Manly Hydraulics Laboratory | Transport for NSW | 29th NSW Coastal Conference, 31 May - 2 June 2022, Mantra on Salt Beach Kingscliff, Living with Uncertainty

Assessing 65 Breakwaters on the NSW Coastline Utilising RPAs - A Comparison of Techniques over 25 years

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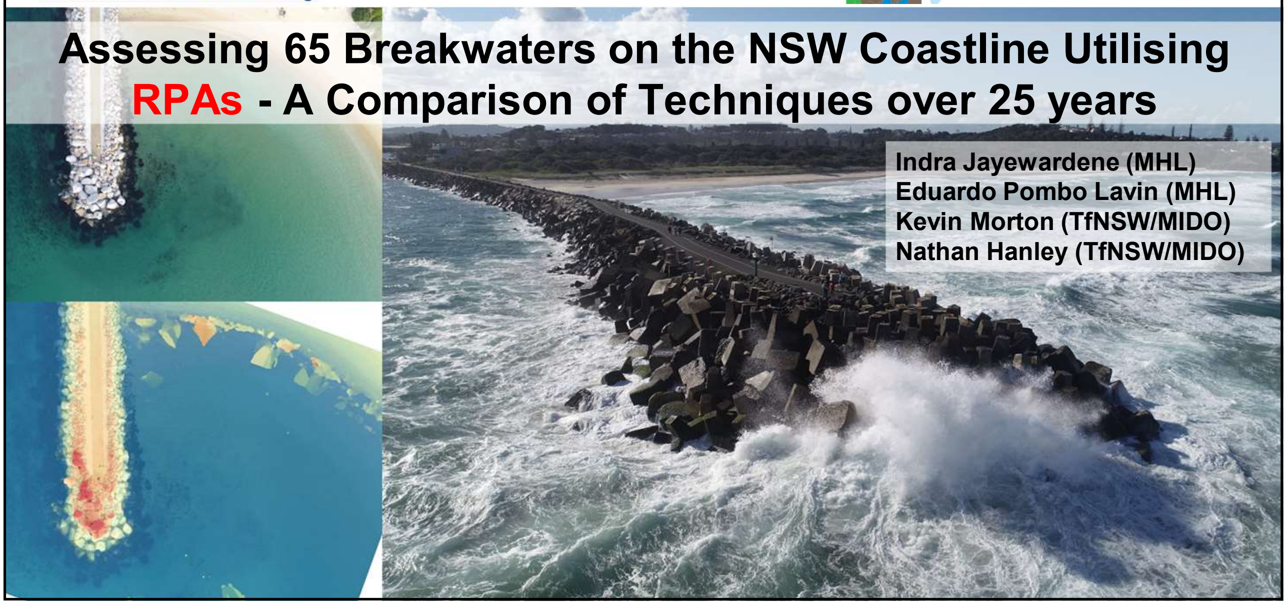
Kevin Morton (TfNSW/MIDO)
Nathan Hanley (TfNSW/MIDO)



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Assessing 65 Breakwaters on the NSW Coastline Utilising Drones

Presentation Outline

- Brief Introduction to the history of assessment of breakwaters
- The relationship between assessment and design formula for breakwaters
- The continuing role of physical modelling, numerical modelling and assessment in breakwater repair strategies
- Some successes and lessons learnt.
- The use of drones in the 20/21 and in the future
- Wrap up

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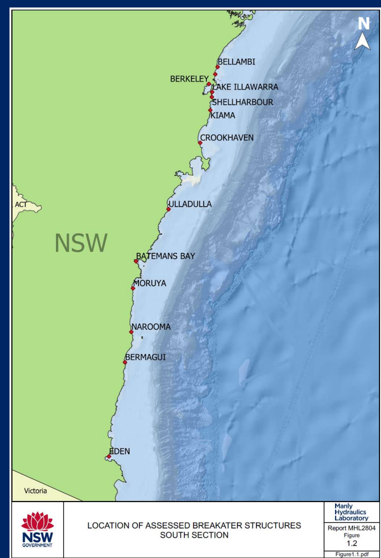

Breakwater Asset Appraisal – 1992 to date – 35 locations

Asset	Number	Length (m)	Value (1993)
Rubble mound structures	63	22,600	$550 million

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NSW Offshore Waverider Buoy Network

Wave Station	Date Site Commissioned	Directional Buoy Deployed
Byron Bay	14-Oct-1976	26-Oct-1999
Coffs Harbour	26-May-1976	14-Feb-2012
Crowdy Head	10-Oct-1985	19-Aug-2011
Sydney	17-Jul-1987	03-Mar-1992
Port Kembla	07-Feb-1974	20-Jun-2012
Batemans Bay	27-May-1986	23-Feb-2001
Eden	08-Feb-1978	16-Dec-2011

- 7 Datawell Directional buoys
- Moored 6 - 12 km offshore
- 4 stations > 38 yrs data
- Sydney > 24 yrs Directional data
- 3 stations > 15 yrs Directional
- > 230 station yrs wave data

