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Ref WA.L1
29 October 2025

RE: WAMBERAL BEACH: RISKS ARISING FROM GROUND MOVEMENT AND/OR STRUCTURAL COLLAPSE AS OF 25 OCTOBER 2025

This short report provides a technical assessment of Risks, as they existed in October 2025, along the length of Terrigal/Wamberal Beach from the entrance of Terrigal Lagoon to the Wamberal Surf Club; a beach length of approximately 1.4km.

Risk is defined as per International and Australian Standards, by considering the **Likelihood** and **Consequences** of potential events (herein termed **Scenarios**)

Three Scenarios are dealt with, being:

1. "**Sunny Day",** meaning after several weeks of dry weather and no wave attack on the beach; specifically, as of 11 October and 24 October 2025 when I conducted my inspections,
2. After a sustained period of **Heavy Rain**; specifically equivalent to the 1 day 1 in 10-year rainfall event, or 5 day 1 in 10-year rainfall event (as defined by BOM), but with no wave attack on the beach,
3. After an **Extreme Storm** event, being an event as defined by the NSW Public Works Dept in 1985.

It is obvious, from material on the Internet, that different people have different views as to what protection works, if any, should be undertaken along the 1.4km of beach. I do not address the alternative proposals; I deal only with the situation as existed between 10 and 25 October 2025.

This report, and all time taken in field work and data processing has been performed *pro bono.*

I have sought in the body of this report to use normal lay persons language, although I am aware that formal Risk Assessments, such as these, are not easy to grasp.

Technical and backup information is set out in the Appendices.

Yours faithfully

PHILIP PELLS
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CONTENTS

1 INTRODUCTION

1.1 Definition of Risk

Herein I am presenting what is known as Qualitative Risk Assessments. This is what is commonly done. In this system Risk comprises the answer to three questions[1]:

Q1: *What can go wrong?* (**Scenario** or **Hazard)**
Q2: *How likely is it to go wrong?* (**Probability** also called **Likelihood),** and
Q3: *If it goes wrong, what is the outcome?* (**Consequence**)

For a particular Hazard, Risk is defined from a combination of Likelihood and Consequence, using a plot of the following kind[2].

LIKELIHOOD	CONSEQUENCES				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	Medium
Rare	Low	Low	Low	Low	Medium

This diagram may look simple, but the truth is that most lay persons find it difficult to grasp that, for a particular Scenario, **Risk** is defined by a combination of **Likelihood**[3] (Probability) and **Consequence**[4]**.** It must also be understood that **Likelihood** refers to the likelihood of the Scenario (**Sunny Day, Heavy Rain, Extreme Storm**) but has also to take into account what are called Conditional Probabilities, as explained in Appendix 1.

The Australian Standard diagram given above (called a Risk Matrix) has too many subdivisions of Likelihood and Consequences to be meaningful for this work at Wamberal Beach and is not specific to Consequences in that place.

I note that a valid criticism directed to the Qualitative Risk Assessment approach is that, in decision making, there is a 4th question[5]:

> Q4 "*How do you (the decision maker) feel about the result*"? In other words: "*how much does the decision maker want to avoid the outcomes representing loss*?"

This 4th question is essentially what separates the views of different persons in the decision-making process and is not for me to address.

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[1] Kaplan and Garrick (1981)
[2] Australian – NZ Standard for Risk Management.
[3] In so doing I am aware of the point made by Nobel Laureate Daniel Kahneman that almost all people have difficulty with Probability or Likelihood. As he says:
" People who are asked to assess probability are not stumped, because they do not try to judge probability as statisticians and philosophers use the word. A question about probability or likelihood activates a mental shotgun, evoking answers to easier questions".
[4] International Standard ISO – 31000 "Risk is usually expressed in terms of *risk sources,* potential *events,* their *consequences* and their *likelihood.*"
[5] Wall, K (2011) The Trouble with Risk Matrices.

1.2 The Risk Plot (matrix)

I have adopted the following matrix for assessing Risks The defined consequences need to be read carefully as they are critical to the assessed Risks.

Specifically, I must make it clear that Consequence **C1** includes

- new erosion of sand, and
- falling of physical things under the action of gravity and wind and/or time-related weakening of materials that have been disturbed by previous events[6] .

Consequences **C2** to **C4** are for new disturbances. Also, Category **C4** includes infrastructure such as gas lines, sewer, water supply, roads and the like.

LIKELIHOOD in any one year	**CONSEQUENCES** →increasing severity					
	Things				**People**	
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
	Temporary loss of more than 3m average depth of sand over most of the beach; fall of rocks, man-made objects, trees.	Loss of private or Government land including landscaping, retaining walls, stairways and similar, plus C1	Damage to one or more buildings on private land, by land instability and/or erosion, but not necessitating loss of such buildings. Plus C1 and C2	Collapse or catastrophic damage to one or more buildings.. Plus C1 to C3	Serious injury to any one person (ongoing treatment by medical profession)	Loss of life of one or more persons (*).
Greater than 50% (meaning more than 5 times in 10 years)	Low	Medium	High	Extreme	Extreme	Extreme
10% to 50% (meaning about 1 to 5 times in 10 years)	Low	Medium	Medium	High	Extreme	Extreme
1% to 10% (meaning once to 10 times in100 years)	Very Low	Low	Low	High	High	Extreme
Less than **1%**	Very Low	Very Low	Very Low	Low	Medium	High

*The Australian Government, Office of the Prime Minister and Cabinet (Nov 2024) sets the Value of Statistical Life as $5.7 million. This to be used to *"estimate the value of reductions in the risk of unforseen fatality by chance"*

For each Scenario (**Sunny Day, Heavy Rain, Extreme Storm**) I have assessed Risks without and with persons in the affected place.

[6] As illustrated in Appendix 1

This is because the probability of a person being in the place at exactly the same time as the hazard occurs, is lower than the probability of the hazard itself[7].

2. SCENARIO 1: RISK ASSESSMENT 'SUNNY DAY'

Details of what is meant by 'Sunny Day' are given in Appendix 2.

I do not address events associated with children and adults, tripping over uneven ground, climbing broken staircases, digging into fragile slopes (sand or rubble), cutting themselves on protruding metal, and the like. Such risks are the bailiwick of Health and Safety experts, not a civil engineer like me. Herein, I address Consequences that are external physical occurrences, and which may or may not cause injury or death depending on whether people are in the trajectory of the physical occurrence.

In making my assessments I have considered previous work of this kind, such as by Lord and MacDonald (following 2016 storm event); from which I quote:

> Public access to the base of the scarp should be restricted with barriers and signage. The community generally do not appreciate the dangers posed by an unstable slope at the back of a beach. It offers an attractive opportunity for children to dig in the base of the sand cliff, or to play in holes in the exposed rock works. The materials embedded in the slope or above (such as concrete foundations, retaining walls, or boulders that may weigh upward of 100kg) can be dislodged without warning."

Also, from Douglas (2025)

"During the inspection on 5 May 2025, it was observed that some of the beach frontage had retreated beyond that of the 2020 erosion event. Whilst emergency protection works in 2020 appear to have resulted in reinstatement of the beach and the stabilisation of the toe of the bank (also referred to as the 'frontal dune') for some localised sections, it appeared that many properties had been further eroded, or steep slopes along the frontal dune had slumped. Additionally, some structures including access stairs, retaining walls, and decks had collapsed or slipped further downslope as a result of being undermined."

My assessed risks are given in Tables 1 and 2 (without and with people).

The way these tables work is:

- firstly, assess Likelihood.
- secondly, assess Consequence or Consequences, and then
- Risk is defined automatically.

[7] For example , the probability of a boulder tumbling down a hillside may be 1% (1in 100years), and the probability of a person being in the place of that boulder fall may be 2%. The probability of both occurring at the same time is 0.02%

In Table 1, for the 'Sunny Day' scenario, the **Likelihood (probability)** is more than 5 times in 10 years[8], and the **Consequence** is erosion of sand, and/or falling of things (retaining wall, trees, boulders, footings etc.) disturbed by previous storms (particularly 2020 and 2025). Combining this Likelihood and Consequence C1 automatically gives a Low Risk when no one is in the danger areas.

Table 1: Sunny Day Assessed Risks- No people involved (such as closed beach)

LIKELIHOOD in any one year	**CONSEQUENCES →** increasing severity					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
	Temporary loss of more than 3m average depth of sand over most of the beach; fall of rocks, man-made objects and trees	Loss of private or Government land including landscaping, retaining walls, stairways and similar, plus C1	Damage to one or more buildings on private land, by land instability and/or erosion, but not necessitating loss of such buildings, plus C1 and C2	Collapse or catastrophic damage to one or more buildings, plus C1 to C3	Serious injury to any one person (ongoing treatment by medical profession)	Loss of life of one or more persons (*).
Greater than 50% (meaning more than 5 times in 10 years)	**Low**	**Not Applicable**				
10% to 50% (meaning about 1 to 5 times in 10 years)	**Not applicable**					
1% to 10% (meaning once to 10 times in100 years)						
Less than **1%**						

[8] In reality very much more frequent than 5 times in 10 years (more like 100 times in 1 year) – but this is my highest probability category because it is relevant to the more concerning scenarios, namely Heavy Rain and Extreme Storms

Appendix 1 sets out the probability of Consequences C5 and C6 taking into account the condition of people being in the fall zone at the same time as the fall of an object occurs.

It is possible that the Likelihood of persons being in a danger zone is higher than I have judged; in which case the assessed Risk would be worse than I have interpreted.

Table 2

Sunny Day Assessment – with people in falling object trajectory

LIKELIHOOD in any one year	**CONSEQUENCES** →increasing severity					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
	Temporary loss of more than 3m average depth of sand over most of the beach; fall of rocks, man-made objects, trees.	Loss of private or Government land including landscaping, retaining walls, stairways and similar, plus C1	Damage to one or more buildings on private land, by land instability and/or erosion, but not necessitating loss of such buildings. Plus C1 and C2	Collapse or catastrophic damage to one or more buildings.. Plus C1 to C3	Serious injury to any one person (ongoing treatment by medical profession)	Loss of life of one or more persons (*).
Greater than 50% (meaning more than 5 times in 10 years)						
10% to 50% (meaning about 1 to 5 times in 10 years)						
1% to 10% (meaning once to 10 times in100 years)					**High**	**Extreme**
Less than **1%**						

An illustration of a person being in or very close to a danger zone is given in Photo 2.1, below.

Photo 2.1: Person in a danger zone (see Photo P16 in Appendix 1)-***1/6/2025***

3. SCENERIO 2: DURING OR FOLLOWING HEAVY RAINFALL

Appendix 3 sets out technical material which defines this scenario.

In relation to the issues addressed in this report, rainfall (heavy and/or sustained) has three actions, the first simple for the lay person, the other two somewhat opaque.

1. Surface runoff may cause erosion of surficial sands and rubble, and where concentrated, undermining of structural elements (landscaping, retaining walls, footings and the like)

2. Initial wetting up of cohesionless ground, particularly sand, creates internal soil suction which in turn generates cohesion which allows such cohesionless material to form very steep temporary slopes.

   Temporary, because if the sand dries fully the slope will slump; and temporary because if the level of saturation increases the slope will slump. Children building sandcastles know this – even if they don't know why.

3. Saturation, or near saturation, of ground can, and usually does, generate positive internal water pressures and these pressures lower the level of safety of sloping ground and decrease the bearing capacity for footings, including piles.

For this Scenario the Consequences are extended to include.

C2: Instability in the form of surface sloughing of sand and rubble slopes as they existed on 25 October 2025 (almost all caused by previous wave-attack erosion and undermining).

C2 and C3: Instability in the form of deep-seated landslides of the kind developing at Nos 93 to 97 Ocean View Drive (see Appendix 3); being associated with the Patonga Claystone Formation.

In this regard I concur with the following from Douglas (2025)

"Remobilisation of the earlier failure that affected 91 – 95 Ocean View Drive. Should retriggering of this slide occur, it is likely that this would result in damage to one or more of the residences within these three properties."

The assessments are given below in Tables 3 and 4.

Assessment of the likelihoods taking into account conditional probability is given in Appendix 1.

Table 3

During or following heavy rainfall – no people (such as beach closed)

	CONSEQUENCES →increasing severity					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
LIKELIHOOD in any one year	Temporary loss of more than 3m average depth of sand over most of the beach: fall of rocks, man-made objects, trees.	Loss of private or Government land including landscaping, retaining walls, stairways and similar, plus C1	Damage to one or more buildings on private land, by land instability and/or erosion, but not necessitating loss of such buildings. Plus C1 and C2	Collapse or catastrophic damage to one or more buildings.. Plus C1 to C3	Serious injury to any one person (ongoing treatment by medical profession)	Loss of life of one or more persons (*).
Greater than 50% (meaning more than 5 times in 10 years)						
10% to 50% (meaning about 1 to 5 times in 10 years)	Low	Medium	Medium			
1% to 10% (meaning once to 10 times in100 years)				High		
Less than 1%						

Table 4

During or following Heavy Rain - assuming <u>people in danger zones</u>

LIKELIHOOD in any one year	CONSEQUENCES →increasing severity					
	C1	C2	C3	C4	C5	C6
	Temporary loss of more than 3m average depth of sand over most of the beach; fall of rocks, man-made objects, trees.	Loss of private or Government land including landscaping, retaining walls, stairways and similar, plus C1	Damage to one or more buildings on private land, by land instability and/or erosion, but not necessitating loss of such buildings. Plus C1 and C2	Collapse or catastrophic damage to one or more buildings.. Plus C1 to C3	Serious injury to any one person (ongoing treatment by medical profession)	Loss of life of one or more persons (*).
Greater than 50% (meaning more than 5 times in 10 years)	Not applicable				↓	↓
10% to 50% (meaning about 1 to 5 times in 10 years)					↓	↓
1% to 10% (meaning once to 10 times in100 years)					↓	↓
Less than **1%**	→	→	→	→	**Medium**	**High**

I think this risk assessment (Medium to High) is reasonable based on the observation that in 50 years of substantial rainfall events no person has been injured or killed during or immediately after the event. Hence, a classification of Extreme Risk would not be appropriate.

