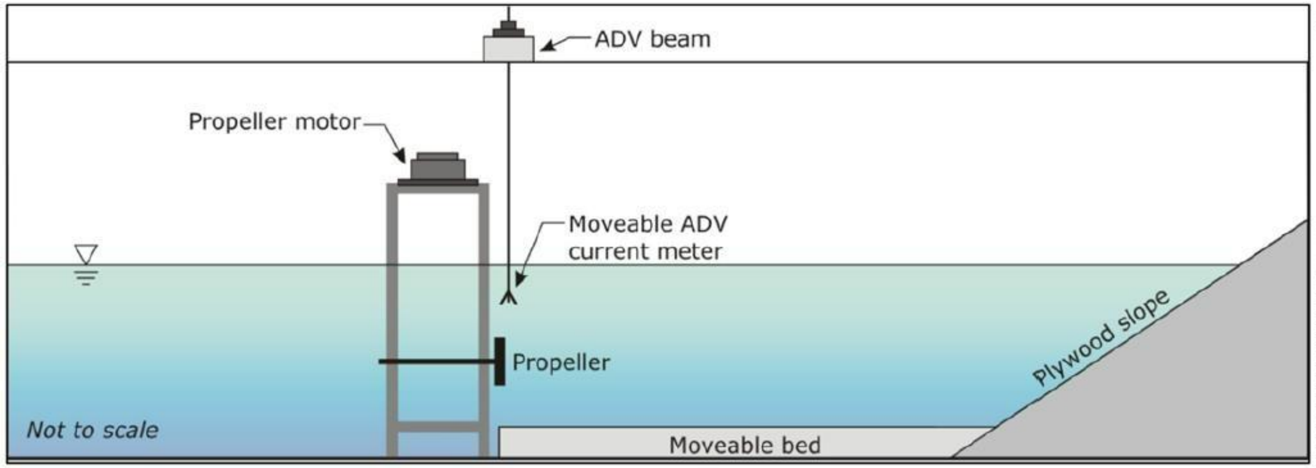
Physical Model

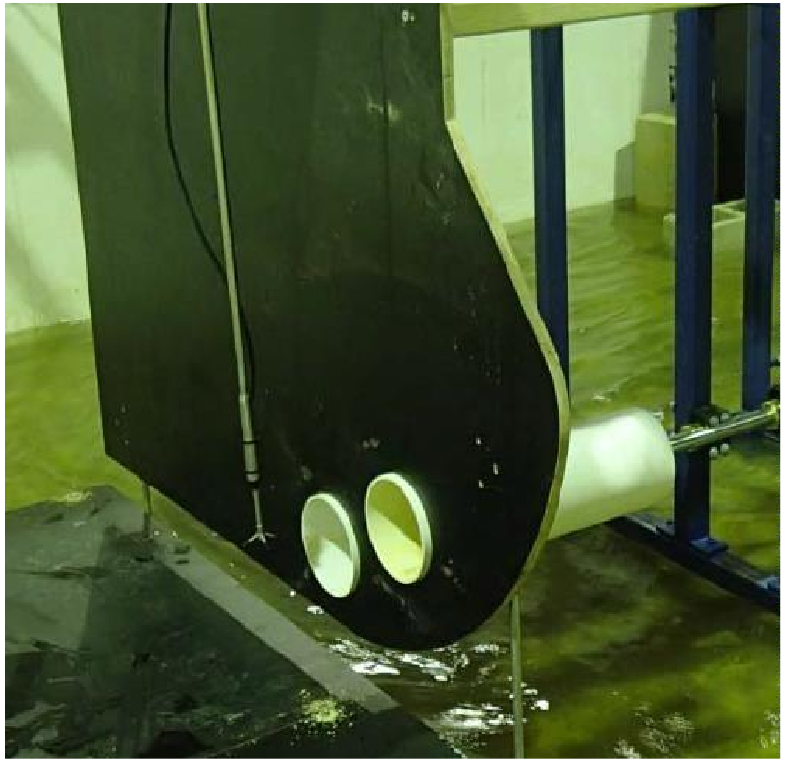
Model Set-up

- UNSW tank size – 4 m x 7 m x 1.4 m
- Scale of 13.5:1
- Acoustic Doppler Velocimeter (ADV)
- FARO laser scanner
- Movable and fixed bed tests