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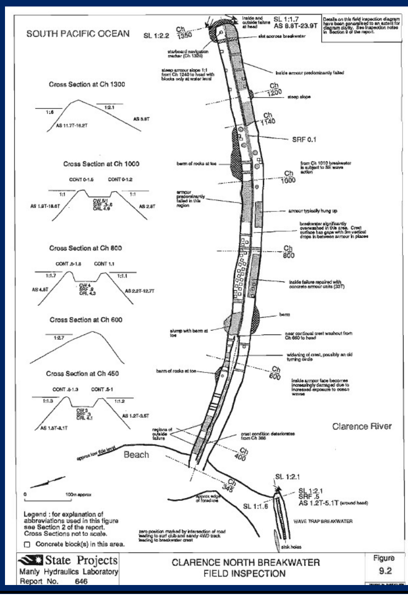

NSW Breakwater Appraisals 92/93

Stone Age!

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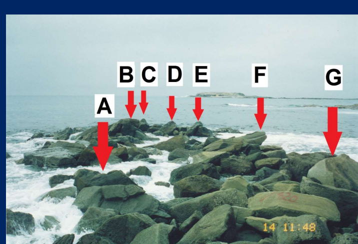
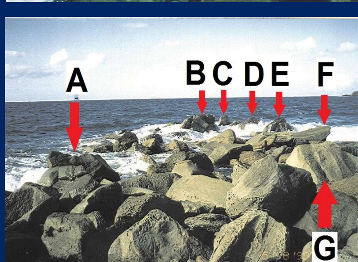


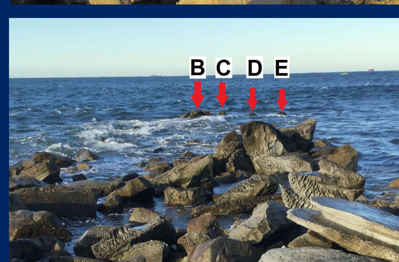
1993

2012

Swansea South



1999



2016

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Assessment After Storm Events – Kevin's Movement – North Head Port Macquarie

2014 Kevin with Kevin

2016 June Kevin Unmoved

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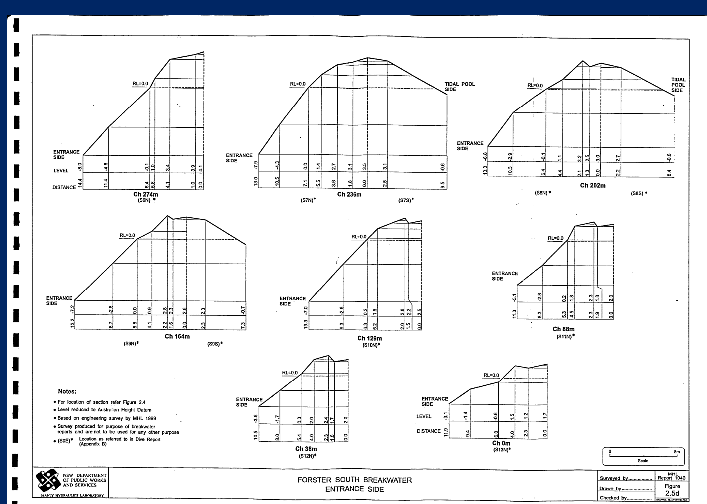
Cross Sections Utilising Theodolite-Forster South



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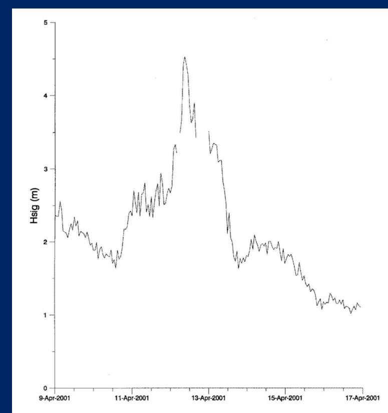
Brief History of Damage and Repair to Breakwater Due to 2001 Storm

- Widening of the crest and placement of approximately 3,700 tonnes of armour rock by June 1998 at a cost of $163,500
- 800 tonnes of 7 to 8 tonne rock was placed on the head
- A temporary repair was carried out on the head in July 2001. 185 tonnes using 3 to 6 tonne rock at a cost of $30,000 was placed on the head



Crowdy Head Waverider Buoy
April 2001 Storm

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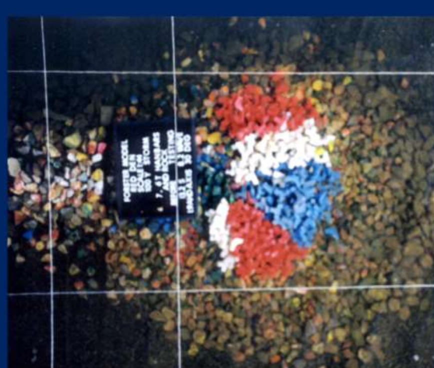
Forster Head Repair – 8 tonne Hanbar Armour Placement and Damage



(a) Stage Two, Test 7 – placement of 8 tonne Hanbars prior to testing with elevated water level

(b) Stage Two, Test 7 - extensive damage to 8 tonne Hanbars after 500 waves

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Repairing Forster head with 12 tonne Hanbars