4. SCENERIO 3: FOLLOWING X SEVERITY STORM

Storms along the Central Coast with reference to Wamberal Beach, are discussed in some detail in Appendix 4. As explained in that Appendix, I have adopted the definition of what is called an **X Severity (Category)** storm given by the NSW Department of Public Works in 1985[9].

The 1985 definition of Category **X** (also called Severity **X**) storms is:

> Category X – extreme events causing significant offshore wave heights in excess of 6.0 metres near the coast. Such storms are characterised by damage to coastal installations, severe erosion and serious disruption to shipping.
>
> Storms generating significant wave heights (up to 10.1 metres) were identified.
>
> As this category is open ended, it covers a wide range of intensities.

As detailed in Appendix 4, '**X'** storms have occurred as plotted in Figure 4.1. This means that the storms have an average recurrence of 1 in 2 years average over about 130 years, but as frequently as 1 per year since about 2010. Therefore, I have adopted an annual probability of greater than 50%.

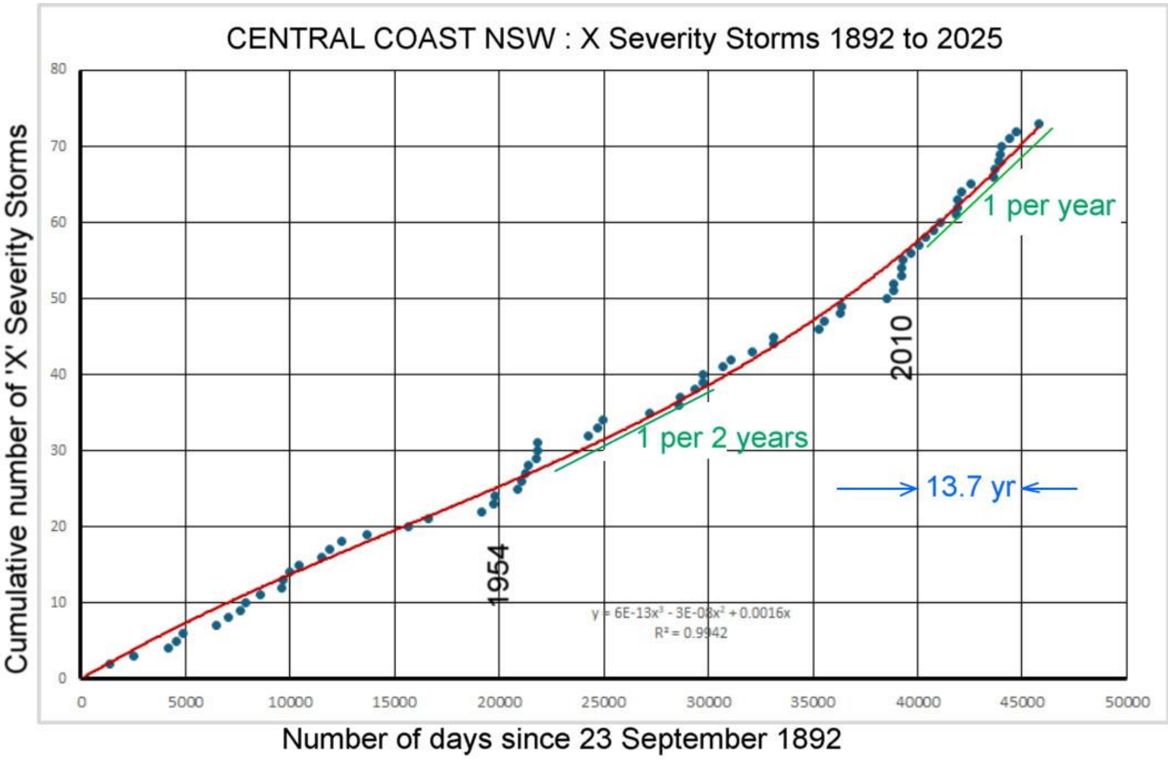

Figure 4.1: Occurrence of Category X storms off Central Coast

9 The 1985 document was prepared by Blain Bremer & Williams in conjunction with Weatherex Meteorological Services

The assessed Risks are as per Table 5 and 6.

Assessment of the likelihoods takes into account conditional probability is given in Appendix 1.

Table 5

X Severity Storm – no people in danger places (such as beach closed).

LIKELIHOOD in any one year	**CONSEQUENCES** →increasing severity					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
	Temporary loss of more than 3m average depth of sand over most of the beach; fall of rocks, man-made objects, trees.	Loss of private or Government land including landscaping, retaining walls, stairways and similar, plus C1	Damage to one or more buildings on private land, by land instability and/or erosion, but not necessitating loss of such buildings. Plus C1 and C2	Collapse or catastrophic damage to one or more buildings.. Plus C1 to C3	Serious injury to any one person (ongoing treatment by medical profession)	Loss of life of one or more persons (*).
Greater than 50% (meaning more than 5 times in 10 years)	Low	Medium	High			
10% to 50% (meaning about 1 to 5 times in 10 years)				High		
1% to 10% (meaning once to 10 times in100 years)	Not applicable					
Less than **1%**						

Table 6

X Severity Storm – <u>people in hazard places</u> during or shortly after the storm

LIKELIHOOD in any one year	CONSEQUENCES →increasing severity					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
	Temporary loss of more than 3m average depth of sand over most of the beach; fall of rocks, man-made objects, trees.	Loss of private or Government land including landscaping, retaining walls, stairways and similar, plus C1	Damage to one or more buildings on private land, by land instability and/or erosion, but not necessitating loss of such buildings. Plus C1 and C2	Collapse or catastrophic damage to one or more buildings.. Plus C1 to C3	Serious injury to any one person (ongoing treatment by medical profession)	Loss of life of one or more persons (*).
Greater than 50% (meaning more than 5 times in 10 years)	Not applicable					
10% to 50% (meaning about 1 to 5 times in 10 years)						
1% to 10% (meaning once to 10 times in100 years)						
Less than **1%**					**Medium**	**High**

5 SUMMARY

As stated at the outset of this report, the matter of implementing properly designed, shoreline protection works along Wamberal Beach is not relevant to the scope of this study. I have only assessed Risks as exist at the time of writing, being 29 October 2025. In summary:

1. For the scenario defined herein as "Sunny Day' conditions, the situation is assessed as Low Risk if no persons are within the danger areas of the beach, and High to Extreme Risk for the present conditions where people are free to be anywhere on the beach for a long as they like.

2. For the scenario defined herein as Heavy Rain, the situation is High Risk during and shortly after such rain (1 in 10-year event) for conditions without or with people on the beach.

3. For the scenario of Extreme storm, as defined by the NSW Public Works Department, the situation is assessed as High Risk during or shortly after such a storm for conditions without or with people on the beach.

It is not for me to express a view as to the acceptability or otherwise of the assessed risks. It is the responsibility of the relevant Authorities to make decisions as to whether action is to be taken to mitigate risk.

Philip Pells
MacMasters Beach NSW

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APPENDIX 1

CONDITIONAL PROBABILITIES (LIKELIHOODS)

A1.1 MEANING OF CONDITIONAL PROBABILITY

Conditional probability is the likelihood of an event happening given that another event has already occurred.

For example, at Wamberal, let us say that an **X** storm has occurred (Probability of 50%, or =0.5). Now we know that not every X storm causes a major erosion event. In other words, there is a second condition that must be considered.

In considering this, cognisance must be taken of the fact that because of damage sustained in 2020 and 2025 many properties are presently more vulnerable than in times past. It is true that ad hoc and emergency protective measures have been put in place, but as discussed in Appendix 3, no scientific reliance can be placed on these non-designed and poorly documented works.

Evidence over the past 50 years suggests that that about 25% of storms cause major erosion, but that likelihood is now higher because of present vulnerability. It is therefore assumed that I in 2 (50%) of **X** severity storms will cause major erosion.

The annual probability that major erosion will occur given that an **X** storm has occurred is: 0.5*0.5 = 0.25 or 25%.

A1.2 SUNNY DAY SCENARIO

<u>With no people</u> to be considered there is no conditional probability – just Sunny Day.

<u>With people</u> involved we must consider the probability of a person being at a particular location on the beach and within the zone potentially affected by falling debris. This is difficult, and the easiest way is as follows:

- Assume that the relevant beach area is divided into patches about the size of two beach towels
- Assume that we have cameras recording each patch night and day, taking photos every hour
- Take a period of 1 year (8740 hours, so 8740 photos). Half of these are at night (when objects can fall as easily as in the day), so we can discard half the photos, leaving 4380 photos. In winter and when it is raining nobody is on any patch, so we can discard roughly another half, leaving, say, 2000 photos.
- Now for the difficult part that is a matter of judgement; how many of those photos of <u>one towel-sized patch</u> record people being there for an hour or more. My judgement is about 100, giving an annual conditional probability of 100/8740 = 0.011 or 1.1%

Because the Sunny Day Scenario is a near certainty it is taken that the combined probability is 1.1%

A1.3 HEAVY RAIN

Heavy rain is a 1 in 10-year event , i.e. 0.1 or 10% (see Appendix 3)

No people

Consequence **C4** is *Collapse or catastrophic damage to one or more buildings and infrastructure, plus C1 to C3.*

History indicates that there have not been **C4** consequences during or following heavy rain. But historically, the situation was mostly not as it is now. Now we have incipient landslips at various locations along the beach, and deep-seated landslips where the Patonga Claystone is overlain by only a few metres of sand (see Appendix 3 for evidence)

It is assumed that, as of October 2025, 1 in 4 Heavy rain events will cause catastrophic collapse. So, the probability for C4 is 0.1*0.25 = 0.025 or 2.5%.

There are no conditional probabilities for C1, C2 and C3

With people

The logic is as set out in A1.2, above, except that now we are considering people being on a patch either in heavy rain, or within a couple of days of heavy rain (i.e. a period of about 10 days. That reduces our number of photographs to 120 (10 days and 12 hrs per day). My judgement is about 10 photos with people in any one patch, giving an annual conditional probability of 10/8740 = 0.001 or 0.1%. Therefore, overall probability of 0.1*0.001 =0.0001 or 0.01%

A1.4 X SEVERITY STORM EVENT

No people

As per Heavy rain events, history is a poor statistical guide because now many properties are vulnerable from damage sustained in 2020 and earlier 2025.

It is true that ad hoc and emergency protective measures have been put in place, but as discussed in Appendix 3, no scientific reliance can be placed on these non-designed and poorly documented works.

Possibly, not every major erosion event (probability 25% as per A1.1, above) will cause consequence C4 but given the precarious state of many of the properties it is appropriate to assume that any and every major erosional event will cause catastrophic damage. Therefore, the likelihood is 25% (see A1.1, above)

It is considered there are no condition probabilities for C1 to C3; they will happen in every major storm event (50% annual chance) given the precarious conditions of many properties as of October 2025

With people

The logic is as set out in A1.2, above, except that now we are considering people being on a patch either in an X severity storm, or within a couple of days of such storm (i.e. a period of about 10 days. That reduces our number of photographs to 120 (10 days and 12 hrs per day).

However, there is another group of people to consider, namely those coming to view the unfolding catastrophe, and also homeowners.

This combination of people makes it very difficult to assess the conditional probability. My judgement is about the same as the Heavy rain scenario, namely overall probability of 0.025%.

APPENDIX 2

‘SUNNY DAY’ DRY PERIOD CONDITIONS

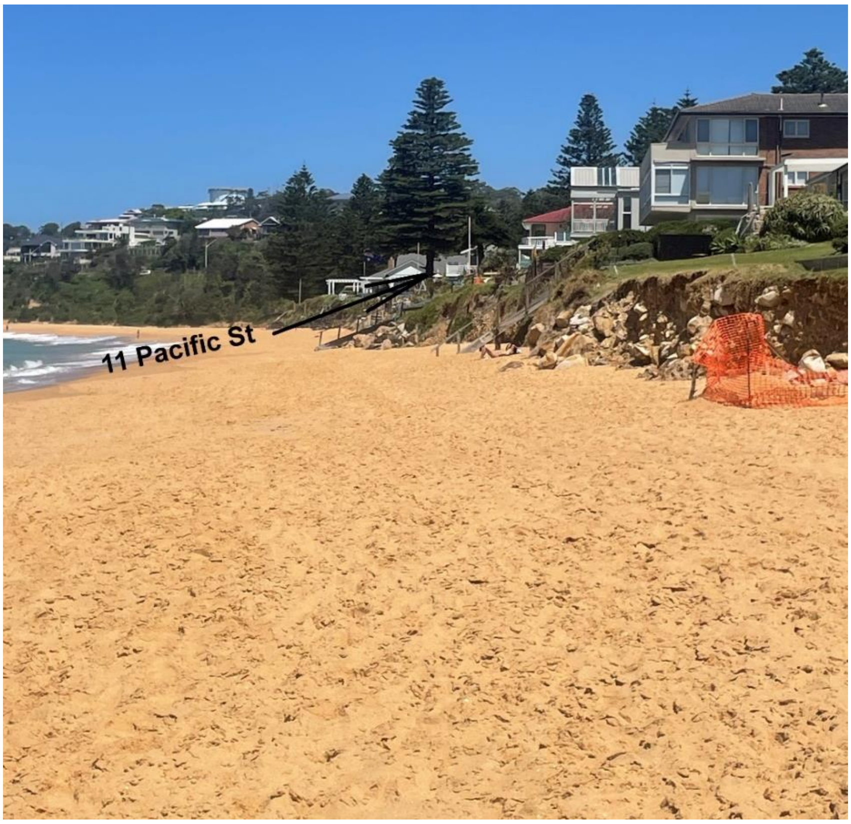
I inspected Wamberal beach from Terrigal Lagoon to the Wamberal Surf Club on 10 October and, in-part, on 25 October 2025.

For 10 days prior to the 10th 6.2mm rain was recorded at Gosford, and from 10th to 23rd 2.8mm. In the afternoon of 25th the wind speed was about 25km/hr. At the time of my inspection on 10th the temperature was about 30°C and on the 24th it was about 22°C. On both occasions there were people on the beach.