Bow Thruster



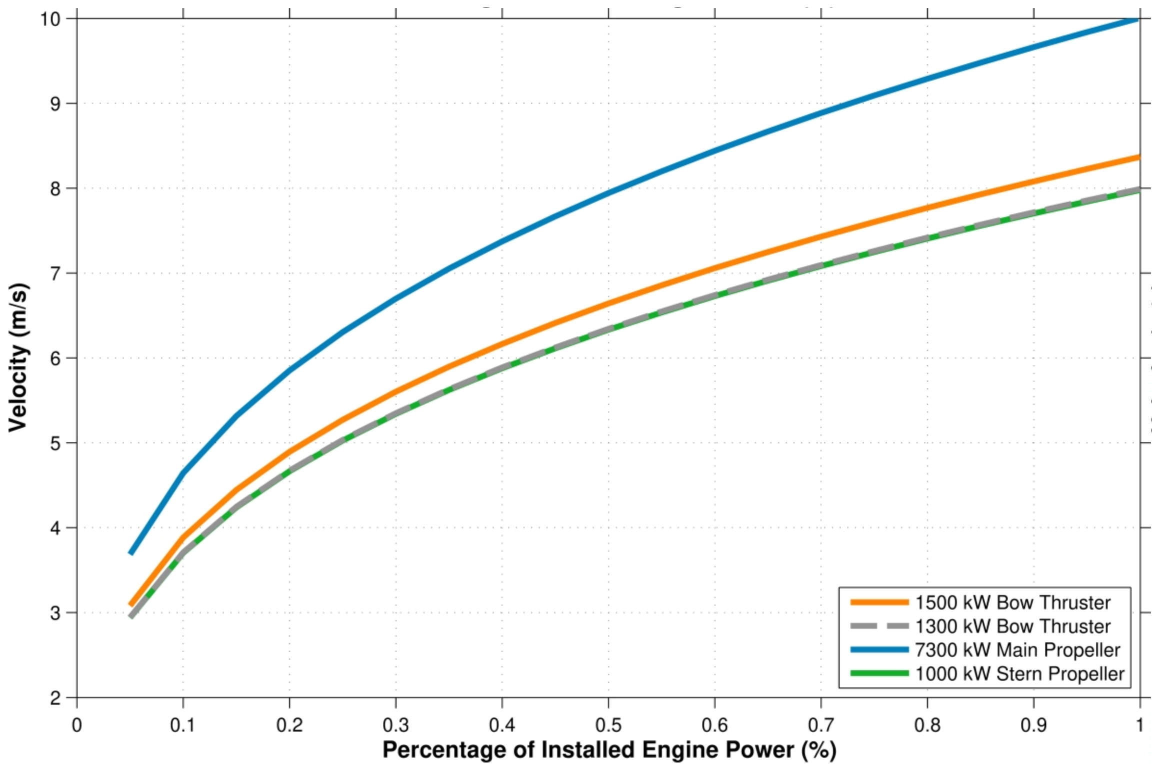
Test Program

- 30 minutes (full scale) per test
- Fixed and mobile bed tests
- Engine power modelled:
  - main propeller (30/70/100%)
  - bow/stern thrusters (40/100%).
- Efflux velocity from PIANC (2015)