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Prototype - Storms After Construction

Date	Hsig (m)	Tp (s)
20/07/2004	5.3	12.1
21/10/2004	5.2	9.6
30/10/2004	5.3	13.8
14/05/2005	6	10.2
29/05/2005	4.6	13.5
30/06/2005	4.6	11.1
11/07/2005	4.9	13.5

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Repair Timing – Performance of Forster Head – Aerial Photos

After May 2009 Storm

2006

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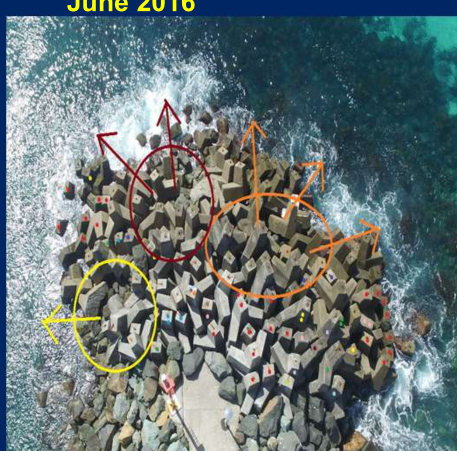
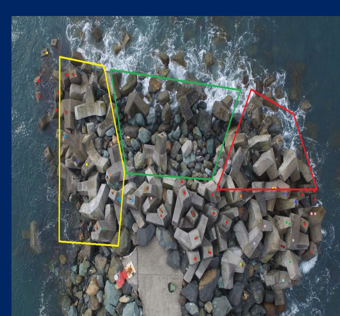
Repair Timing – Damage to Forster Head Drone Photos March and June 2016





Green area = 92m^2 existing coverage	0 %
Yellow area = 100m^2 existing coverage	25 %
Red area = 100m^2 existing coverage	40 %

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Chainage 240m

Coffs Harbour Underwater Survey - MHL

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Hudson Equations for Stability (1957)

$H_{sig} / \Delta D_n = (K_D \text{ Cot } \alpha)^{1/3}$ (1)

where:

H_{sig} = design significant wave height at the structure
Δ = relative mass density
K_D = coefficient of damage
D_n = nominal diameter of M_{50} armour
α = angle of breakwater slope (obtained from cross sections in Appendix A)

$$\frac{Hs}{\Delta D_{n50}} = \frac{(K_D cot \propto)^{1/3}}{1.27}$$

Using van der Meer's damage criteria

$$\frac{Hs}{\Delta D_{n50}} = 0.7(K_D cot \propto)^{1/3} \, {S_d}^{0.15}$$

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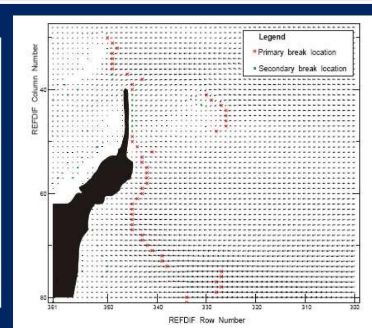

Coffs Harbour Head Storm Damage May 1997 12 x 40 tonne blocks

May 10,1997-2 yr ARI storm-Coffs Breakwater

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Before storm

After storm

Design Success – May 2009 – Before and After Crest Damage

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Verification -2009 May Storm

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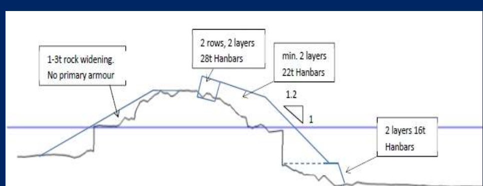
2012-13 Physical Model

- SMEC remediation design for Crown Lands. Design was model tested at WRL
- 3D physical model at MHL
- Scale 1:45.5
- Calibrated using May 2009 storm
- Design incorporating two layer 28t, 22t and 16t Hanbars with variable slope and cross-sections along breakwater and head



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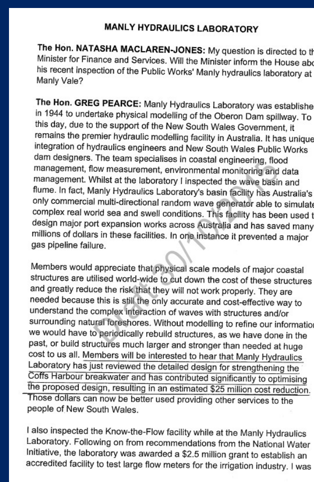
Hansard Publication on $25 million Saving By MHL



MANLY HYDRAULICS LABORATORY

The Hon. NATASHA MACLAREN-JONES: My question is directed to the Minister for Finance and Services. Will the Minister inform the House about his recent inspection of the Public Works' Manly hydraulics laboratory at Manly Vale?

The Hon. GREG PEARCE: Manly Hydraulics Laboratory was established in 1944 to undertake physical modelling of the Oberon Dam spillway. To this day, due to the support of the New South Wales Government, it remains the premier hydraulic modelling facility in Australia. It has unique integration of hydraulics engineers and New South Wales Public Works dam designers. The team specialises in coastal engineering, flood management, flow measurement, environmental monitoring and data management. Whilst at the laboratory I inspected the wave basin and flume. In fact, Manly Hydraulics Laboratory's basin facility has Australia's only commercial multi-directional random wave generator able to simulate complex real world sea and swell conditions. This facility has been used to design major port expansion works across Australia and has saved many millions of dollars in these facilities. In one instance it prevented a major gas pipeline failure.