The above is taken as typical of conditions termed 'Sunny Day'. This allows for wind speeds up to Beaufort Force 4[10], and some preceding light rain.

The beach condition on 10th October comprised an upper sand bench at about RL4m[11], about 30m wide in the southern approximately 700m length, and about 50m wide in the northern 500m length (see Photographs P1 and P2, below).

The upper sand bench was approximately at the level of the tops of rocks and rock bags placed post 2020 and 2022 storms (see P3, P4 and P5). This enabled me to estimate that between 200,000 and 250,000 cubic metres of sand had returned to the beach since the 2020, 2022 and July 2025 events. I cannot determine in what stages this occurred because even in July 2025 (31/2 months before my viewing) significant erosion occurred. (see P6 and P7) and Douglas (2025)

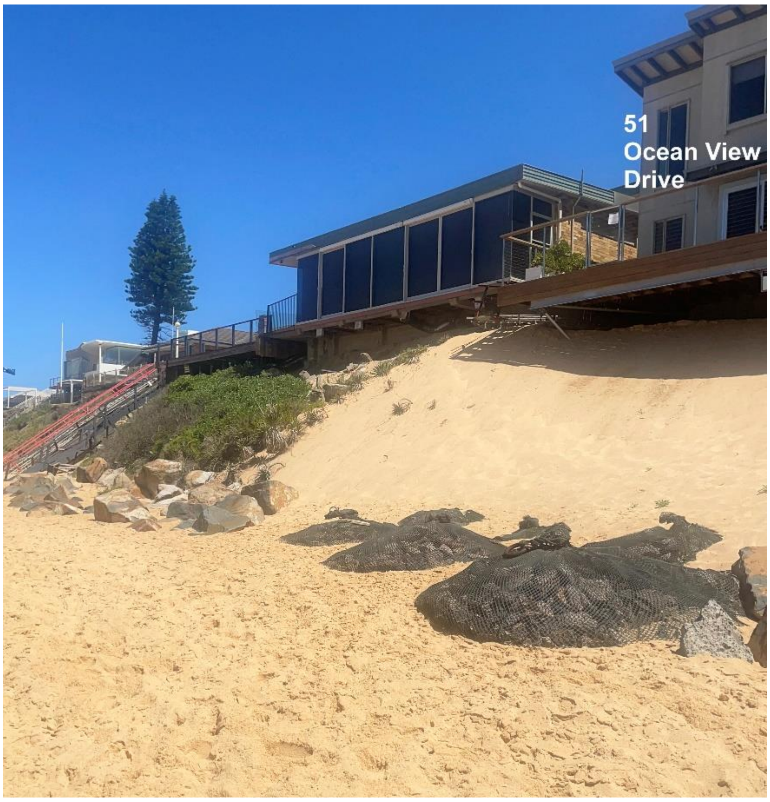


P1: Southern portion of Beach 10 Oct 2025

[10] Force 4 is 20 to 30km/hr

[11] Based on optical levelling I did on 24 October (using my 1950 vintage Kern DK1 theodolite; first time used in 30 years) working from State Survey Mark 49646 in Ocean View Drive.

P2: Northern portion of beach 10 Oct 2025



P3: Tops of rock bags near 51 Ocean View Drive; 10 Oct 2025 (see also **P3B**)

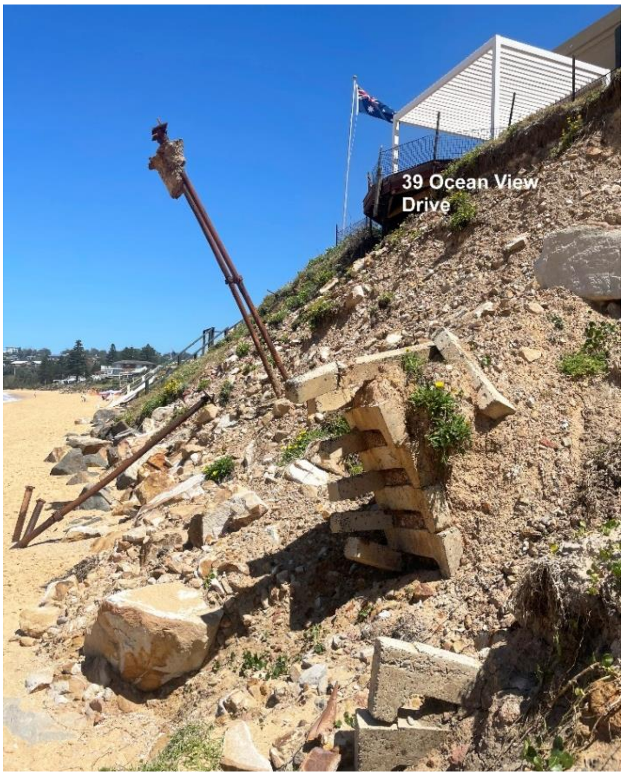
P3B: Photo at 51 Ocean View Drive taken by unknown person dated 2 May 2025

P4: Photo dated July 2020 – Nos 45 to 51 Ocean View

P5: Photo dated July 2020 – Nos 53 to 61 Ocean View

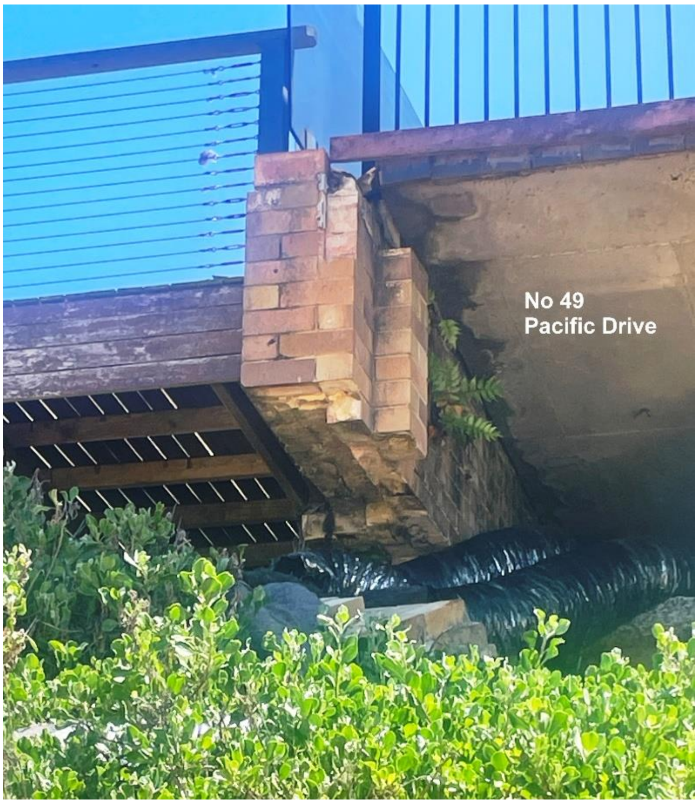
P6 and P7: July 2025 – extracted from video (ABC) : (No 15 Pacific St)
https://www.abc.net.au/news/2025-07-01/central-coast-residents-asked-leave-homes-erosion-fears/105480510

I have not inspected every property on the ocean side of Pacific Street, Ocean View Drive and Calais Rd, because of limitations of time, and access to private property. I have concentrated on those places of significant Risk. Relevant photographs are given as P8 to P16, below.

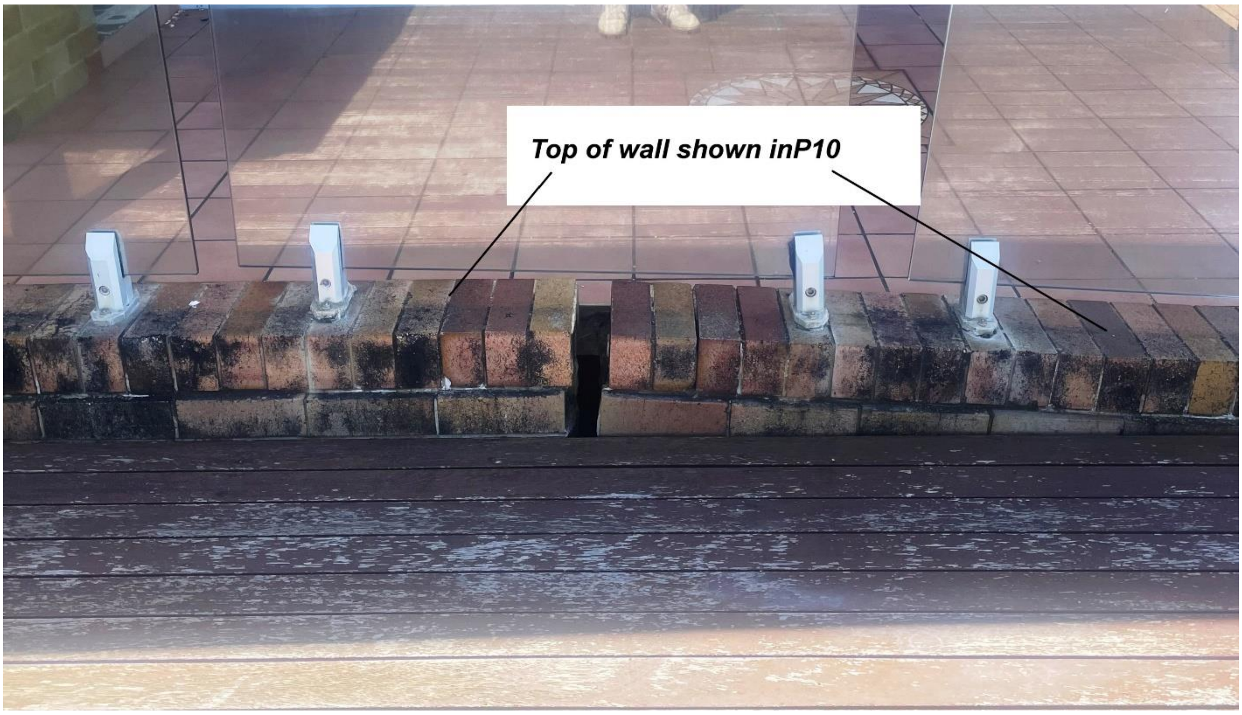


P8: Debris slopes in vicinity of No 39 Ocean View Drive

P9: Sand slope between 45 and 47 Ocean View Drive

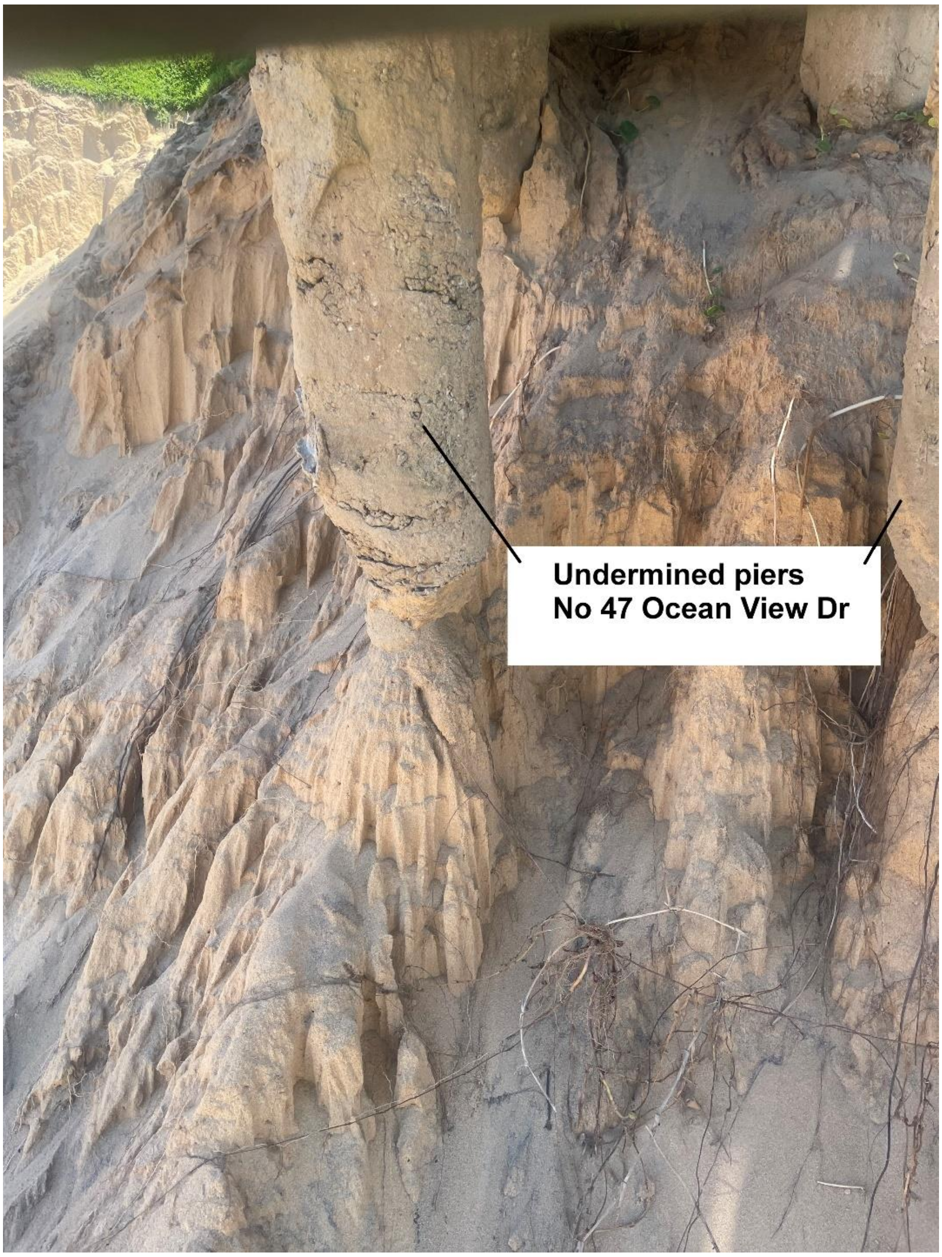


P10: Undermined structural wall at No 49 Ocean View Drive



P11: Top of wall shown in P12

P12: Undermined pier at No 47 Ocean View Drive



P13: Other undermined piers at No 47

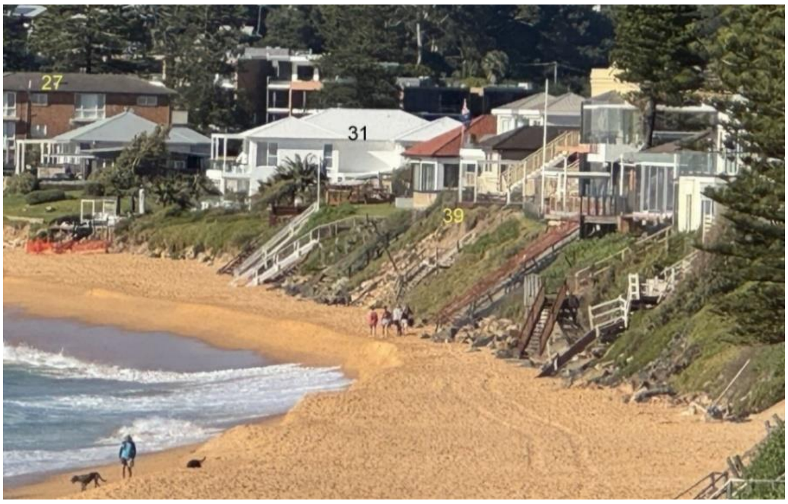
P14: Partly undermined Norfolk Pine at No 75 Ocean View Drive (see also P17).