$$V_0 = C_3 \left(\frac{f_p P_D}{\rho_w D_p^2} \right)^{0.33}$$

(Blaauw and van de Kaa)

C_3 = 1.17 for ducted and 1.48 for free propeller



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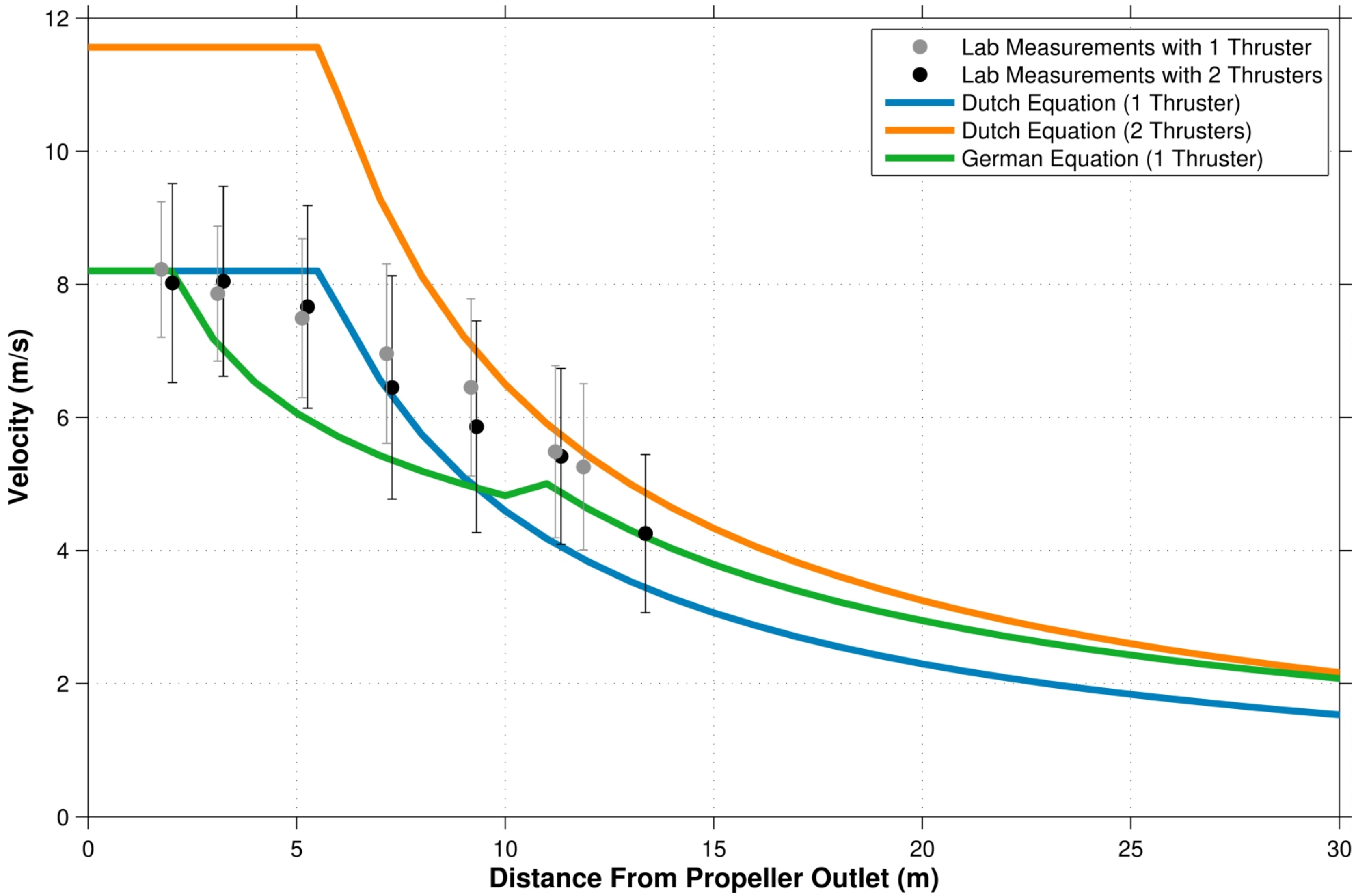
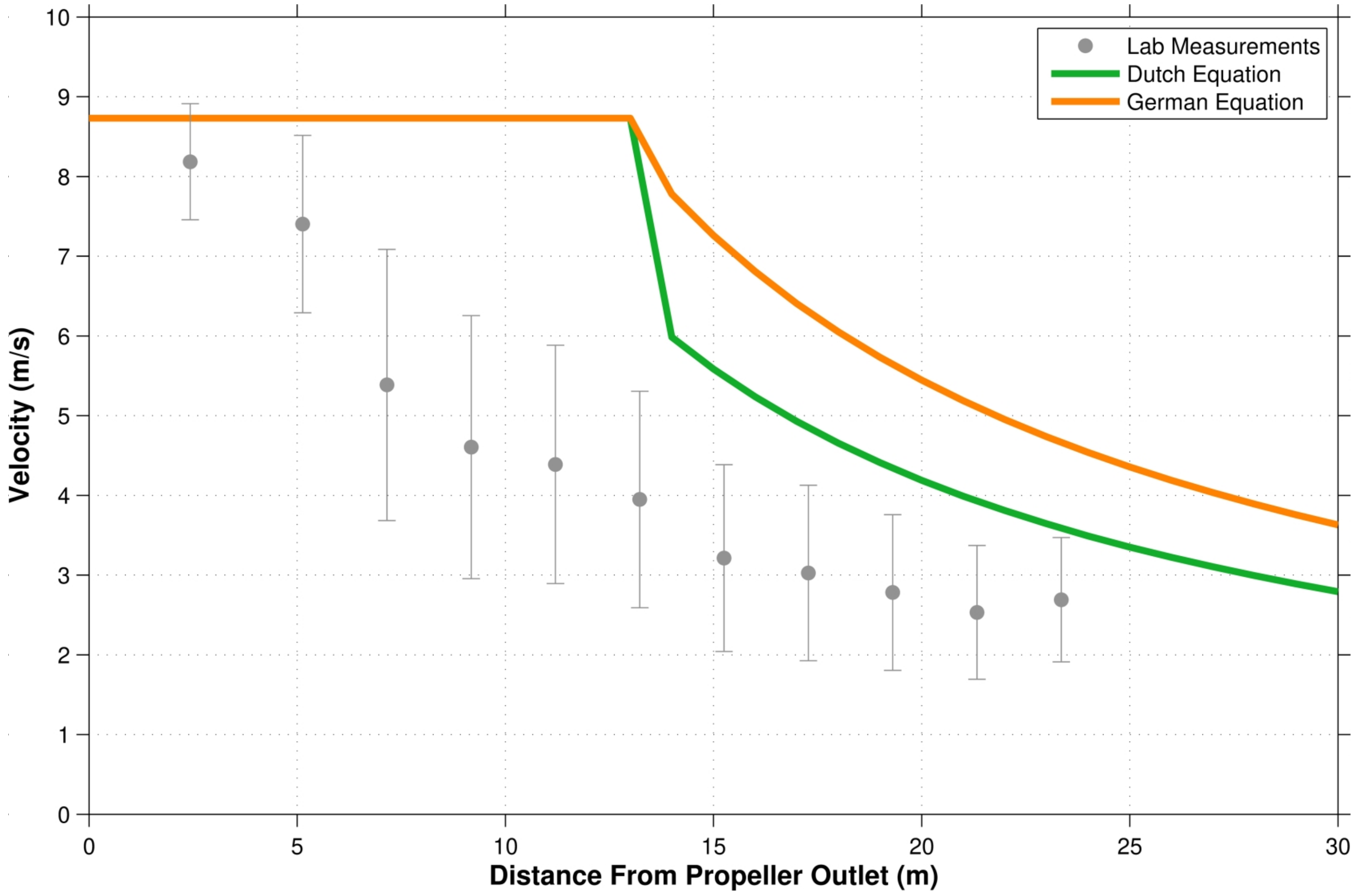
Velocity Profiles