Members would appreciate that physical scale models of major coastal structures are utilised world-wide to cut down the cost of these structures and greatly reduce the risk that they will not work properly. They are needed because this is still the only accurate and cost-effective way to understand the complex interaction of waves with structures and/or surrounding natural foreshores. Without modelling to refine our information we would have to periodically rebuild structures, as we have done in the past, or build structures much larger and stronger than needed at huge cost to us all. Members will be interested to hear that Manly Hydraulics Laboratory has just reviewed the detailed design for strengthening the Coffs Harbour breakwater and has contributed significantly to optimising the proposed design, resulting in an estimated $25 million cost reduction. Those dollars can now be better used providing other services to the people of New South Wales.

I also inspected the Know-the-Flow facility while at the Manly Hydraulics Laboratory. Following on from recommendations from the National Water Initiative, the laboratory was awarded a $2.5 million grant to establish an accredited facility to test large flow meters for the irrigation industry. I was

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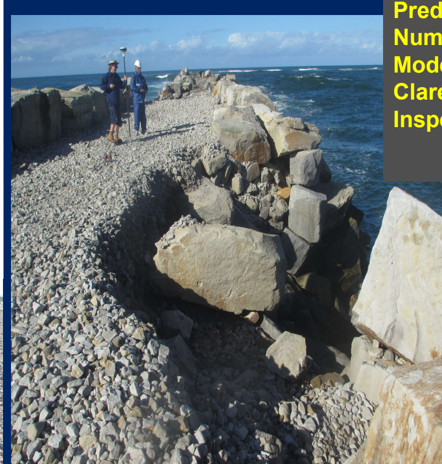
1996 Numerical Model

Table 8a Wave Height along Breakwater Structure Obtained from Refraction/Diffraction Analysis

Chainage (m)	Ocean Side Wave Height (m)	River Side Wave Height (m)
1350 (Head)	7.5	5.2
[illegible]	[illegible]	[illegible]
1200	4.5	4.6
1100	5.9	5.6
1000	3.5	4.0
900	3.0	2.4
[illegible]	[illegible]	[illegible]
700	2.3	1.6
600	2.5	1.0
500	1.5	1.0
400	1.0	0.9



Predictive Numerical Modelling 1996 – N. Clarence 2014 Inspection

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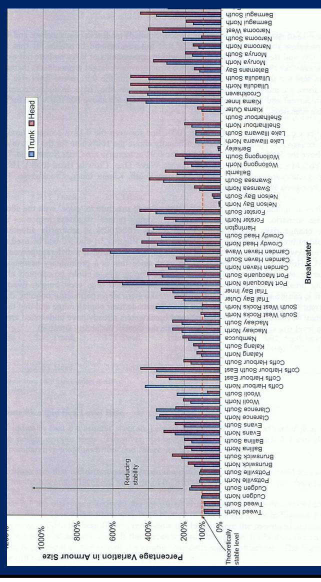
Sea Level Rise – Armour Size Requirements for .91m Rise



Theoretically stable level – 100%

Runup Levels for Ballina South Breakwater

Chainage	Crest Level (m AHD)	Runup Level (mAHD)
350	5.5	10.4
300	5.4	9.9
250	5.5	9.3
200	5.2	9.1
150	5.4	7.6
100	5.1	7.2
50	5.3	6.0

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van der Meer Equations for Stability (1987)

$$\frac{H_s}{\Delta D_{n50}} = 6.2\, P^{0.18} \left(\frac{S}{\sqrt{N}}\right)^{0.2} \xi_m^{-0.5}$$

(for plunging waves where $\xi_m < \xi_{mc}$)

$$\frac{H_s}{\Delta D_{n50}} = 1.0\, P^{-0.13} \left(\frac{S}{\sqrt{N}}\right)^{0.2} \cot g\, \alpha^{0.5}\, \xi_m^{P}$$

(for surging waves where $\xi_m > \xi_{mc}$)

P = notional permeability factor
S = damage level = $A_e/D_{n50}{}^2$
N = number of waves (storm duration)
$\xi_{m = Hs}$ / tan α / $(Sm)^{0.5}$, A_e=damage area
D_{n50} =diameter of 50% armour, α=slope angle

$$\xi_{mc} = \left[6.2\, P^{0.31} \sqrt{\tan \alpha}\right]^{\frac{1}{P+0.5}}$$

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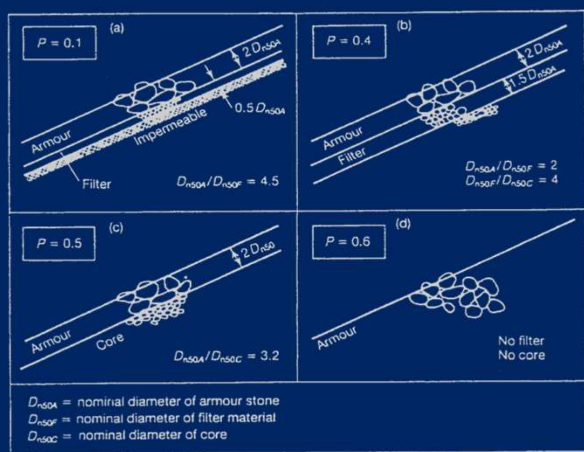
Simulating Notional Permeability in a Physical Model (van der Meer 1987)