P15 No 95 Ocean View Drive

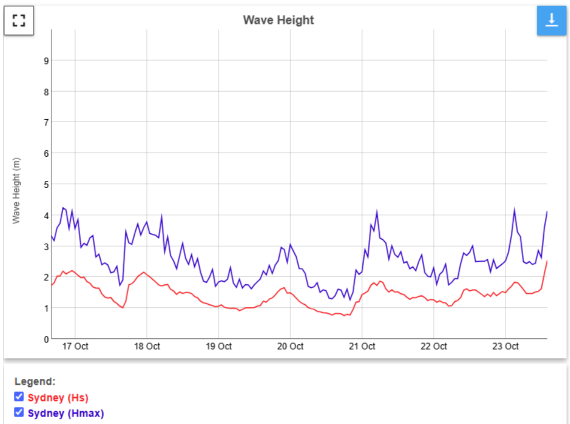
P16: Near No 97 Ocean View Drive

P17: Erosion at No 75; 17 July 2020

A matter of relevance that illustrates the vagaries of beach erosion is the fact that within a few days of my inspection of 10th October an approximately 1m erosion scarp had developed where I had seen a uniform sloping beach and a 30m to 40m wide, near flat upper part (see Figure P20). By the 23rd of Oct there was a portion of beach where the upper-level part was only about 6m wide; by 24 Oct it was 1.5m wide at this location. This occurred during a benign ocean period where the Sydney Waverider measured as shown below.



P20: Photograph from North showing 1m to 2m high scarp opposite 37 and 39 Ocean View Drive; morning 23 Oct 2025



Sydney Waverider data 17 to 23 Oct 2025

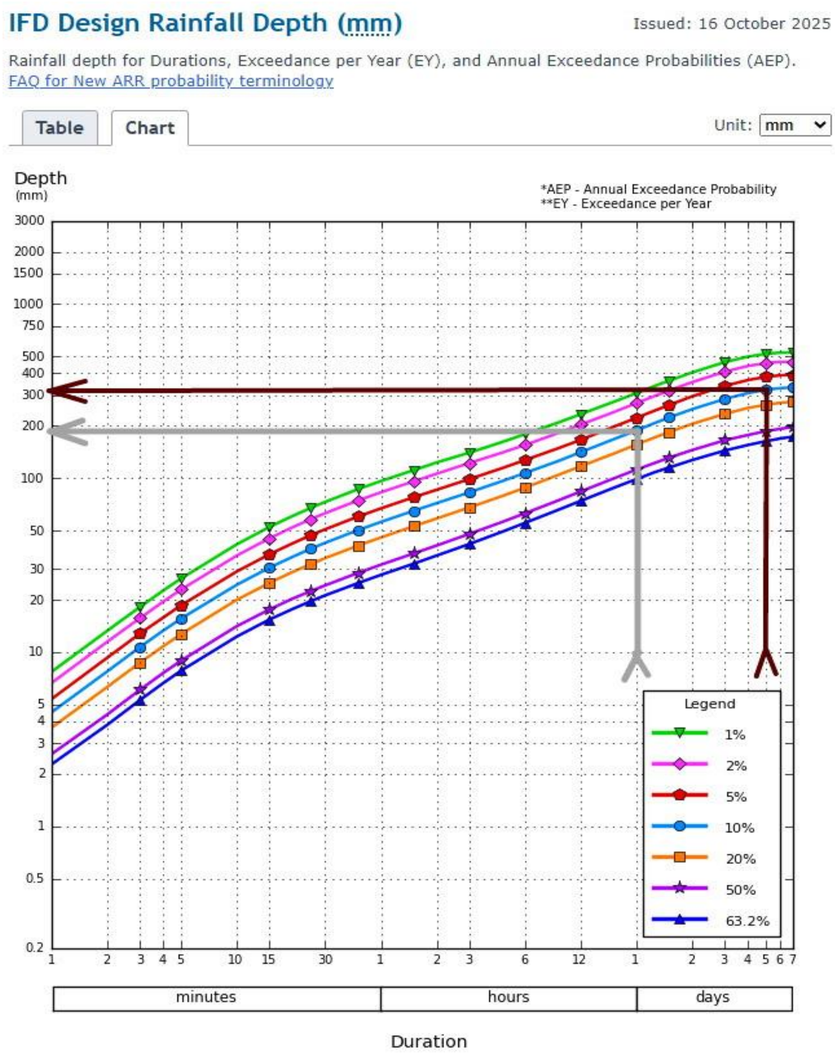
APPENDIX 3

SECENRIO 2: SUSTAINED HEAVY RAIN

3.1 Rainfall

Based on my training, technical publications[12], and some 50 years of experience, I assess that possible instability of slopes along Wamberal Beach could follow high 1 day rainfall or sustained 5-day rainfall. I have chosen a 1in 10-year frequency event.

The Bureau of Metrology rainfall intensity-duration-recurrence interval plot for Wamberal is given below. From this I adopt the 1 in 10 yr one day rainfall as 200mm, and the 5-day rainfall as 300mm.



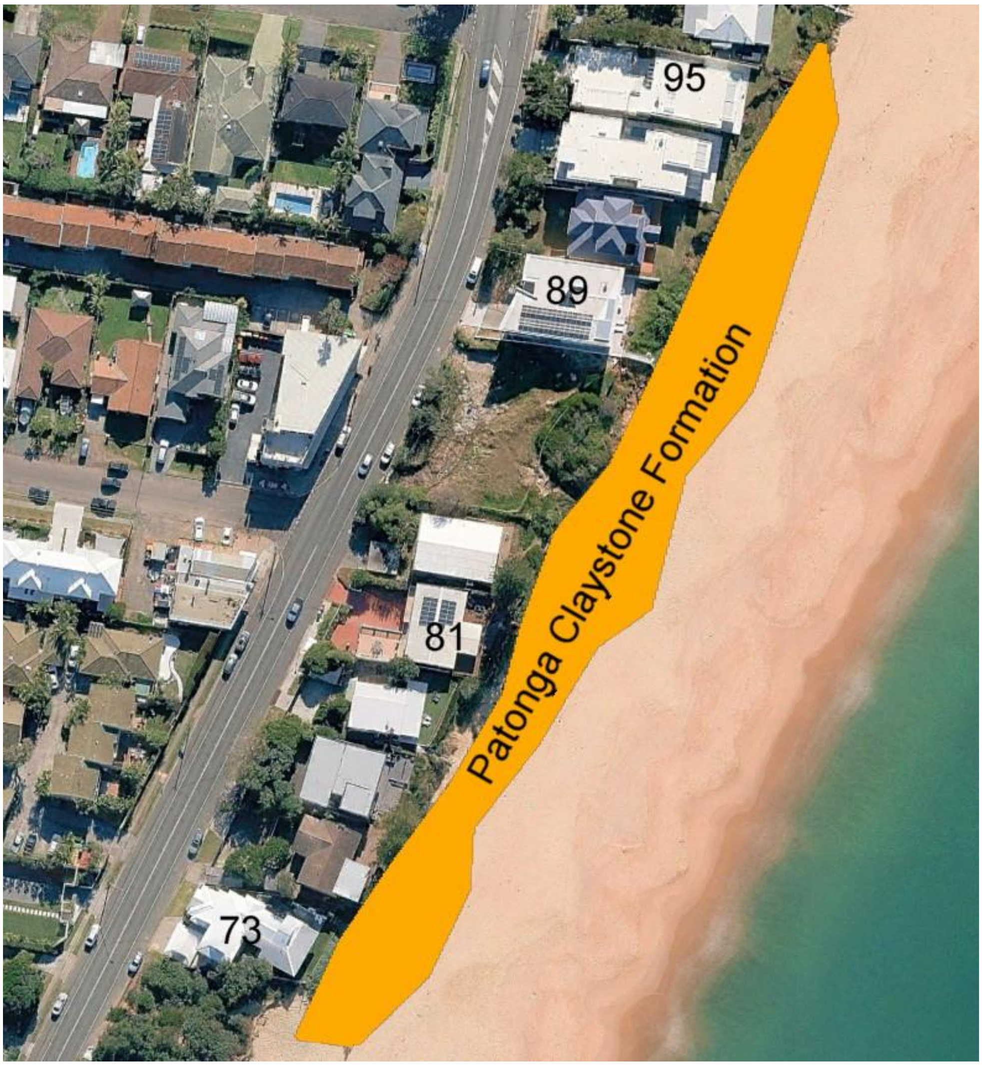
[12] Mac Gregor, Walker, Fell and Leventhal (2007) *Assessment of Landslide Likelihood in the Pittwater Local Government Area.*
This paper included the following findings:
• A 50 mm 1-day rainfall has about a 40% chance of resulting in one or more landslides.
• A 70 mm 1- day rainfall has about a 50% chance of resulting in one or more landslides.
• If 125 mm or more rainfall is experienced in one day it is almost certain that there will be one or more landslides in the Pittwater area.

3.2 Geology

A relevant matter to potential land instability is the fact that for an approximate 400n length of the beach a metre or two of sand normally covers bedrock at between RL -2m and RL1m. This bedrock is exposed in and after periods of erosion (see Photo P3.1). The importance of this is that this exposed bedrock is the Patonga Claystone Formation. This is a notorious[13] Formation implicated in land instability in the Central Coast region because of low shear strength when saturated[14],[15]. It underlies properties such as Nos 73 to 95 Ocean View Drive (see Photo 3.2) and is, in my opinion, most probably a controlling factor in the deep-seated instability at Nos 93 to 97 Ocean View Drive (see Photo 3.3).

P3.1: Patonga Claystone Formation exposed following erosion

[13] For geotechnical engineers !
[14] Sorawit (2006) Engineering Geology of the Patonga Claystone, Central Coast, NSW, with particular reference to slaking behaviour, Phd Thesis Uni NSW
[15] Fell, MacGregor, Williams and Searle (1978) A landslide in Patonga claystone on the Sydney-Newcastle freeway. *Geotechnique* Vol 37, No 3.



P3.2: Mapped location of Patonga Formation normally beneath beach sand

P3.3: Deep seated landslip; 93 to 97 Ocean View Drive

3.3 Existing Protection Works

For obvious reasons detailed engineering documentation of the *ad hoc* protection works that have been placed/built since the 1974 storm do not exist. Even the emergency works with rock boulders and rock bags in 2020, 2022 and 2025 were not done to engineering specifications and then surveyed and measured as-constructed. Figure P3.4 is a drawing prepared by the Manly Hydraulics Laboratory

P3.4: MHL drawing of existing works post 2020 but pre-2022

I have found the MHL drawing reproduced in P3.4 difficult to interpret, mainly because the same colour appears to be used for different works. In an attempt to figure out what was where, I enlarged the drawing in pieces and superimposed on the Google Earth aerial photograph, as presented in P3.5 to P3.9.

Also shown on these photographs are places where I could see the tops of rock bags, or rock boulder revetment, on 10 and 24 October 2025.