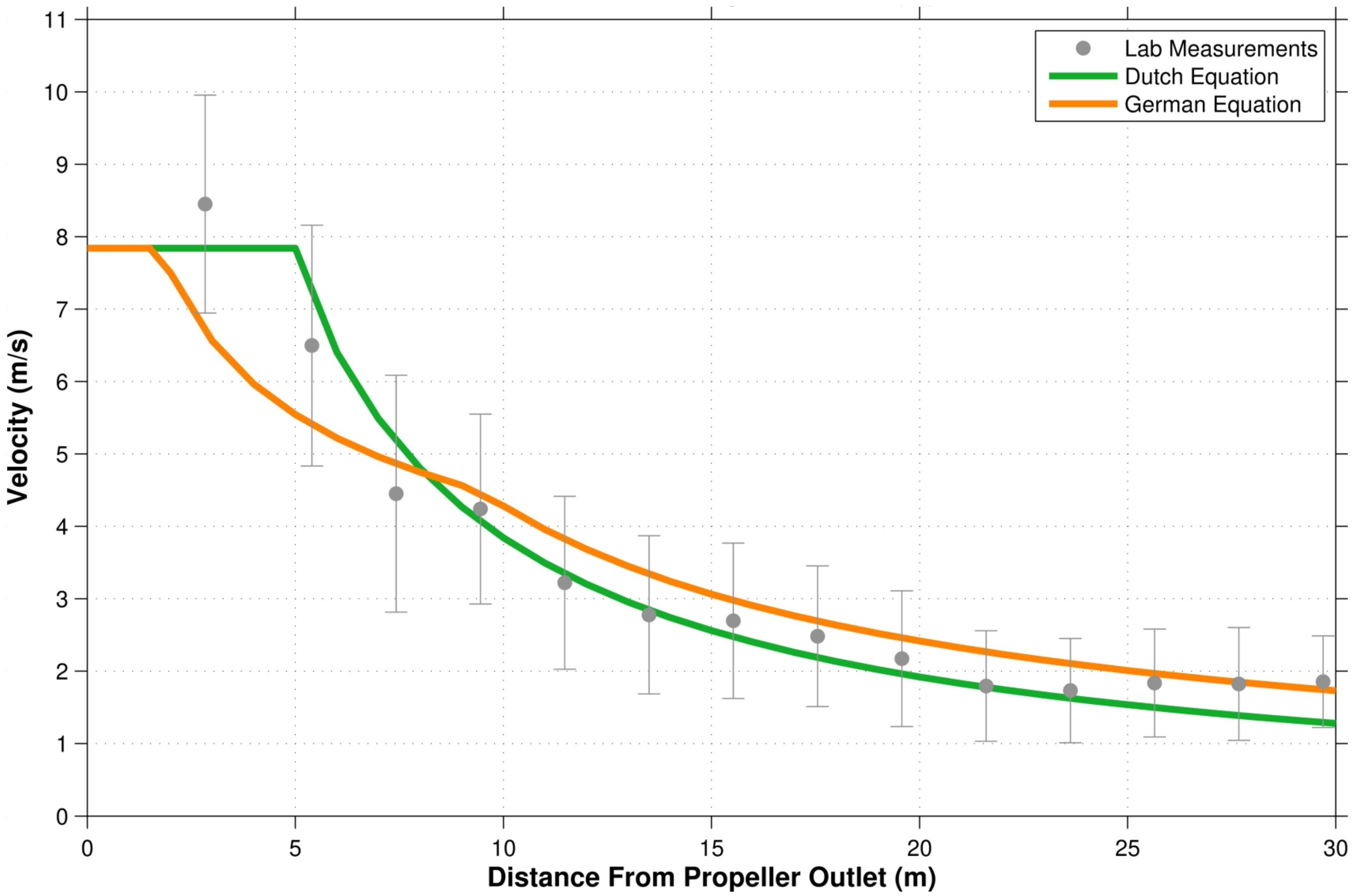
Bow Thrusters



Main Propeller



Stern Thruster



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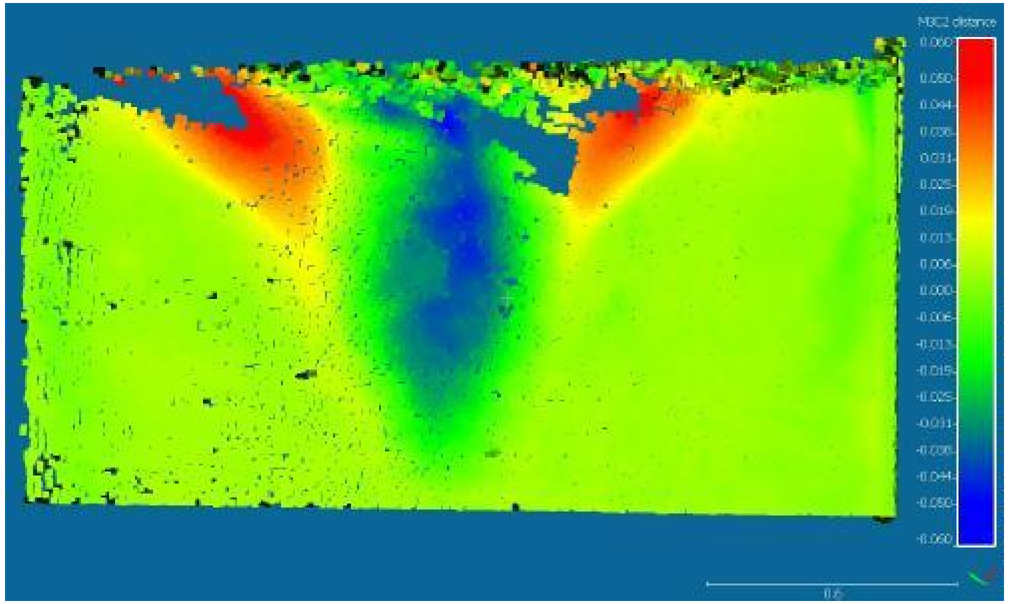
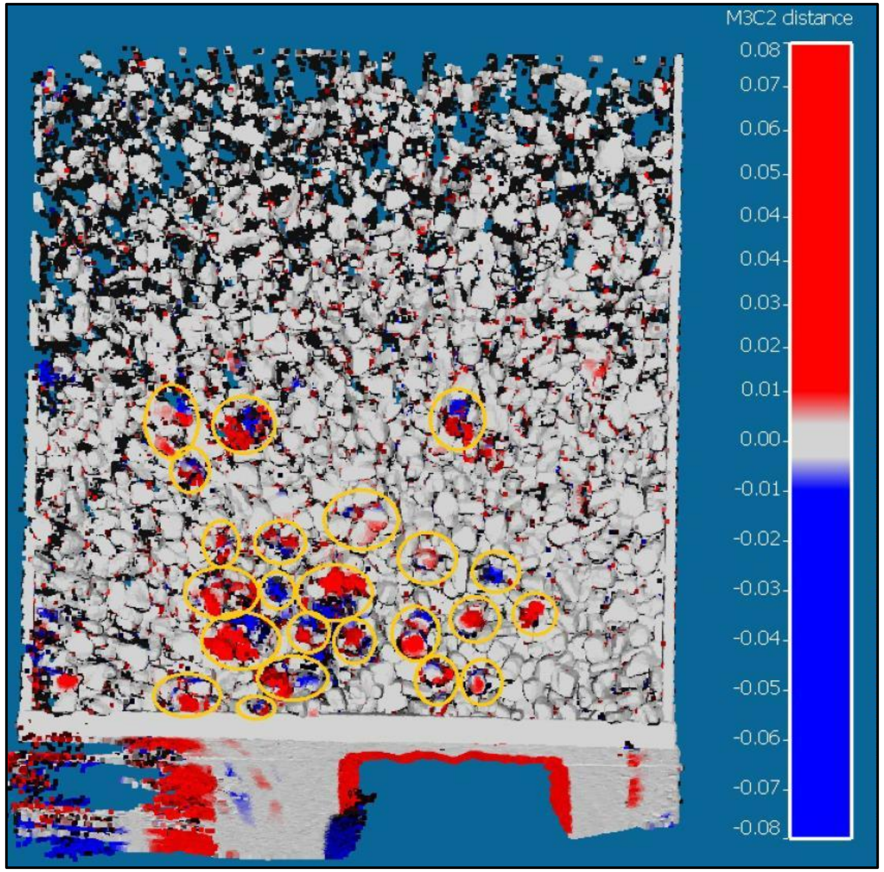
Test Results