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Application to the Assessment of a Breakwater in the Field –
Bellambi Breakwater constructed in 1978 – 400 x 12T Hanbars

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Maximum Momentum for Stability Flux Equation using Linear Theory (Hughes and Melby 2004)

$$M_F(x,t) = \int_{-h}^{\eta(x)} (p_d + \rho u^2)\,dz$$

$$\left(\frac{M_F}{\rho g h^2}\right)_{max} = \frac{1}{2}\left(\frac{H}{h}\right)\frac{\tanh kh}{kh} + \frac{1}{8}\left(\frac{H}{h}\right)^2 \times \left[1 + \frac{2kh}{\sinh 2kh}\right]$$

Using Extended Linear Wave Theory

$$\left(\frac{M_F}{\rho g h^2}\right)_{max} = \frac{1}{2}\left(\frac{H}{h}\right)\frac{\sinh[k(h+H/2)]}{kh\cosh(kh)} + \frac{1}{8}\left(\frac{H}{h}\right)^2 \times \left[\frac{\sinh[2k(h+H/2)] + 2k(h+H/2)}{\sinh 2kh}\right]$$

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Results from Boussinesq Modelling to Assess Suitability of Armour Size

Direction	(Point)	NE			ESE			SSE		
Event	depth (m)	5yr	20yr	100yr	5yr	20yr	100yr	5yr	20yr	100yr
Deepwater point target (Wave tool)		3.2	3.6	3.9	4.7	5.1	5.6	5.9	6.3	6.6
Deepwater point (10m contour)	0	3.23	3.78	4.1	4.99	5.46	6.33	6.03	6.64	6.74
Oceanside- 60m from head	(1)-2.02	2.42	2.58	2.71	3	3.09	3.23	1.71	1.76	1.9
Oceanside- 40m from head	(2)-2.98	2.57	2.81	2.92	3.48	3.51	3.67	1.86	1.96	2.16
Oceanside- 20m from head	(3)-3.72	2.95	3.24	3.37	3.84	3.93	4.11	2.16	2.26	2.46
Head (0 deg)	(4)-4.42	3.34	3.99	4.18	3.78	3.94	4.25	2.19	2.35	2.36
Head (45 deg)	(5)-5.06	2.76	3.23	3.4	3.58	4.01	4.16	1.77	1.78	1.77
Head (90 deg)	(6)-5.02	2.31	2.72	2.92	2.69	3.1	3.23	1.29	1.30	1.35
Head (135 deg)	(7)-4.11	1.42	1.58	1.69	1.45	1.63	1.73	1.02	1.04	1.06
Head (180 deg)	(8)-3.49	0.94	1.06	1.15	1.03	1.06	1.18	0.67	0.70	0.65
Car park - 0 from b/w	(9)-2.64	0.89	1.03	1.12	1.02	1.03	1.19	0.67	0.71	0.64
Car park - 20 from b/w	(10)-2.25	1	1.13	1.24	1.23	1.31	1.43	0.71	0.75	0.69
Car park - 40 from b/w	(11)-2	1.24	1.39	1.51	1.46	1.59	1.7	0.81	0.85	0.81

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Results from Spectral Wave Modelling to Assess Suitability of Armour Size

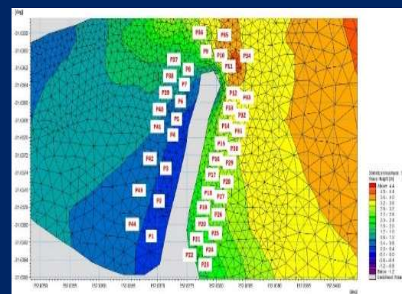

Table – Armour sizing for 50-year ARI event using formulae – for an Ursell number of 23-30

Expression	Tonnes
Hudson	10.4
van der Meer (shallow water)	7.3
Melby and Hughes (linear)	3.2
Melby and Hughes (extended linear)	4.5
Melby and Hughes (non-linear)	5.6

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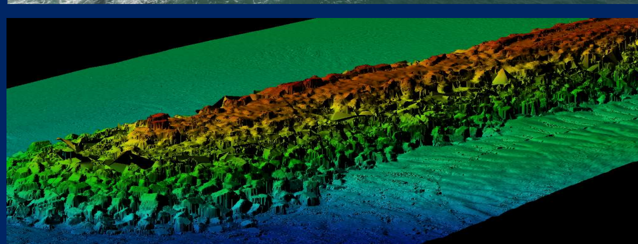