P235 23A to 25 Ocean View Drive


39
Large Rocks front 39
37
35
Large Rocks front 35 & 37
33
31
29
27
25
25A
25B
OCEAN VIEW DR
Image © 2025 Vexcel Imaging US, Inc.
Materials mapped from MHL drone surveys after July 2020 storm
Imagery: NSW Spatial Servi

P3.6 25B to 39

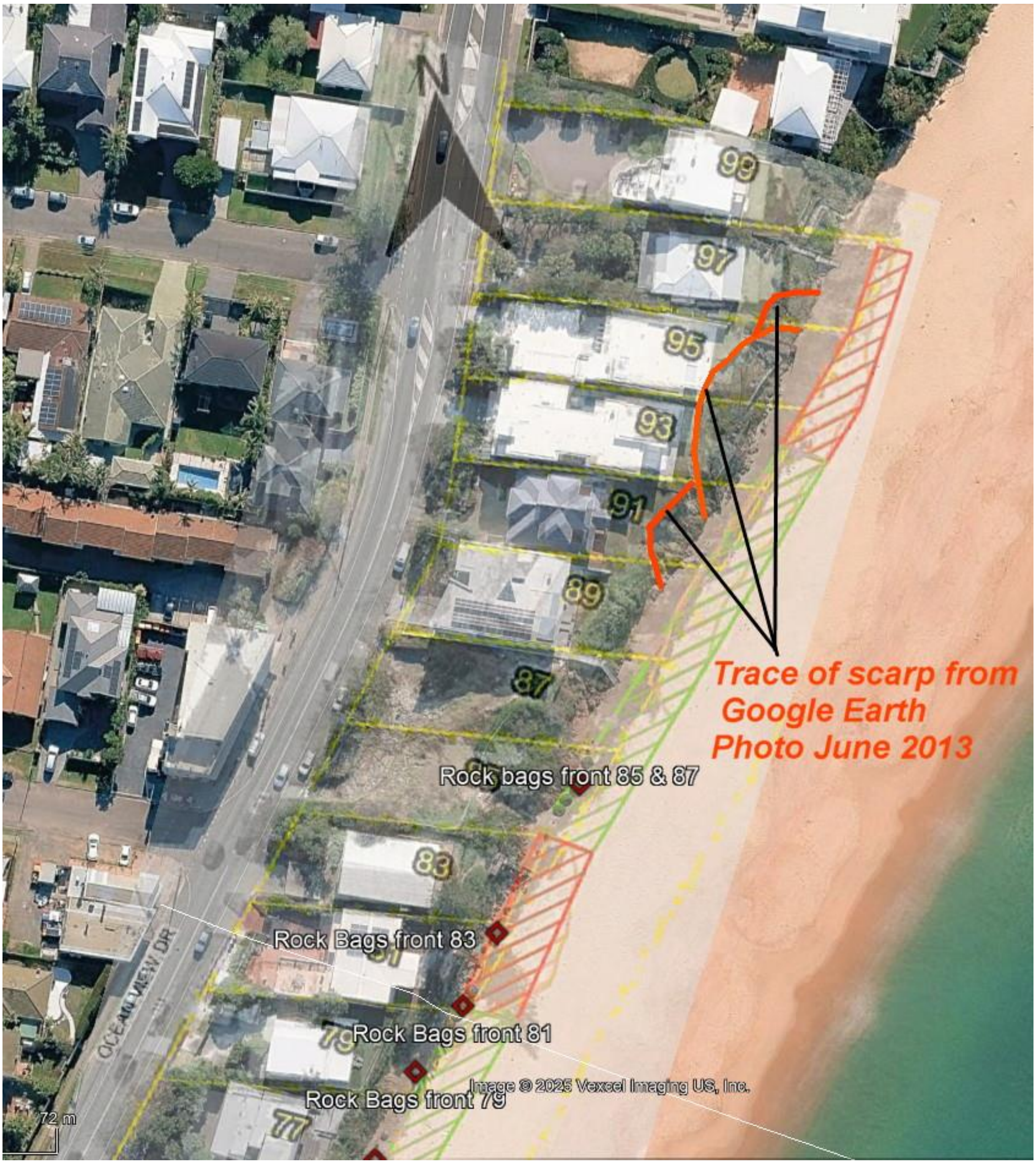
3.

59-61
Large rocks front 61
57
55
Large Rocks front 55
60
53
Concrete wall front 53
51
Large Rocks front 5
49
Large Rocks front 49
20
47
45
0
Large Rocks front 45
43
Large Rocks front 43
41
39

P3.7:39 to61

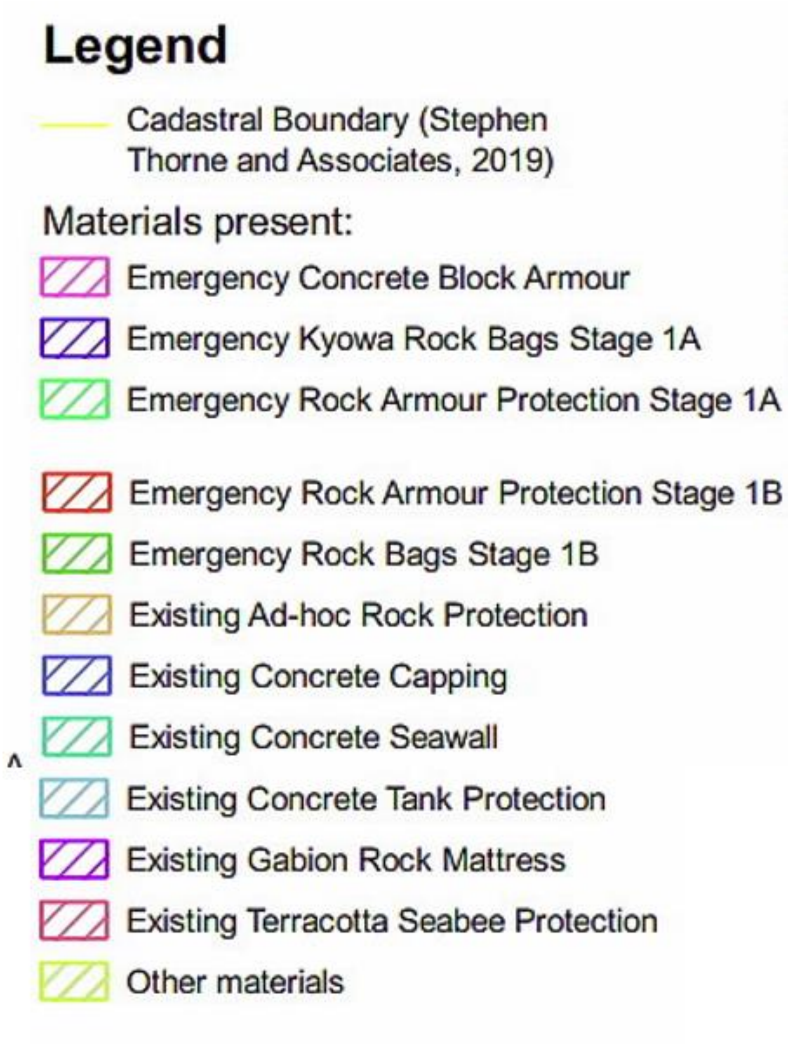

Rock Bags front 79
77
Rock Bags front 77
75
Rock Bags front 75
73
71
67
65
63
Image © 2025 Vexcel Imaging US, Inc.
Large rocks front 61

P3.8:59 to 77



P3.9: 77 to 99 Ocean View Drive

For clarity I reproduce below an enlargement of the NHL Legend for Figures 3.4 to 3.9.



I acknowledge there are subtle differences in the colours in the above legend, but I cannot relate many of the items to hatching on the drawings. Even if I could it is obvious that there are works on top of works, e.g. it can be seen that in P3.7 there are at least 3 overlapping layers, and I cannot determine what is on top of what.

In an attempt to resolve my dilemma, I set about examining videos and photographs available on the Internet. For example, P3.10 to P3.11 are stills taken from a Newcastle Herald drone-video[16], which give good views of existing ‘defensive" works south of about No 31 Ocean View Drive. However, I cannot fix an accurate date for this video.

I know, also, that the MHL drawing given in P3.4, above, is based on NHL drone surveys, but these are not available on the Internet.

[16] https://www.dailymotion.com/video/x9oqafu

P3.10: Still from drone survey – correct date uncertain (possibly 2025)

P3.11: As for P2.10

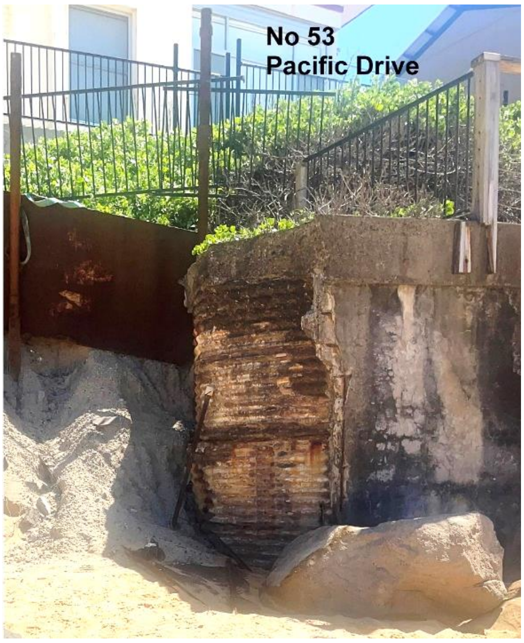
P3.12: As for P2.10

2.4 My Conclusion

In my opinion, in the absence of detailed cross-sections, and the fact that post-2020 works are not shown, the existing works cannot be determined to engineering analysis standards. To solve this dilemma for Risk Assessment purposes, I have taken the following approach.

<u>Firstly</u>

Almost all the existing works (an exception being the concrete wall at No53 Ocean View Dr shown in P3.13) are located below about RL4m[17], but with foundations at different levels, most on sand but some on Patonga Claystone Formation



P2.13: Southern end of concrete wall at No 53

[17] My survey of level of top of rock bag on the seaward side of No 65 Ocean View Drive.

Secondly

The following has been said by other specialists regarding the existing works.

> "Advice to Council, at this time, is that only a terminal protective structure correctly designed in accordance with Council's Engineering Design Requirements (consistent also with Council's Draft Coastal Management Program) can provide an acceptable level of further risk reduction to dwellings while improving and sustaining public beach amenity and public safety."

MHL letter 26 August 2025

> "More recently, in 2020, significant beach front protection works which included the placement of more than 4,000 tonnes of rock, rock-filled bags, and large concrete blocks placed in front of both private properties and Council land were carried out. Some of these materials were placed by landowners, whereas it is understood that the remainder was placed by Central Coast Council.
>
> Notwithstanding these works, the erosion control measures have not completely prevented erosion. Heavy seas with large swell in April 2025 eroded additional material with sections of the beach front being cordoned off by NSW State Emergency Services (SES) due to safety concerns."

Douglas Partners; Inspection Summary Report 6 May 2025

> "… it is important to note that all properties between the Wamberal Surf Life Saving Club and 1 Pacific Street have significant risk of major damage and hazards to life during moderate to major and extreme coastal events.
>
> THE PROPOSED TEMPORARY EMERGENCY ACTIONS AND WORKS DO NOT PROVIDE LONG-TERM COASTAL PROTECTION AND ARE INTENDED TO ONLY MITIGATE EROSION AND LANDSLIDE HAZARDS FOR UP TO MINOR / MODERATE EVENTS."

MHL3123 Wamberal V01a_LR 30 June 2025

There are other documents that follow the same theme as the quotes given above, but the extracts above are sufficient.

They allow me to conclude that, whatever existing works are at places along Wamberal Beach from Terrigal Lagoon to the Wamberal Surf club, these are <u>insufficient to provide protection of land or man-made structures against Heavy Rain events and **X** Severity storms as defined in Appendix 4</u>

APPENDIX 4

SCENARIO 3: EXTREME STORMS

My objective was to adopt a type of storm with of magnitude likely to cause significant beach erosion reasonably frequently. I also needed to use a definition of such storms that is easily understood by lay persons.

Initially I was drawn to words in recent Manly Hydraulics Laboratory documents which referred to Minor, Moderate, Major and Extreme erosion events, viz:

Doc No 1:

…..there is no immediate risk of significant structural collapse notwithstanding the recognised likelihood of significant structural collapse during a major or extreme coastal storm event…

Manly Hydraulics Laboratory letter of 26 August 2025 (File No 0005058.08): my underline

Doc No 2

THE PROPOSED TEMPORARY EMERGENCY ACTIONS AND WORKS DO NOT PROVIDE LONG-TERM COASTAL PROTECTION AND ARE INTENDED TO ONLY MITIGATE EROSION AND LANDSLIDE HAZARDS FOR UP TO MINOR / MODERATE EVENTS.

MHL3123 Wamberal V01a_LR.pdf; my underline

Because I could find no definition of Minor, Moderate, Major and Extreme erosion events I made a formal request through the MHL public internet portal. The first reply I received was (with my underline):

Regarding your earlier query, I followed up your query with our Coastal specialist, his response was that there are no defined minor, moderate, major erosion events at a State or National level similar to those you'd see with flood events. However, local councils can sometime have their own definitions specific to their area.

In this same reply MHL requested:

Are there specific MHL reports where MHL where these terms appear that you are inquiring about? I can follow up with the authors.

I replied with the two document extracts given above, and received the following response:

I have followed up with the author. A definition of erosion events were used for analysis by MHL in the report.

"Storm magnitudes are as defined in our annual wave reports (not sure if they still have that definition) and also as per Shand et al. This does not necessarily translate into an equivalent scale beach erosion event though as it is location and storm DIRECTION dependent as well as dependent on coincident ocean water level conditions.

For the purposes of MHL's analysis, minor erosion events are of 1-2 year ARI and moderate are 5-10 year ARI erosion events."

Attached Shand et al 2010 for reference".

I read the Shand et al paper and it shed no further light on the definitions I was seeking, so I gave up this line of thought.

Fortunately, I then came across a wonderful report by the NSW Department of Public Works dated December 1985, titled **Elevated Ocean Levels: Storms Affecting NSW Coast 1880 to 1980** (318 pages of typewriter and hand drawn figures). This document provides the following definitions of storms; meaningful definitions I think most lay persons will grasp.

The category indicates the potential of a storm to generate abnormal water levels along the N.S.W. coastline. The categories are:

Category X - extreme events causing significant offshore wave heights in excess of 6.0 metres near the coast. Such storms are characterised by damage to coastal installations, severe erosion and serious disruption to shipping.

Storms generating significant wave heights (up to 10.1 metres) were identified.

As this category is open ended, it covers a wide range of intensities.

Category A - severe storms causing significant offshore wave heights ranging from 5 to 6 metres. These storms are also characterised by erosion or other damage to coastal installations and disruption to shipping. In the absence of adequate charts, other sources such as newspaper reports or weather reviews were used to confirm this classification.

Category B - storms in this category characteristically generate significant wave heights of 3.5 to 5.0 metres.

Distant severe storms or moderate storms close to the monitoring site make up the bulk of this category. Category A severity storms which move so rapidly that there is insufficient time to develop significant wave heights also fall into this category.

Category C - storms generating significant wave heights in the range of 2.5 to 3.5 metres are in this category. They include the lower intensity storms in close proximity to the coast and more severe storms at relatively greater distances offshore.[1]

The report then provides detailed classification of 846 storms from 1880 to 1980, at each of South Coast, Central Coast, mid-North Coast and North Coast.