Bed Stability – Mobile Bed Tests

- Main propeller and bow thrusters
- Bed scour and local toe damage observed
- Protection of the seabed at toe of slope likely required

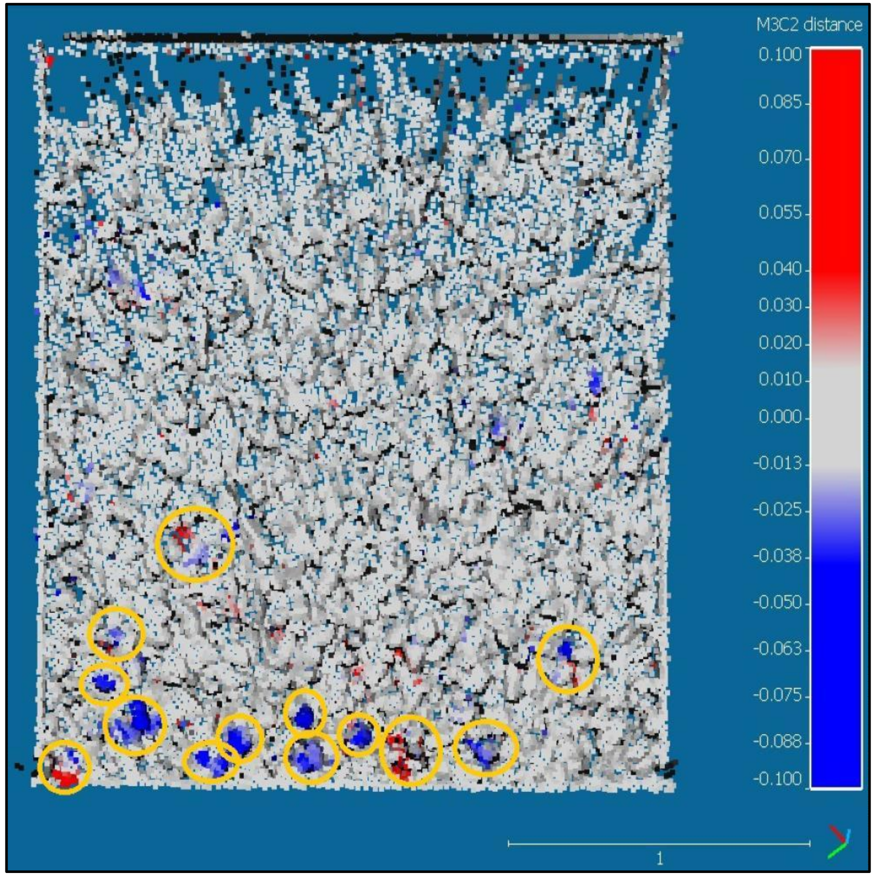


Armour Stability – Fixed Bed Tests



Bow Thrusters (100%)
23 rocks moved

Main Prop & Stern Thruster (70/100%)
13 rocks moved



Armour Stability – Fixed Bed Tests

Test series	Engine Power	Rocks Moved
Bow Thrusters	40 %	5
	70 %	18
	100 %	23
Main Propeller	30 %	2
	70 %	6
Main Propeller + Stern Thruster	30 / 100 %	3
	70 / 100 %	13

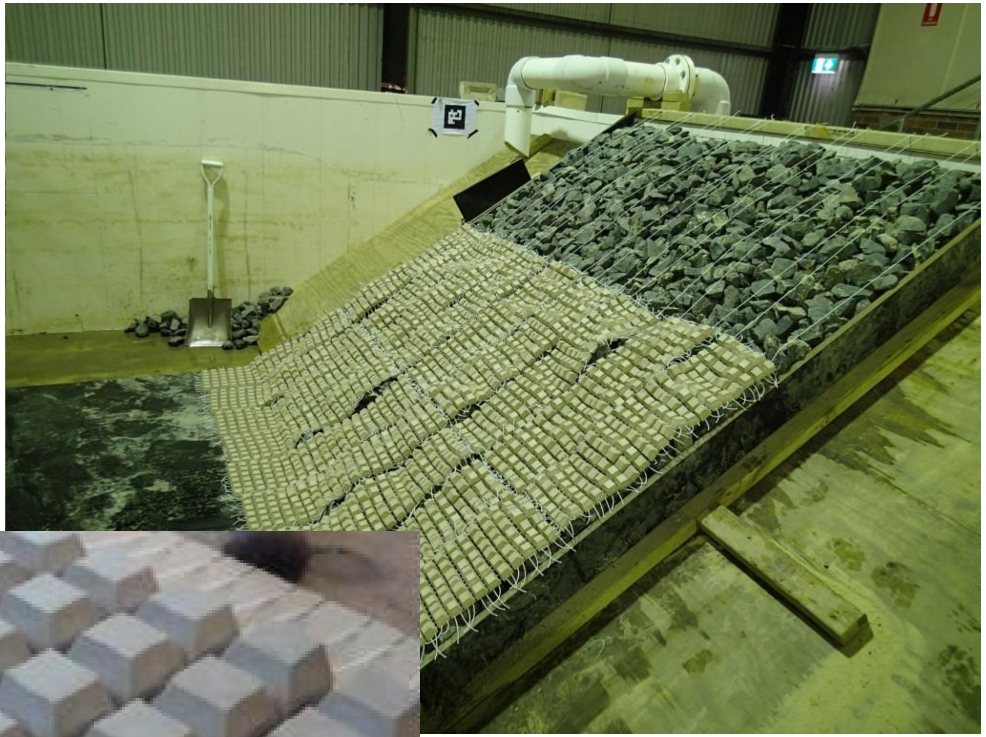
Armour Stability – Equations

- Comparison of stable armour rock weight, W_{50}, estimates based on measured wash velocities using PIANC equations
  - German and Dutch/Izbash methods provide comparable estimates for higher velocities (bow thrusters) but underpredict W_{50} at low velocities (main prop.)
  - Dutch/Pilarczyk method provides a realistic W_{50} estimate at lower velocities (main prop.) but overpredicts for the case of the bow thrusters
- More guidance required on which coefficients are appropriate for use in the design equations