Improved Survey Techniques- Underwater Assessment

Marrying drone footage and dual scan sonar

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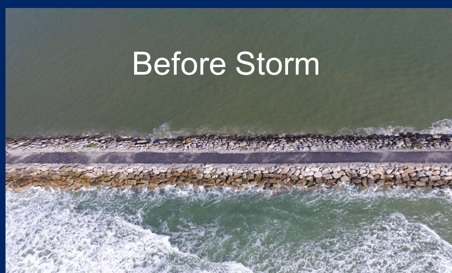

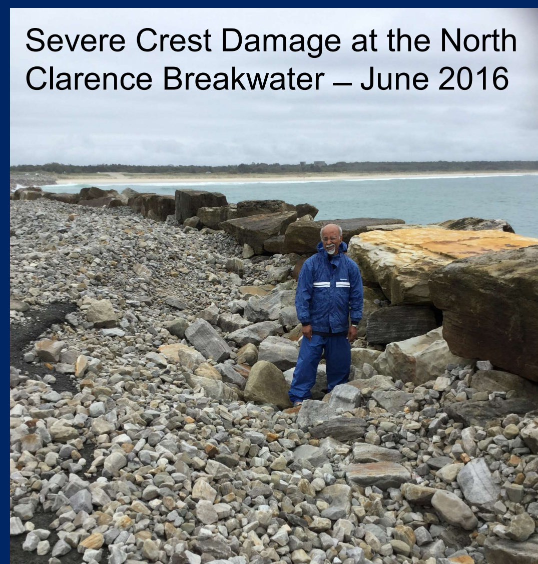

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Improvements to Crest – Cudgen South-2016, South Brunswick 2020

July 2011

July 2016

Sept 2020

Overtopping Standards-2018 EUROTOP

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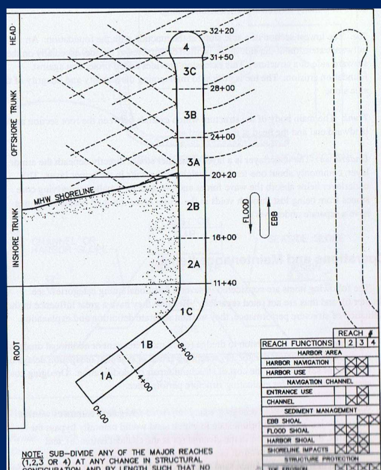
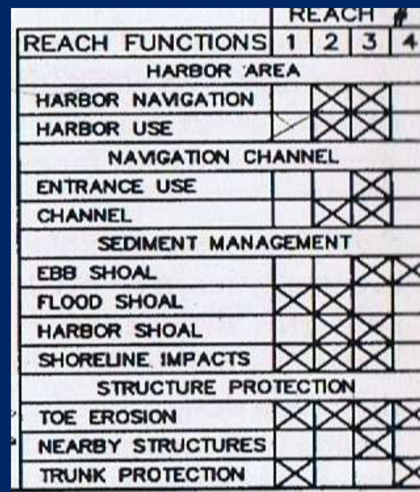
The Repair, Evaluation, Maintenance and Rehabilitation Research (REMR) Program (USACE 1998)





REACH FUNCTIONS	REACH # 1	2	3	4
HARBOR AREA				
HARBOR NAVIGATION		X	X	
HARBOR USE	/	X	X	
NAVIGATION CHANNEL				
ENTRANCE USE			X	
CHANNEL		X	X	
SEDIMENT MANAGEMENT				
EBB SHOAL			X	X
FLOOD SHOAL	X	X		
HARBOR SHOAL		X	X	
SHORELINE IMPACTS	X	X	X	
STRUCTURE PROTECTION				
TOE EROSION	X	X	X	X
NEARBY STRUCTURES			X	
TRUNK PROTECTION	X			X

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Thanks-Over to Eduardo

Overtopping at Port Kembla Breakwater

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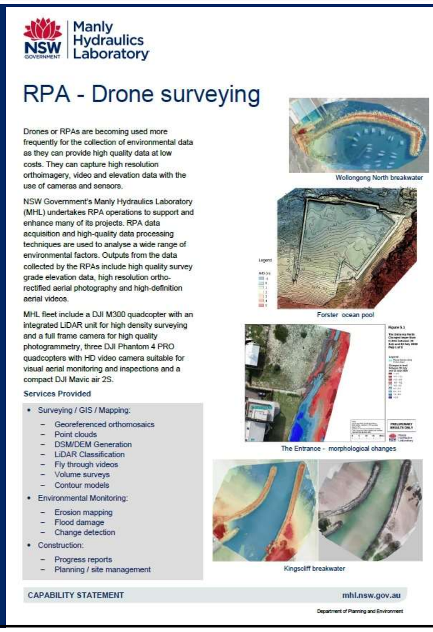
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RPA - Drone surveying

Drones or RPAs are becoming used more frequently for the collection of environmental data as they can provide high quality data at low costs. They can capture high resolution orthoimagery, video and elevation data with the use of cameras and sensors.

NSW Government's Manly Hydraulics Laboratory (MHL) undertakes RPA operations to support and enhance many of its projects. RPA data acquisition and high-quality data processing techniques are used to analyse a wide range of environmental factors. Outputs from the data collected by the RPAs include high quality survey grade elevation data, high resolution ortho-rectified aerial photography and high-definition aerial videos.