From the typewritten pages I have extracted, into an Excel spreadsheet, the data for **X** and **A** Severity storms for the Central Coast. The data are as given below, sorted into Severity **X** and **A.** The Category in the following refers to the type of weather system, defined below the table.

DATE	SEVERITY	CATEGORY	SIGNIFICANT WAVE HEIGHT (m)	DESCRIPTION
14 Jan 1881	A	T		Moved from North
23 Aug 1881	A	S		Very heavy seas
24 Oct 1882	A	S		Winds up to 60kt
4 Feb 1883	A	T		Winds to 49 kt
29 April 1884	A	S		Winds to 49 kt
17 April 1885	A	I		Heavy seas
14 June 1887	A	S		Very heavy seas
2 March 1888	A	S		Winds from south to 49kt
29 May 1889	A	E		
25 June 1889	A	S		Southerly gales and heavy seas
19 Nov 1890	A	I		Strong southerly winds and heavy seas on Central Coast
1 June 1891	A	S		Rough seas and strong southerly winds
13 June 1891	A	E		
8 March 1893	A	C		Disastrous floods in Hunter; Brig 'Hebe' lost near Port Stephens
12 May 1896	A	S		From Bass Str moved north, southerly gales and rough to heavy seas
1 June 1896	A	C		Low developed near Central Coast and moved NE
31 May 1897	A	E		SE to E gales
25 July 1897	A	I		Low from inland Qld; e to NE gales and rough seas
5 May 1898	A	E		SS 'Maitland' wrecked at what is now known as Maitland Bay, Bouddi National Park. SE gales and rough to heavy seas.
26 June 1899	A	E		Storm of vast dimensions and great intensity Category X on Mid-North Coast
6 June 1990	A	C		Barque 'Harvester ‘wrecked at Seal Rocks
4 July 1900	A	C		Centre developed off Newcastle; S to SE gales.
26 April 1902	A	E		Low developed N Coast on 26 with southerlies to gale force and tremendous seas
8 July 1902	A	S		By 10th seas were rough to high south from Sydney
24 May 1903	A	S		Southern depression intensified off Central Coast. Steamer Óakland' founded off Cabbage Tree Island
6 Feb 1904	A	C		American ship 'Whitney' encountered violent whirlwind off Newcastle.
8 July 1904	A	C		Fresh SE gales and rough seas; S.S 'Nemesis' lost with all hand near Wollongong.
30 August 1905	A	S		Southerly gales with rough to high seas. Schooner 'Jones Bros' lost off Newcastle.
26 Feb 1907	A	E		Low formed north of Port Macquarie; violent southerly gales and high seas.

19 May 1909	A	E		Southerly gales and very rough weather
9 June 1909	A	E		Low formed in easterly trough, moved south while intensifying; SE gales, very heavy rain
18 July 1910	A	I		Qld low moved to off Sydney on 19tyh; heavy gales; damage to property in Sydney
12 Dec1910	A	I		Southerly gales and high seas
12 July 1911	A	C		Strong to gale force southerlies, rough to high seas
21 July 1911	A	S		Strong southerlies and rough seas persisted for a long period.
24 July 1912	A	I		Depression formed from inland; very rough.
7 March 1913	A	T		Tropical cyclone from Coral Sea to Lord Howe then southwards; 547kt gusts at Sydney. Probably short duration event
28 June 1913	A	E		Low off Pt Macquarie, barometer to 1003mb; rough weather and gales
18 Oct 1914	A	E		Low in trough off coast; very rough weather.
30 Dec 1914	A	I		Tropical low over north central Qld moved SE to NSW; southerly gales and rough seas.
5 May 1915	A	E		Low off Central Coast; gales as far south as Jervis Bay; coastal steamers held up
5 Oct 1916	A	S		Easterly gales and rough seas
21 June 1917	A	S		SW to SE gales, shipping hampered.
30 Jan 1918	A	I		Tropical low deepened off Sydney
26 July 1918	A	S		Southerly gales and very rough weather
3 March 1925	A	I/A	4.9	Gales and high seas
21 May 1925	A	I	3.8	Depression formed from inland trough NE of Sydney; moved to Jervis Bay
23 July 1927	A	S	5	Depression off north coast, southerly gales; shipping delayed.
18 May 1933	A	E	5.4	Low developed near Lord Howe, tracked south then east; overseas liners delayed.
21 Feb 1934	A	I	4.9	NE to E gales when low from inland developed over mid-north coast.
1 Sept 1934	A	E	5.3	Small Coral Sea depression became intense south of Lord Howe. Very strong winds Central Coast.
23 June 1936	A	E	5.2	Low off Central Coast (998mb); damage to jetties and shipping
16-Feb-37	A	T	5	Tropical cyclone moved to Cape Byron (992mb); damage to shipping and coast; aircraft lost in north
27-Jan-39	A	I	5.5	Trough from inland to mid-north coast
28-Sep-40	A	S	6.4	Secondary east of Tasmania tracked NNE to Coffs Harbour; 60kt at Sydney
16-Nov-40	A	S	5.3	Southerly change on 15th followed by deep low over Tasman (992mb off Newcastle)

28-Apr-41	A	S	4.9	Tasman low developed a secondary moving to south coast and then NE
1-Oct-41	A	S	5.2	Secondary development east of Central Coast (996mb near Newcastle)
19-May-43	A	E	4.9	Low formed med-North Coast deepening off Central Coast; very heavy rain in Sydney
23-May-44	A	C	4.2	Strong gales Central and South Coast
7-Apr-44	A	S		Strong S/SE gales from depression off Central Coast; 65knot gust in Sydney
24-Mar-46	A	T		Tropical cyclone landfall near Fraser Island; moved to off Cape Byron
16-Apr-46	A	E		Formed mod-North Coast, moved South then East; very bad floods in Hunter
19-May-46	A	C		Gusts to 62kts in Sydney; structural damage recorded
30-Apr-48	A	T		Tropical cyclone moved south and another low off North Coast; very heavy rains in Sydney
10-Jan-48	A	I		Low off Central Coast moved NE, very heavy rain
16-Jun-49	A	I		Inland low at North Coast moved south; very heavy rain central Coast.
18-Jan-50	A	I	5.4	Complex inland low with several centres; one crossed near Sydney (988mb); seas very rough
23-Jun-50	A	E		Double-centred low off S Qld moved southwards. Navy ship 'Fairwind' lost with all hands; 'Bangalow' blown ashore at Coffs harbour.
18-Jan-51	A	E		1000mb low off N Coast moved southwards; collier 'Kiama' founded off The Entrance, losing 1/2 the crew.
8-Jun-51	A	E		Low off Pt Macquarie (992mb)- moved NE
26-Jun-51	A	C		Complex continental low deepened off South Coats and moved towards Lord Howe
24-Sep-51	A	C		Low from SW NSW moved east and deepened off Central Coast (998mb)
26-Apr-52	A	I		Inland trough developed into low off South Coast
24-Jul-52	A	I		Shipping confined to Sydney Harbour; flooding and damage Central Coast
3-May-53	A	I		Complex low, flooding Central Coast
16-Feb-55	A	S		Slow moving low west of Tasmania, developed secondary low off Newcastle - very rough seas in Sydney Harbour.
26-Apr-55	A	I		Low moved to off Sydney; damage on Central Coast.
20-May-55	A	S		Complex very deep lows in Tasman; SDE swell inflicted damage at Pt Stevens
10-Feb-56	A	I		Inland low developed to 992mb of Central Coast; very heavy rain

30-Jul-57	A	C		S to SE gales; damage in Sydney
20-Jan-59	A	T		Tropical cyclone tracked to Cape Byron Beaches eroded North Coast, very rough on Central Coast
14-Mar-59	A	E		Low moved from N to S over Tasman; gales on most of NSW coast; damage to beaches; 30 ft wave swept through dance hall at Bronte Beach.
26-Jul-18	A	S		Low moved from south coast; heavy swell; surge into Pittwater; sea wall damaged
21-Oct-59	A	C		Low off south coast moved NE; foreshores damaged; flooding
16-Feb-60	A	I		Depression across SE NSW, intensified off S Coast
25-Jun-60	A	S		Deep low in south Tasman; intense secondary on south coast. Strong southerly gradient moved north as secondary moved NE.
4-Dec-60	A	C		Low off Central Coast followed by heavy swell; several people drowned; small boats wrecked.
5-May-61	A	S		Easterly gales; road to Kurnell damaged
18-Nov-61	A	A		Gale force easterly winds to 49kt, heavy swell; damage in coastal districts.
6-Apr-62	A	E		Intense low off north coast; heavy seas at Port Stevens smashed retaining wall
29-Aug-63	A	C		Southerly gales as low moved to Tasman; 45-52kt art Sydney; very rough seas; ships unable to enter or leave port.
22-Jun-65	A	S		Deep Tasman low; gale warnings south of Newcastle.
18-Feb-66	A	I		Strong to gale force winds with heavy seas; considerable damage to beaches.
26-Mar-66	A	S		Low developed near Lord Howe; heavy seas and gales along coast to Coffs Harbour; widespread damage Illawarra Coast
29-Jan-67	A	T	5.8	Tropical cyclone 'Dinah' moved south from Coral Sea; 968mb at Lord Howe.
6-Aug-67	A	I	5.2	Complex trough to north; small low moved south with winds to 50kt.
15-Nov-67	A	S	5.2	Depression moved east to central Tasman followed by anti-cyclone. Heavy seas, high tides; damage to Central Coast.
23-Jul-68	A	S	5.3	Strong SSE gradient behind Tasman secondary; damage to beaches and structures.
20-Jan-71	A	I	5.8	Low moved to SSE to mid-North Coast
23-Jun-72	A	S	5.3	Secondary low SW Tasman moved rapidly NE
20-Feb-74	A	I	5.3	Inland low; gales of Central Coast.
8-Jun-74	A	S	5.3	Deep depression over Tasman; heavy swell; erosion and damage due to weakening of structures during 25 to 27 May 1974 event.
12-Jun-75	A	S	3.3	Deep Tasman low; intermittent SSE gales.

28-Jan-78	A	I		Gales and strong winds due to low below 997mb off Newcastle.
20-May-78	A	C	5.8	Depression developed off Eden; became intense and moved north along coast and then NE towards Lord Howe.
15-Jun-78	A	S	5.3	Secondary passed through Bass Str the NE
23-Aug-78	A	E	5.1	Depression SE of Lord Howe moved to central Tasman and deepened.
16-Feb-79	A	S	5	Depression 9870mb over Southern Ocean; southerly change up coast.
23 Sept 1892	X	E		Gales and rough to high seas
12 June 1896	X	E		Formed near Lord Howe and moved to near Sydney
5 August 1899	X	S		Secondary formed off South Coast; moved slowly North the NE while deepening: S to SE gales, worst off Central Coast
12 Jan 1911	X	T		Tropical cyclone crossed into Qld, moved S through NE NSW, crossing back to seawards near Wollongong; gusts to 74kt.
14 July 1912	X	I		Low from NT moved rapidly to near Newcastle. Shipping and ferry traffic halted; boulder weighing 235 tons lifted onto beach near Bondi
13 May 1913	X	I		Low from SE Qld moved south to position near Smoky Cape, then to Lord Howe. Floods in Central Coast; strong SE winds; gales; several shipping disasters; ferries in trouble. Storm surge in Sydney
18 Sept 1917	X	E		Severe depression move3d south parallel to coast; much damage around Sydney and Newcastle areas.
15 May 1919	X	E/A		Low formed over Coral Sea, moved southwards parallel to coast. Southerly winds to gale force. SS ''Tuggerah'' floundered near Port Hacking - 6 lives lost.
8 Dec 1920	X	E		Low developed off Central Coast; hurricane-like winds.
22 July 1921	X	E	7.2	Low off Qld moved south; 996mb at Clarence Heads; Manly ferries damaged; high winds
25 June 1923	X	C	7.2	Low developed south coast moved N/NE. SS "Sumatra" sunk of Port Macquarie; Manly ferry nearly sunk; ship ashore at Cronulla
25 March 1926	X	I	7.2	Low in trough in NT passed close to Pt Macquarie; Manly ferry stopped; much wind damage in Sydney.
16 May 1926	X	E/A	6.6	Low developed over Coral Sea, moved to Lord Howe (985mb); shipping badly affected. Said at time to be "longest and severest on north coast for 20 years"

15 April 1927	X	E	8.4	Intense low off Pt Macquarie (1000mb); great damage in Sydney; steamer aground at Gabo Island
13 June 1928	X	C	8.4	Low developed explosively from eastward moving trough over continent. Damage in Sydney and Newcastle. Waves reported 40 to 50ft high.
6 July 1931	X	S	6.9	Low formed to SE off Cape Byron, moved S then ENE. Considerable damage in Sydney and ferries suspended.
7 July 1932	X	S	6.4	Secondary formed in southern trough, moved north then back south; fierce southerly gales; big swell on coast.
2 Feb 1934	X	T	7.1	Severe cyclone crossed land to sea of south Qld coast; 985mb over south Tasman Sea. Floods all coasts; very severe coastal storm; 40 ft waves reported at Bondi.
19-Jun-37	X	E	8	low developed off North Coast (995mb); developed into intense Tasman low, worst since 1927')
12-Oct-42	X	E	6.4	Intense depression E of Brisbane moved south; stationary on 12th to 14th; gradient extreme because of high over Tasman
15-Jul-45	X	E		Centre formed off S Qld and moved south, deepening. Two ships lost off Southwest Rocks
14-Jun-52	X	C	7.2	Strong complex deepened while moving over inland NSW giving gale force winds along entire coast; small craft damage in harbours
2-Jan-54	X	S		Low formed near Pt Kembla and moved NNE, then traced southwards; long period of strong to gale force southerlies
19-Feb-54	X	T	7.4	Cyclone moved down coast of Qld; huge seas north coast; affected central and South Coasts later; Byron Bay fishing fleet destroyed
9-Jun-56	X	C		Complex continental low moved of central Coast - then intense centre off Jervis Bay; gale force winds; extreme high tide in Sydney
18-Feb-57	X	T		Tropical cyclone moved south; 992mb at Pt Macquarie; extensive damage to shipping, harbours and foreshores; 6-day gale in Sydney
22-Aug-57	X	E		Strong NE winds reaching 50kts; intense low off NSW coast; ne gale od 22nd followed by S/SE gales; damage to ships in harbour
9-Mar-58	X	E		Heavy seas metropolitan coast: sand and rock washed away; floods; shipping delayed
29-Jun-58	X	C		S/SE gales; intense low off Newcastle then moved to central Tasman; all shipping affected; launches wrecked.