Wash Source	Stable Rock Weight, W_{50} (kg)		
	German	Dutch/Izbash	Dutch/Pilarczyk
Main Propeller (2.5 m/s)	21 - 155	75	1,770
Bow Thrusters (4 m/s)	360 – 2,585	1,280	29,700

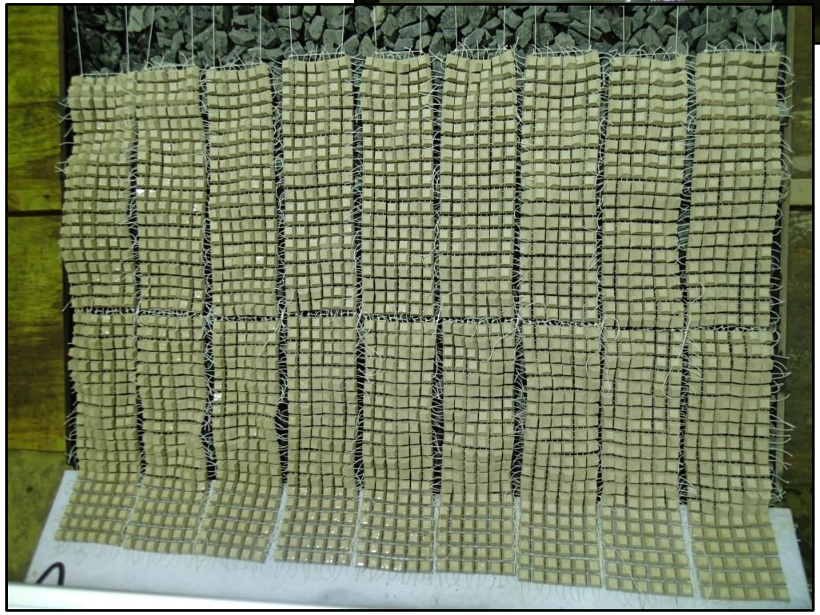
Articulated Concrete Mattresses (ACM)

- Design by Australian manufacturer Subcon
- Subcon used previous model test experience to advise on how to achieve correct density of block material and ensure mats were a good representation of actual product