MHL fleet include a DJI M300 quadcopter with an integrated LiDAR unit for high density surveying and a full frame camera for high quality photogrammetry, three DJI Phantom 4 PRO quadcopters with HD video camera suitable for visual aerial monitoring and inspections and a compact DJI Mavic air 2S.

Services Provided

- Surveying / GIS / Mapping:
  - Georeferenced orthomosaics
  - Point clouds
  - DSM/DEM Generation
  - LiDAR Classification
  - Fly through videos
  - Volume surveys
  - Contour models
- Environmental Monitoring:
  - Erosion mapping
  - Flood damage
  - Change detection
- Construction:
  - Progress reports
  - Planning / site management

Wollongong North breakwater

Forster ocean pool

The Entrance - morphological changes

Kingscliff breakwater

CAPABILITY STATEMENT mhl.nsw.gov.au

Department of Planning and Environment

Manly Hydraulics Laboratory

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Assessing 65 Breakwaters on the NSW Coastline Utilising Drones

PROJECT DETAILS

- 32 sites, 65 structures
- 14,000 pictures
- +20h flight time
- 160 GB data

Table 2-1 Descriptive rating guidance for structure condition

Ranking	Condition	Comments
1		Structure requires immediate attention. May be subject to high level of failure due to future storm damage.
2		Structure is functional but requires immediate attention to prevent future damage.
3		Structure displays signs of deterioration since last inspection in 2016.
4		Structure was damaged by the June 2016 storm and now it displays signs of minor deterioration.
5		Structure was not damaged by the June 2016 but now shows signs of minor deterioration.
6		In good condition. Structure does not display signs of deterioration or present safety issues.

Table 1-1 Condition of breakwalls - Summary

Breakwater	Crest/Pathway	Head	Trunk
Tweed Head North	6	4	3
Tweed Head South	6	3	3
Kingscliff North	6	5	5
Kingscliff South	6	5	5
Pottsville North	1	1	1
Pottsville South	1	1	1
Brunswick North	5	5	5
Brunswick South	6	5	4
Ballina North	6	5	4
Ballina South	6	5	5
Evans Head North	6	5	5
Evans Head South	6	5	5
Clarence North	4	4	5
Clarence South	5	5	5
Wooli North	5	5	5
Wooli South	3	2	1
Coffs East	6	5	5
Coffs North Eastern	6	6	6

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DRONE OUTPUTS

Obliques	Orthos	DSM	Orthomosaic

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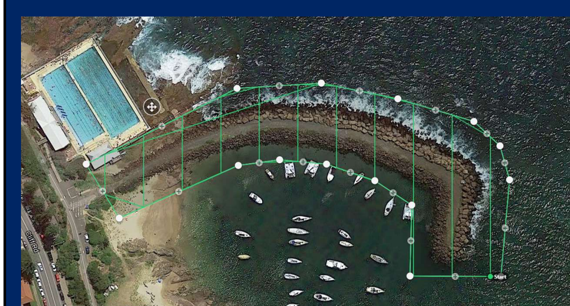
WOLLONGONG Breakwater Inspection



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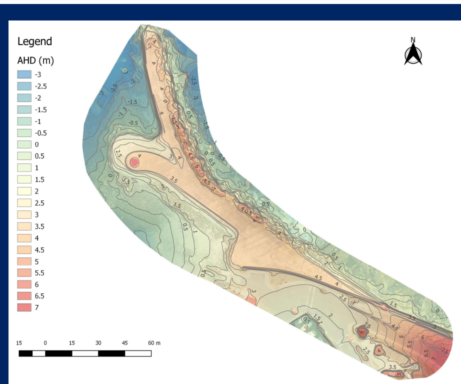
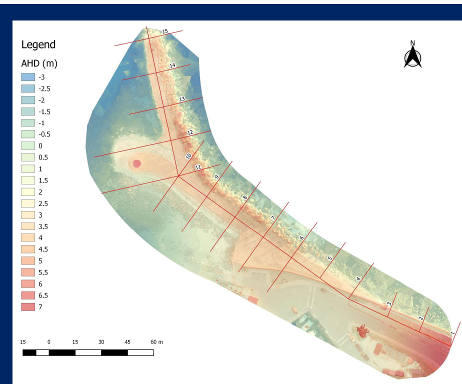
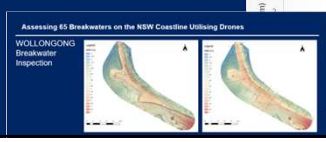
WOLLONGONG
Breakwater
Inspection