20-Jul-59	X	C		Low developed off Sydney (990mb); surge reported in Sydney area; shipping damaged
4-Oct-59	X	C		Low developed off mid-N Coast; Sydney 47kt, Newcastle 50 kt winds. Sea wall lost at Dee Why; many yachts lost
20-May-66	X	S		Intense depression off S coast; gales and rough seas; dredge foundered; damage to craft
5-Sep-67	X	C	7.7	Intense low off Newcastle; tight gradient to Central and South coasts.
13-May-68	X	S	7.9	Intense low off south coast moved north. Ships reported 50 to 60kt winds off Sydney and 75kt north of Sydney
25-May-74	X	S	8.8	Strong secondary developed rapidly on 25 May offshore Sydney and during a few hours caused widespread damage between Wollongong and Sugarloaf Point. Falling pressures at 9pm 25 May indicated development of extreme secondary low had begun. Very rapid intensification as storm moved north off the coast. Damage included destruction of coastal installations, serious beach erosion, beaching and total loss of 52000ton ship 'Sygna' near Newcastle. By 3am 26th storm was at maximum intensity moving NE from Newcastle. One house severely damaged North end Wamberal. SES & Army placed rocks & sandbags in front of the eroding dune face
18-Mar-78	X	E	7.7	Depression from Coral Sea moved SW and inland over Cape Byron

31-May-78	X	I	6.9	Inland low developed mid-North Coast, then moved inland WSW over Hawkesbury and on to South Australia. The major storms of June 1978 also produced significant erosion along the beaches in the study area, most notably at Avoca and Terrigal-Wamberal. Following the severe effects of the 1974 storms, many beachfront owners at Avoca and Terrigal-Wamberal constructed a variety of shore protection structures comprising rock rubble, corrugated iron, rubber tyres, Besser blocks and concrete walls, while some sprayed the dune face with gunite and others attempted to mitigate erosion by planting vegetation (PWD 1985b). These ad hoc shore protection measures did not appear to be designed or constructed on sound coastal engineering principles, which was demonstrated during the severe storms of June 1978 when two houses collapsed into the ocean at Wamberal Beach (PWD 1985b)

T = Tropical Cyclone
E = Easterly Trough Low
C = Continental Low
I = Inland Trough
S = Southern Secondary Low
A = Anticyclone Intensification

I have adopted Category (Severity) **X** storms as likely to impact Wamberal Beach. I note that erosion impacts are, from the viewpoint of physics, chaotic events. This means that the extent and degree of erosion at Wamberal, or Collaroy, or MacMasters Beach etc. depends on many effects, some quite small,[18] in addition to wave height (Peak H_{sig}) and the duration of big waves. Matters such as wave direction, storm surge, tides, wind direction, beach profile, rips etc. play a role[19].

Thus, while the 1997 storm, Classified as **X**, was one of the most severe on record, it does not seem to have impacted Wamberal to a memorable extent.

Notwithstanding these difficulties, I have taken the view that an **X** severity storm has a high probability of causing significant erosion at Wamberal.

[18] The Butterfly Effect: This effect grants the power to cause a hurricane in China to a butterfly flapping its wings in New Mexico. It may take a very long time, but the connection is real. If the butterfly had not flapped its wings at just the right point in space/time, the hurricane would not have happened. A more rigorous way to express this is that small changes in the initial conditions lead to drastic changes in the results.

[19] Kemp and Douglas (1981) note: In some heavy swell situations, the waves are generated so far away that their causative meteorological system can only just be identified at the edge of weather charts. Recent observational data from wave-rider buoys shows that there are more incidences of heavy seas than may be easily detected by reference to daily meteorological charts""

I therefore set about assessing the frequency of such storms by extending the PWD (1984) data (covering up to 1980) using the Sydney Waverider data made available on the MHL website. This gives storm information in terms of wave height and direction from 1988 to 2022. Thus, I was left with a gap from 1981 to 1988 but found from Umwelt (2011) that 5 extreme storms occurred between 1980 and 1990.

In assessing the Waverider data, I have assumed that a reasonable equivalent to the 1984 definition of **X** Severity is to use:

- the same criterion of Peak Significant wave height (Peak H_{sig}) as used in 1984, and
- to use the storm duration with H_{sig} of greater than 5.5m

The resulting table of data, sorted in terms of Peak H_{sig} is given below.

DATE	TOTAL DURATION (hrs)	DURATION ABOVE Hsig 5.5m (hrs)	Peak Hsig (m)
16/06/07	180	1	6.0
2/07/22	272	2	6.0
14/07/99	224	2	6.0
14/10/14	34	1	6.0
18/07/14	195	0	6.0
24/08/08	85	1	6.1
30/06/00	218	2	6.1
30/08/96	103	1	6.1
10/07/05	58	1	6.2
2/09/14	200	2	6.2
21/04/99	263	2	6.2
11/06/06	112	1	6.2
7/10/09	152	3	6.2
18/11/01	324	3	6.2
29/06/02	212	5	6.2
24/08/90	182	6	6.3
19/07/11	223	2	6.3
23/08/19	87	3	6.3
14/07/20	325	3	6.3
22/05/20	392	5	6.3
19/06/21	128	2	6.4
3/08/10	86	3	6.4
4/06/16	219	10	6.5
8/02/20	113	4	6.5
28/07/07	170	4	6.5
2/06/06	196	8	6.5
22/03/05	157	9	6.6
18/07/04	168	3	6.7
4/06/19	108	5	6.8
11/11/87	190	7	6.8
7/06/07	290	15	6.9
29/07/01	146	20	7.0
1/08/90	133	7	7.2
5/06/12	197	34	7.8
19/04/15	312	61	8.1
9/05/97	400	58	8.4

It is interesting that the two most severe storms in the period 1988 to 2022 appear to be those of 2015 and 1997, which don't feature in terms of Wamberal beach erosion to the extent of the 2020 storms. However, from the viewpoint of this report the important point is that **X** Severity storms are sufficient to capture storms likely to impact on the beach (see Appendix 5 for further information).

I have plotted all the **X** Severity storms against date in Figure 4.1 below.

Figure 4.1: X severity storms plotted against date.

On average, for 140 years, **X** severity storms occurred as 1 in 2 years recurrence interval. This is consistent with a statement by the Central Coast Council that "this 2020 coastal erosion event was not rare and has a 50% chance of occurring in any given year:"

The same data are plotted in Figure 4.2 as cumulative storms versus time (days) since 23 September 1892.

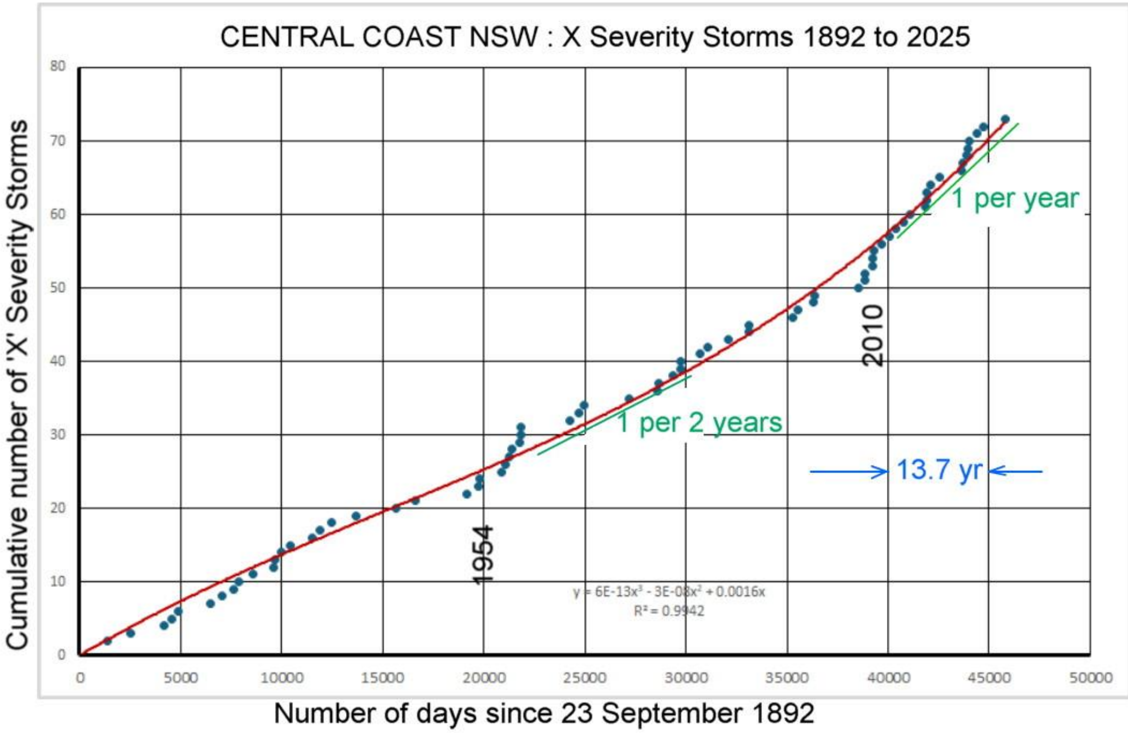


Fig 4.2. Cumulative 'X' Severity storms versus time

Figure 4.2 indicates an increase in the frequency of the 'X' severity storms since about 2010. This trend could reflect climate change influences, or it could be the result of

- better data on ocean conditions since the placement of the Wave Rider buoys in about 1980,
- More comprehensive meteorological data, and
- the interpretation of what constitutes an 'X' severity storm.

As a check I considered the publications by meteorological specialists listed as References 17,18 and 19.

Callaghan and Power (2014) tabulate 253 meteorological events that caused major floods in SE Australia between 1860 and 2012. These events covered from Brisbane to Eden. Therefore, I extracted from their tabulation those events which from their descriptions appeared to occur between about Port Macquarie and the Illawarra. I then compared their storms with the tabulation of 846 storms by Public Works Department in 1985. I concluded that Callaghan and Power seemed to miss a few storms that apparently caused floods. I then checked against data in the Australian Severe Weather archives, and documentation in *Archives of Storm Articles* (extremestorms.com.au), which also allowed me to extend the data base to 2025. Putting all this together I added 18 storms to the data base extracted from Callaghan and Power, giving 120 storms which caused significant flooding in many places between the Illawarra and Port Macquarie.

Figure 4.3 shows the 120 storms plotted against time in days since 8 February 1860.

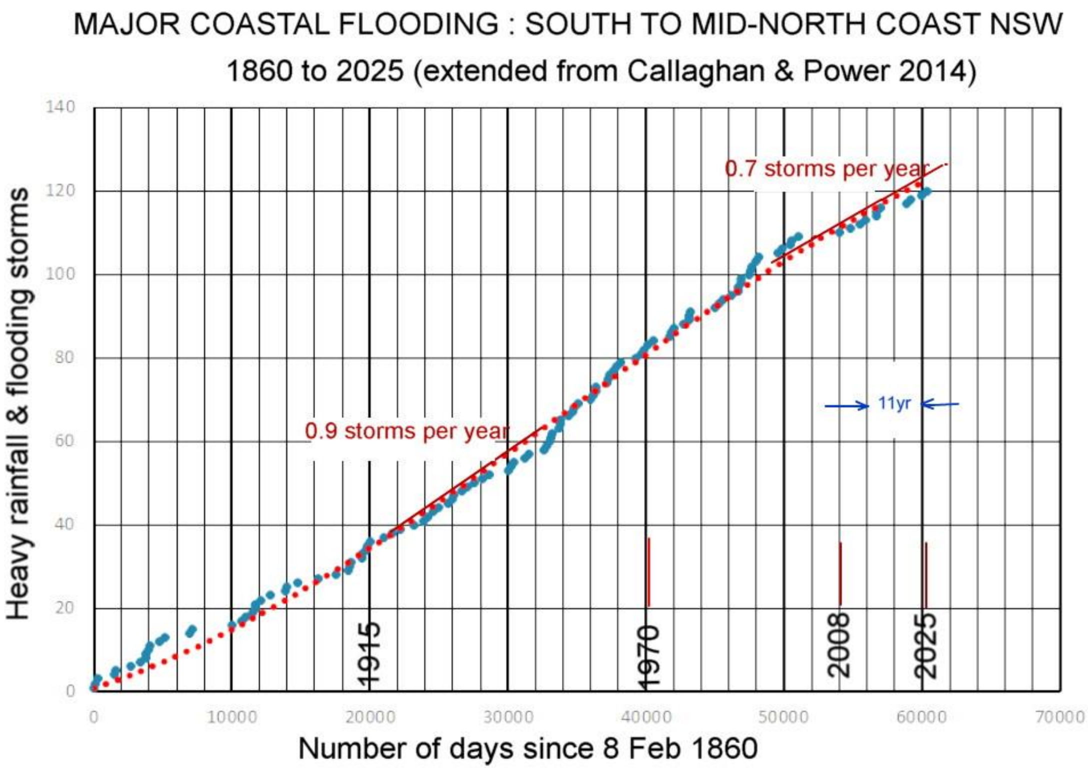


Fig 4.3 Storms causing major coastal flooding

The data in Figure 4.3 do not support the trend shown in Figure 4.2, leading to the conclusion that the trend in Figure 4.2 is not due to climate change.

This is supported by Fei et al (2018) who conclude, from an analysis of East Coast Lows (ECL) :

"The correlation between ECL frequency and climate drivers are generally weak, this indicates that ECLs are a regional low system which are not strongly influenced by the major climate drivers that affect rain elsewhere in southeast Australia."