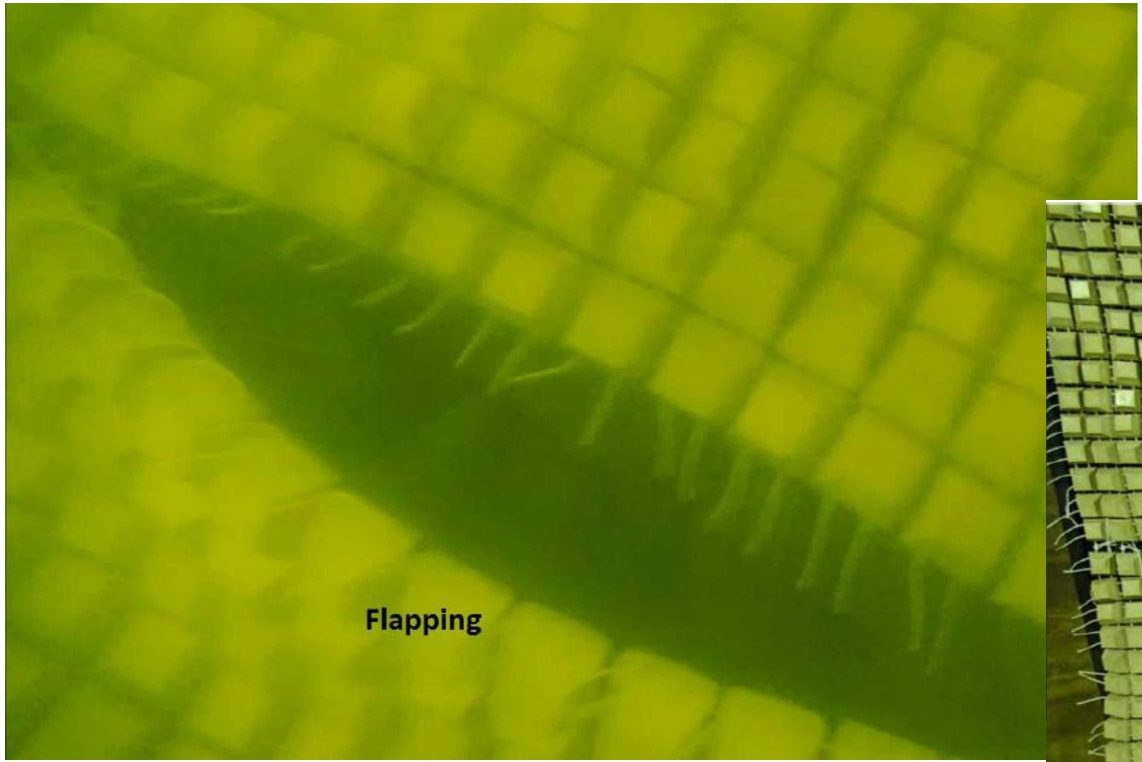


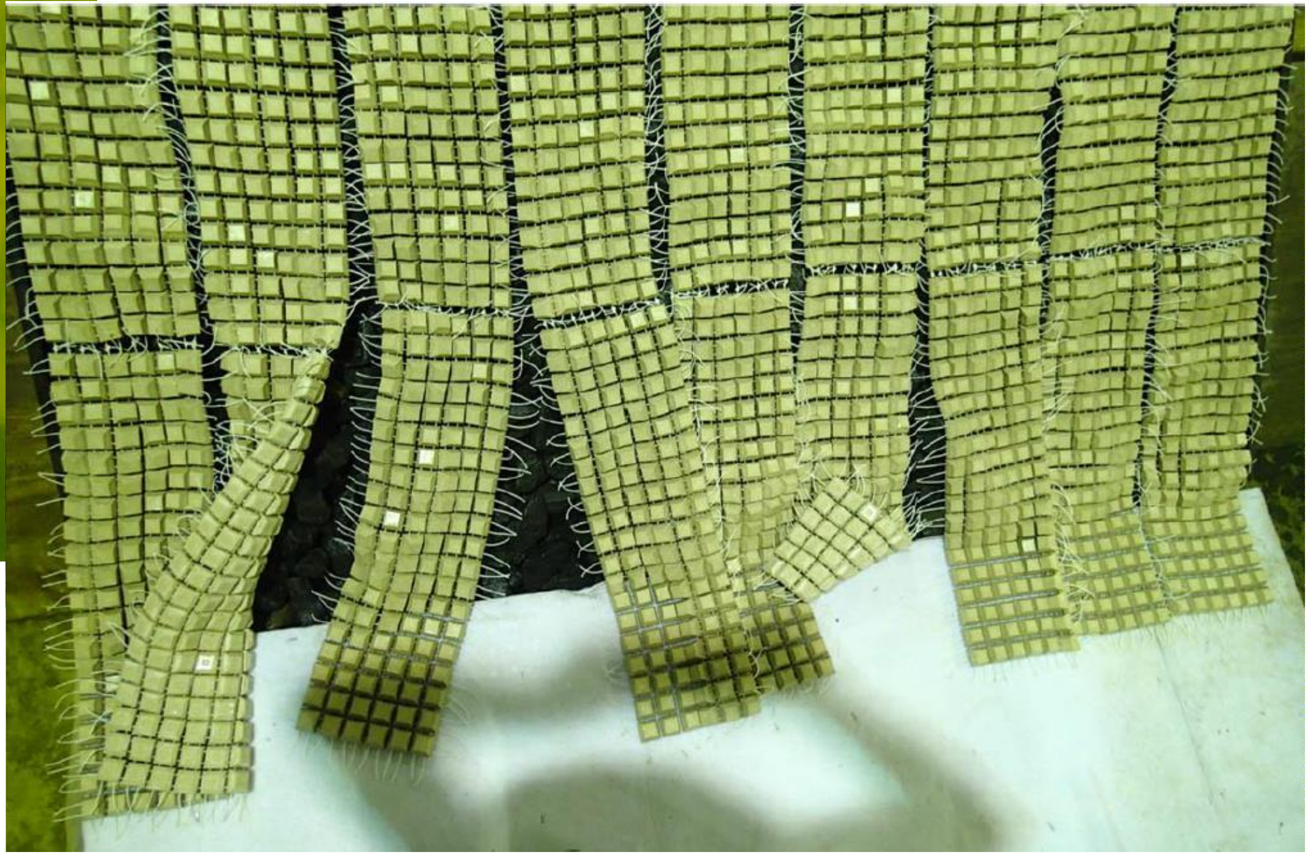
ACM Stability Tests

- Two test series were performed with the ACMs
- In the first series mats were tied to the top of the slope
- Flipping of the lower edge and movement of the long edge of the mats was observed



ACM Test Observations





Tying mats together at the toe of the slope for the final test resolved this issue