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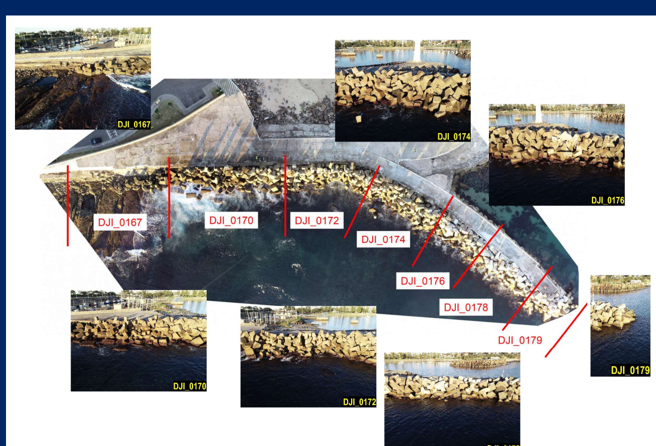
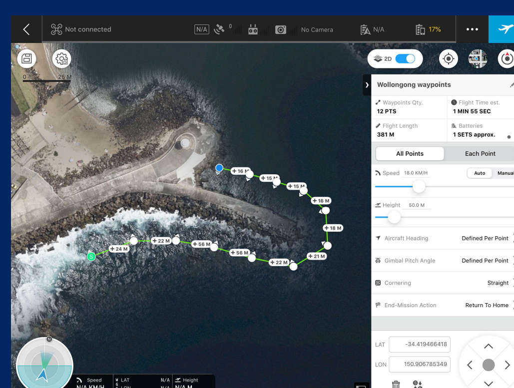
WOLLONGONG





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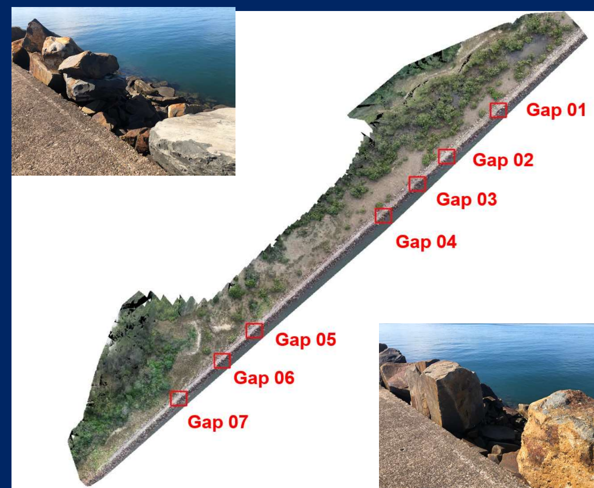
HARRINGTON

DEMs from the drone outputs useful to detect missing armour units on the crest



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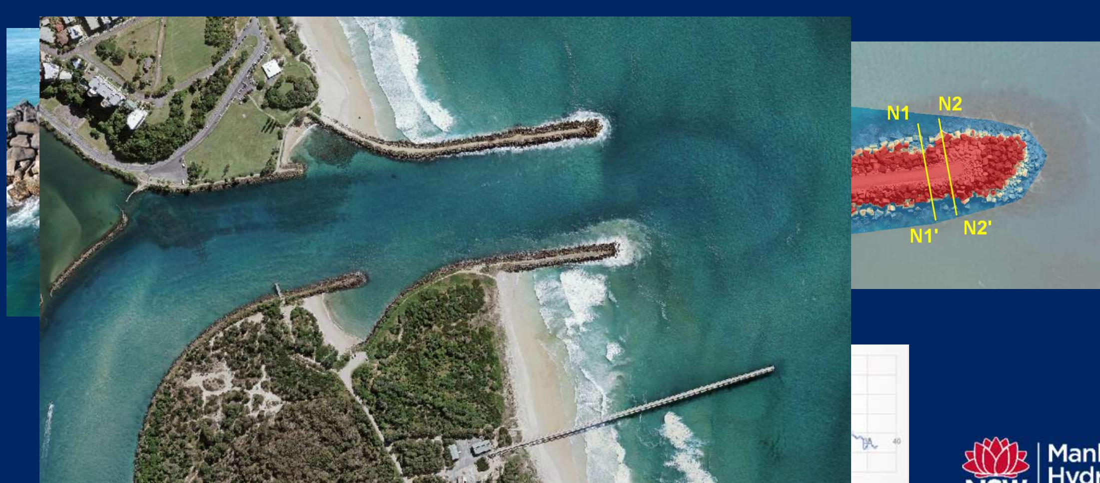
TWEED HEADS



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UNDERWATER DRON

Narooma, Harrington

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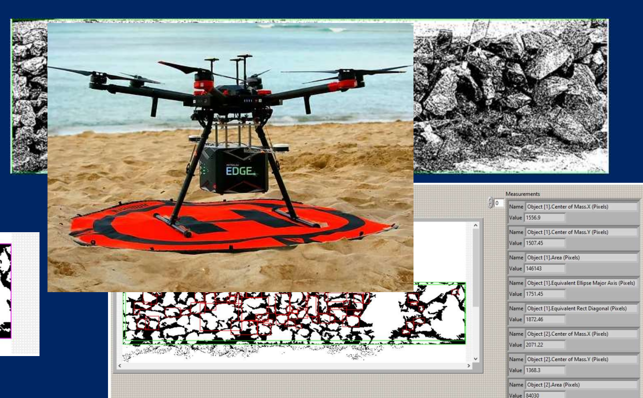
FUTURE DEVELOPMENTS

- Addition of other novel techniques are welcome (USV, bathy LiDAR, machine learning)



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Thanks!

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