APPENDIX 5

STORMS OF 2020 and 2025

The photographs and data included herein relate to the Wamberal Beach erosion events of 2020 and 2025.

For me, documenting these events supported the postulation given by James Carley of WRL in a personal communication, to the effect that substantial erosion including the foredunes at places like Collaroy and Wamberal typically occurs when an Extreme storm has precursors of one or more major storms. Simplistically the logic is as illustrated in Figure 1. The pre-cursor storms remove the beach sand berm thereby allowing the waves from the Extreme storm to attack the foredune system.

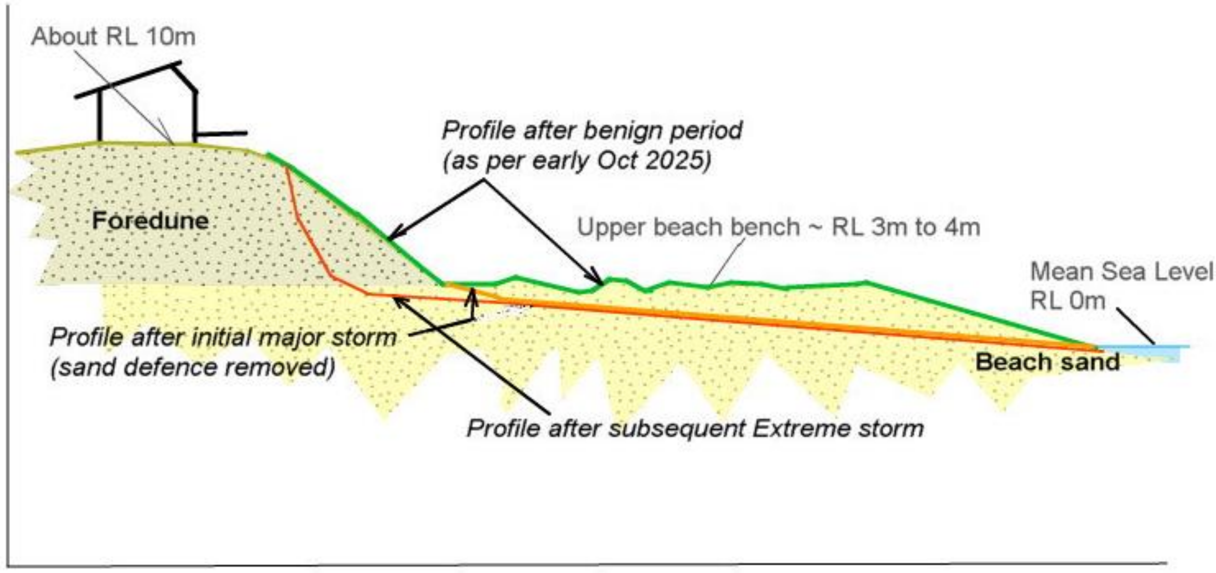


Fig 1: Combination of precursor storms and an Extreme storm

This postulation probably explains why the violent and prolonged Extreme storms of 1997, 2012 and 2015 did not impact Wamberal as severely as did the 2020 and 2025 storms.

The 1997 storm occurred on 9 to 12 May; the preceding category B storms were in Nov 1996 and Jan 1997.

The 2015 storm was 19 to 22 April, with category B preceding storms in early December 2014 and early March 2015

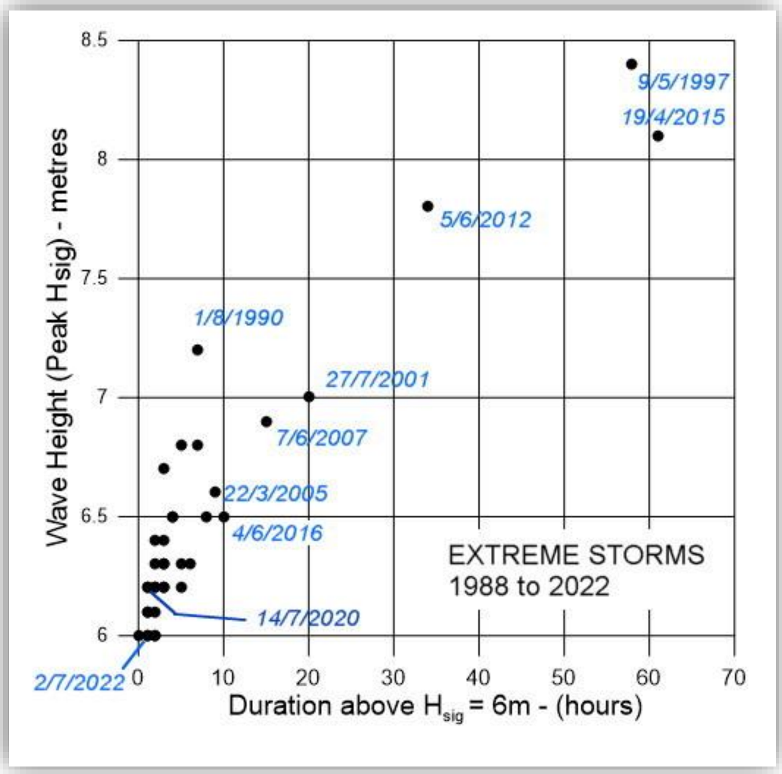
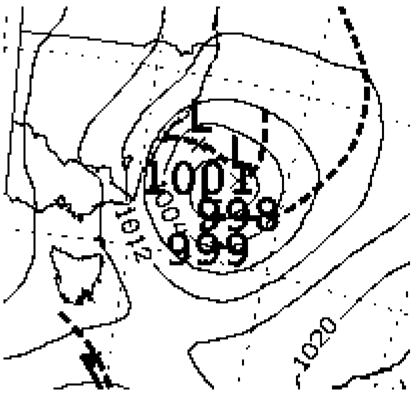


Fig 2: Extreme storms 1988 to 2022

2020 EROSION EVENT

On 26 May 2020 the Sydney Waverider recorded:

- Peak H_{sig} = 6.3m[20]
- Duration of H_{sig} at or above 5.5m = 20hrs
- Deepwater wave direction = South

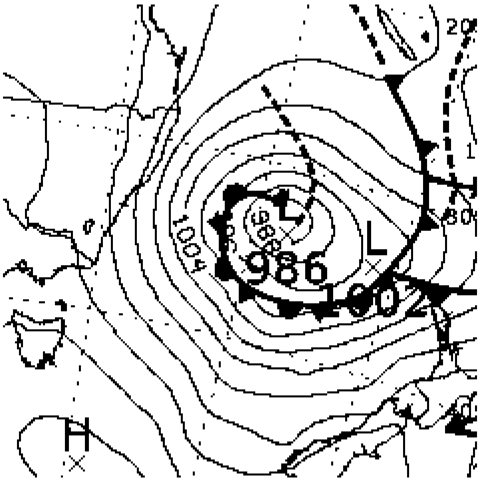


22 May 2020

[20] H_{sig} is termed the significant wave height

On 18 July 2020, recorded:

- Peak H_{sig} = 6.3m
- Duration of H_{sig} at or above 5.5m = 21hrs
- Deepwater wave direction = South-South-East



15 July 2020

Photos 28 July 2020

Nos 7 to 21 Pacific St

Nos 27 to 35 Ocean View

Nos 33 to 41 Ocean View Drive

Nos 39 to 43 Ocean View Dr

Nos 47 & 49 Ocean View Parade

Nos 51 to 55 Ocean View Parade

Nos 63 & 65 Ocean View Parade

No 73 Ocean View Parade

Nos 81 & 83 Ocean View Parade

Nos 81 & 83 Ocean View Parade

Nos 91 and 93 Ocean View Parade

Nos 93 to 99 Ocean View Parade

Nos 101 Ocean View to No 4 Calais

2025 STORM EVENT

June - July 2025

The May to early July 2025 period was one of successive storms in the Sydney and Central Coast areas. Drone video is available from 23 May indicating onset of erosion.

Central Coast Council issued the following on 2 April:

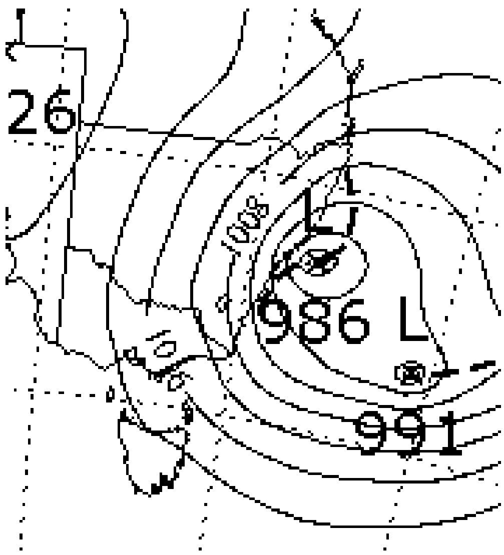
Issued 2 April 2025

Last night's ocean conditions with large swells have caused significant coastal erosion, specifically impacting the southern end of The Entrance North and Wamberal.

Erosion has caused landslips at some private beachfront properties and steep sand escarpments. Debris is also washing up on other beaches including Blue Bay and Toowoon Bay.

Our crews inspected and have closed public beach access points for community safety.

An intense East Coast Low developed at the end of June and early July. Emergency evacuations occurred on 1 & 2 July 2025



2 July 2025

(*At the time of writing the Sydney Waverider data were not available for this period.)*

No 33 Pacific St to 23B Ocean View Parade – 23 May 2025

No 33 to No 37 Ocean View Drive – 23 May 2025

No 91 and No 93 Ocean View Drive – 23 May 2025

In vicinity of 11 Pacific Street – 12 June 2025

In vicinity of 11 Pacific Street – 12 June 2025

APPENDIX 6

SOME DEFINITIONS FOR WORDS USED IN THIS REPORT AND NOT DEFINED IN THE TEXT AND APPENDICES 1 to 3

Risk

The concept of measuring Risk by combining Consequences and likelihood is often attributed to Pascal in the 17th century. His work saw the light in 1662 in a series of volumes known as *Logic, or the Art of Thinking,* which included : **"our fear of some harm ought to be proportional not only to the magnitude of the harm, but also to the probability of the event".** That is where we are today.

5.3.4 Ranking risks: The consequence-likelihood matrix

In many fields of risk management, risks are compared qualitatively using a consequence-likelihood matrix such as the example in Figure 9. The qualitative level of risk produced provides one input to decisions about priorities and can help draw attention to risks that are perceived to be the most important to inform more senior management or to help to exclude trivial risks from further attention.

Likelihood \ Consequence	1	2	3	4	5
A	S	S	H	E	E
B	M	S	S	H	E
C	L	M	S	H	E
D	L	L	M	H	E
E	L	L	M	S	H

E = Extreme, H = high, S = Significant, L = Low

Figure 9: Example of a consequence-likelihood matrix

Cross, J. (2019). Risk. In The Core Body of Knowledge for Generalist OHS Professionals. 2nd Ed. Tullamarine, VIC: Australian Institute of Health and Safety.

Short Term Erosion

Short-term erosion refers to erosion that occurs over a period of days, as a result of extreme weather events, such as severe storm or cyclone activity. Short-term erosion results in changes to the profile of the beach. During short term erosion events, the main sand transport mechanisms occur offshore. After the storm passes normal beach processes usually produce onshore sand transport that restores the beach naturally.

Storm Tide

A storm tide is the combination of a storm surge and the normal astronomical tide. A storm surge is an increase (or decrease) in water level associated with some significant meteorological event (for example, a change in atmospheric pressure such as a low-pressure system). Combined with a normal astronomical tide, this can result in a recorded water level higher than the predicted tide.

Coastal Erosion

The wearing away of land or the removal of beach or dune sediments by wave or wind action, tidal currents, wave currents, or drainage.

AEP Annual Exceedance Probability

The likelihood of a natural hazard event occurring in a calendar year, generally expressed as a percentage. For example, a 1% AEP event has a one per cent chance of occurring in a year, or once in every 100 years.

Landslide

The downslope movement of land. On the coast landslide is typically caused by the removal of material at the toe of the landslide due to wave or storm activity and /or heavy rainfall.

Patonga Claystone

Overlies the Tuggerah Formation; underlies the Terrigal Formation. Comprised “red beds’ of interbedded sandstones, siltstones and claystones.

Conditional Probability

The conditional probability of an event A is the probability that the event will occur given the knowledge that an event B has already occurred.

APPENDIX 7

SHORT CURRICULUM VITAE

PHILIP J. N. PELLS

Educational Qualifications:	BSc (Eng), Cape Town, 1966 MSc (Eng), London, 1968 DIC (Soil Mechanics), London, 1968 DSc(Eng), Cape Town, 1993
Professional Associations:	Fellow, Engineers Australia Fellow, Australian Academy of Technological Sciences Member American Society of Civil Engineers
Awards:	1972 SA Inst of Civil Eng. – Best Paper in Transactions 1993 EH Davies Memorial Lecture, Australian Geomechanics Society 2003 Australian Centenary Medal for Services to Civil Engineering 2008 Allen Neyland Award, AusIMM 2020 Awarded Lifetime Membership, Australian Geomechanics Society 2017 Best paper Canadian Geomechanics Society 2024 H G Poulos Award, Australian Geomechanics Society

- tunnels and mining rock mechanics
- earth and rockfill dams, and tailings dams
- slope stability
- hydrogeology
- mine subsidence
- foundations

EMPLOYMENT:

2009 - Present
Principal, Pells Consulting
Adjunct Professor of Civil Engineering, University of NSW

1993 - 2009
Principal, Pells Sullivan Meynink Pty Ltd
Adjunct Professor of Civil Engineering, University of NSW

1981 - 1993
Director, Coffey Partners Pty Ltd, Sydney
Manager, New South Wales

1975 - 1980
Senior Lecturer in Rock Mechanics, University of Sydney

1971 - 1974
Senior Research Officer, Rock Mechanics Division, CSIR

1967 - 1970
Design Engineer, Ninham Shand & Partners, Cape Town - Assistant Resident Engineer, Xonxa Dam