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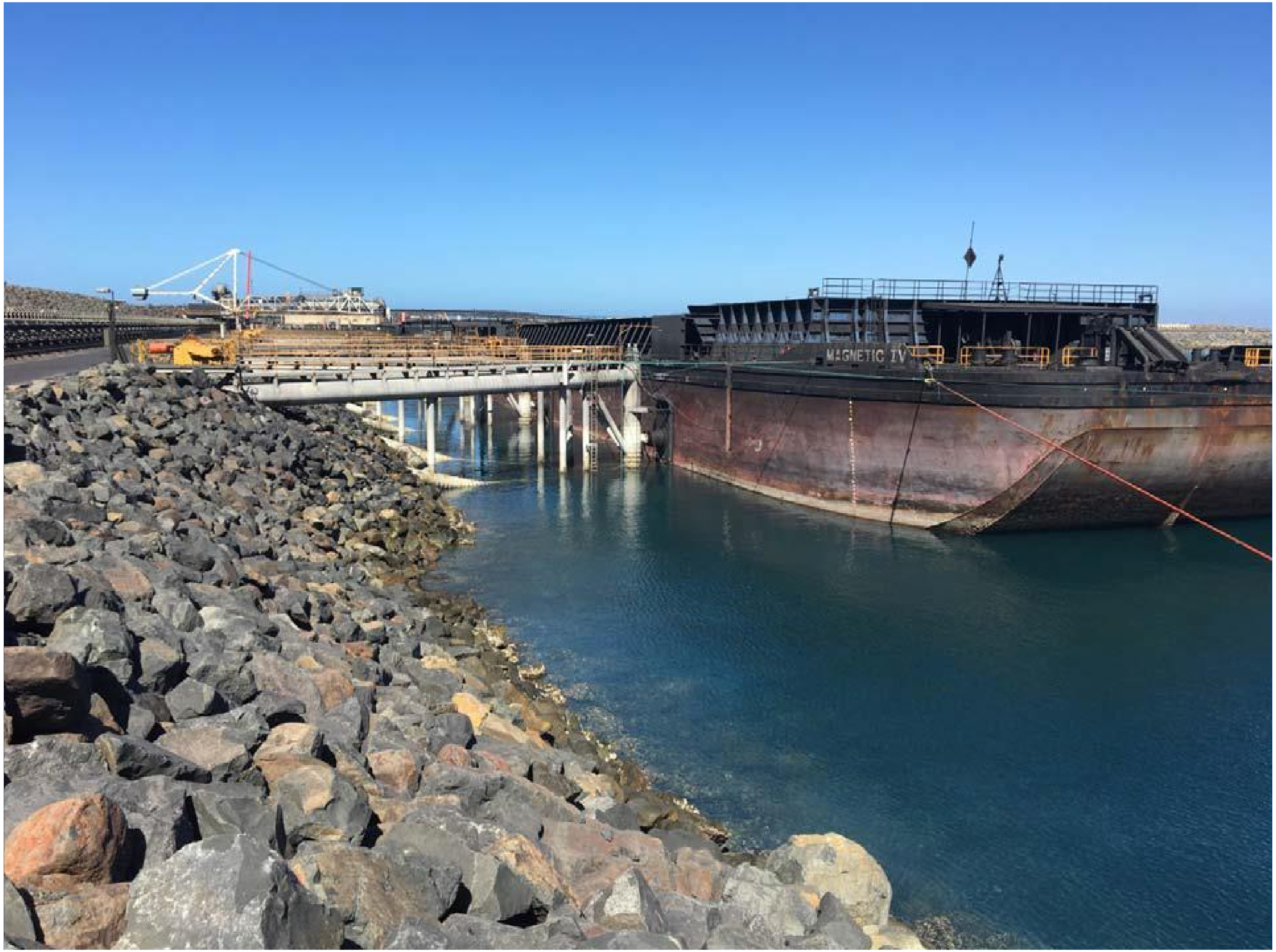
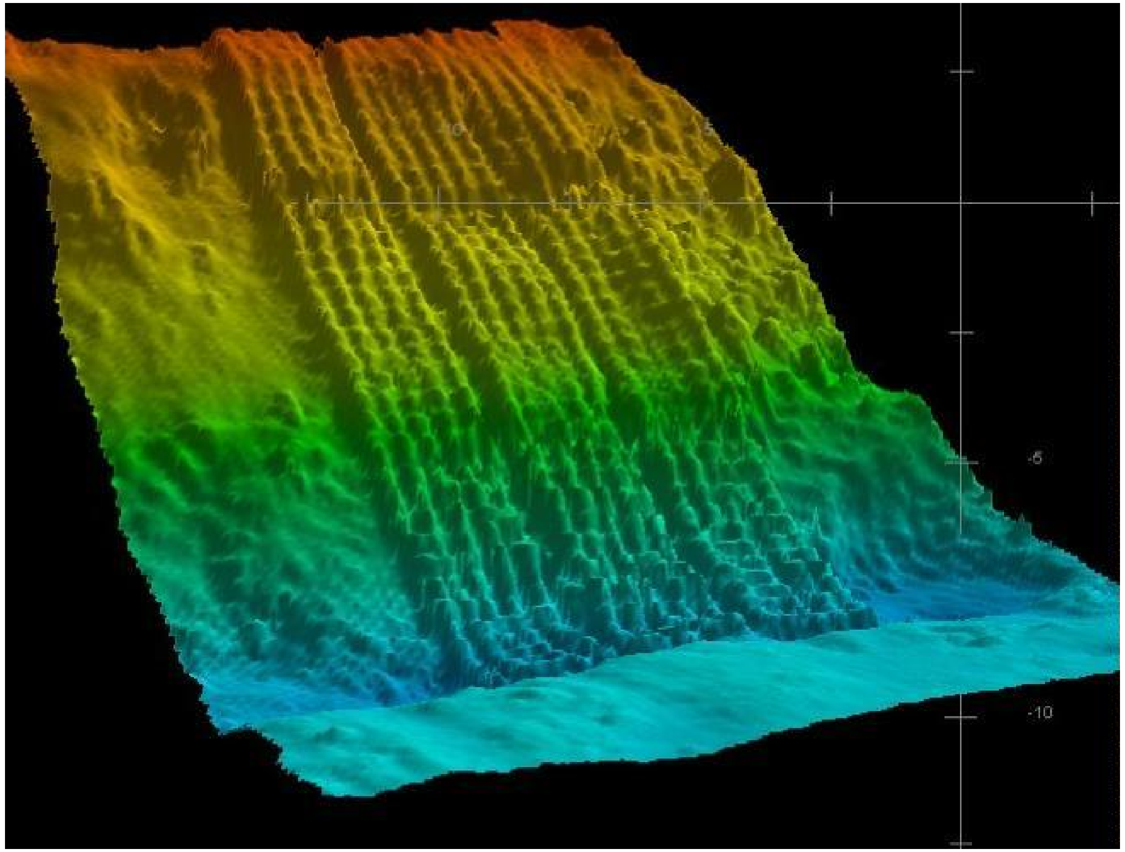
Site Observations



Slope damage after TSV Donnaconna operations

Mattress Installation

Mattress installation



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Conclusions

Conclusions – Velocity Decay

1. Measured velocities in the model tests decreased rapidly in zone of flow establishment (more evident for main propeller)
   - zone of flow establishment (typically ~2.6*Dp) may be overestimated for large propellers
2. Both the Dutch and German equations overestimate the wash velocities in the decay zone for the main propeller
3. There was no measured increase in velocity along the propeller axis when the second bow thruster was operational – but decay characteristics agree well with equation
4. The Dutch equation provided the overall best approximation of flow velocity decay

Conclusions – Armour Stability

1. During bow thruster tests, rock movement was witnessed outside of the expected wash footprint (based on 10 deg plume spread)
2. Articulated Concrete Mattresses were observed to perform better in thruster wash when tied together at the toe and top of the slope
3. More lab and field data is required to understand and refine the equations for stable armour weight from PIANC (2015)
   - German and the Dutch/Izbash equations provided reasonable estimates of stable rock sizes for higher wash velocities but underestimated rock sizes at 2.5 m/s
   - Dutch/Pilarczyk method predicted notably higher stable rock weight in comparison to other formulations

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Thank you

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