



FINAL REPORT

NOVEMBER 2016

Collaroy-Narrabeen Beach Coastal Protection Works - Benefit Distribution Analysis

Report prepared for the Northern Beaches Council

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Executive summary

Overview

The Northern Beaches Council (the Council) engaged Marsden Jacob Associates (Marsden Jacob) to assess the distribution of benefits between stakeholders from building coastal protection works at Collaroy-Narrabeen Beach.

Following severe storms that occurred at Collaroy-Narrabeen Beach that caused severe erosion and damage to property, the Council has been investigating the cost of building coastal protection works and associated funding options. The results from our distributional analysis will inform the Council in apportioning the costs of building coastal protection works based on the 'beneficiary pays' principle.

Approach

In undertaking the benefit distribution analysis, we assessed the benefits or avoided costs from building coastal protection works such as avoided loss in land and property values, avoided loss of infrastructure (roads, utilities), avoided clean-up costs and avoided amenity impacts. This means we assessed the benefits arising from coastal protection works by comparing the base case of no coastal protection works to the scenario case, with coastal protection works.

Under the base case, we assumed:

- minimal protection would be provided by existing coastal protection works
- no additional coastal protection works would be constructed over the next 60 years.

In the scenario case, we assumed that coastal protection works would be constructed along the beach from the Council reserve at 1068 Pittwater Road Collaroy (near Fielding Street) to 2 Devitt Street Narrabeen.

The Council, through its engineering consultants, provided Marsden Jacob with land erosion impacts associated with probability lines of 0.5%, 1%, 2.5%, 10% and 20% for Year 0, 20, 40 and 60. Appendix B provides further details of how these probability lines have been derived. In the scenario case, we assumed that the constructed coastal protection works would provide protection against erosion from coastal processes (see Appendix B). We then interpolated the impacts from land erosion for each year over the 60 year period and calculated the present value of benefits over the 60 year analysis period, these present values were then used to estimate the distribution of benefits between stakeholder groups.

Results

The key findings from the benefit distribution analysis are:

- About 94% of the benefits from coastal protection works accrue to residents along the study area at Collaroy-Narrabeen Beach.
- The Council would share about 6% of the benefits from coastal protection works.
- Utilities and telecommunications would share little of the benefits from coastal protection works.
- Benefits to Pittwater Road from coastal protection works are minimal as impacts from coastal process occur towards the end of the 60 year analysis period.

- The use of different discount rates does not materially change the proportion of benefits between stakeholder groups.

Report structure

The rest of this report is structured as follows:

- Chapter 1: background to the project
- Chapter 2: our approach to the benefit distribution analysis
- Chapter 3: the results of the benefit distribution analysis.

1. Background

One of the most highly capitalised shorelines in the Northern Beaches area, the Collaroy-Narrabeen Beach is also one of the most at risk in NSW from coastal processes. The Collaroy-Narrabeen Beach also has a history of ad-hoc emergency protection works being placed during and after coastal storms.

Coastal management in NSW is currently being reformed, with a draft NSW Coastal Management Manual published by the NSW Office of Environment and Heritage (OEH).¹ The draft manual outlines principles for sharing the cost of coastal management, in particular, that the cost of coastal protection works should be shared amongst those stakeholders who benefit from coastal protection works.

Further, the draft Northern Beaches Coastal Erosion Policy (CEP) states that protection works that benefit a private property shall be designed, constructed and maintained (including any mitigation measures) at the expense of the property owner.

In this project Marsden Jacob has apportioned the costs of coastal management actions among beneficiaries. We have not considered the capacity to pay of beneficiaries as this was beyond the scope of the project brief.

In this chapter, we provide a description of the Collaroy-Narrabeen Beach where coastal protection works is being considered, and the frameworks that inform this benefit distribution analysis.

1.1 Site description

The Collaroy-Narrabeen Beach, about 3.6km in length, is located about 22 km north east of Sydney. The beach generally faces east and the average wave heights decrease towards the southern end, mainly due to the sheltering provided by the Long Reef headland and the adjacent rock platform. The width of the beach is generally about 50m, being widest towards the northern end near Narrabeen Lagoon and most narrow near Wetherill Street. An aerial view of the Collaroy-Narrabeen Beach and its surrounds is at Figure 1.

The area that is the subject of this benefit distribution analysis is the stretch of Collaroy-Narrabeen Beach from the Council reserve at 1068 Pittwater Road Collaroy (near Fielding Street) to 2 Devitt Street Narrabeen (the 'study area'), see Figure 3. This stretch of beach suffered significant erosion due to severe storms that occurred in Sydney in June 2016. This erosion caused damage to private and public property including sewer lines, roads, and stormwater assets. The storm also exposed previously buried coastal protection works and revealed areas where no protection was present. Figure 2 shows a sample aerial view of the exposed existing protection works and areas where none is present.

The development within the study area is generally residential, including some high rise residential blocks. The Collaroy Surf Life Saving Club is also included in the study area.

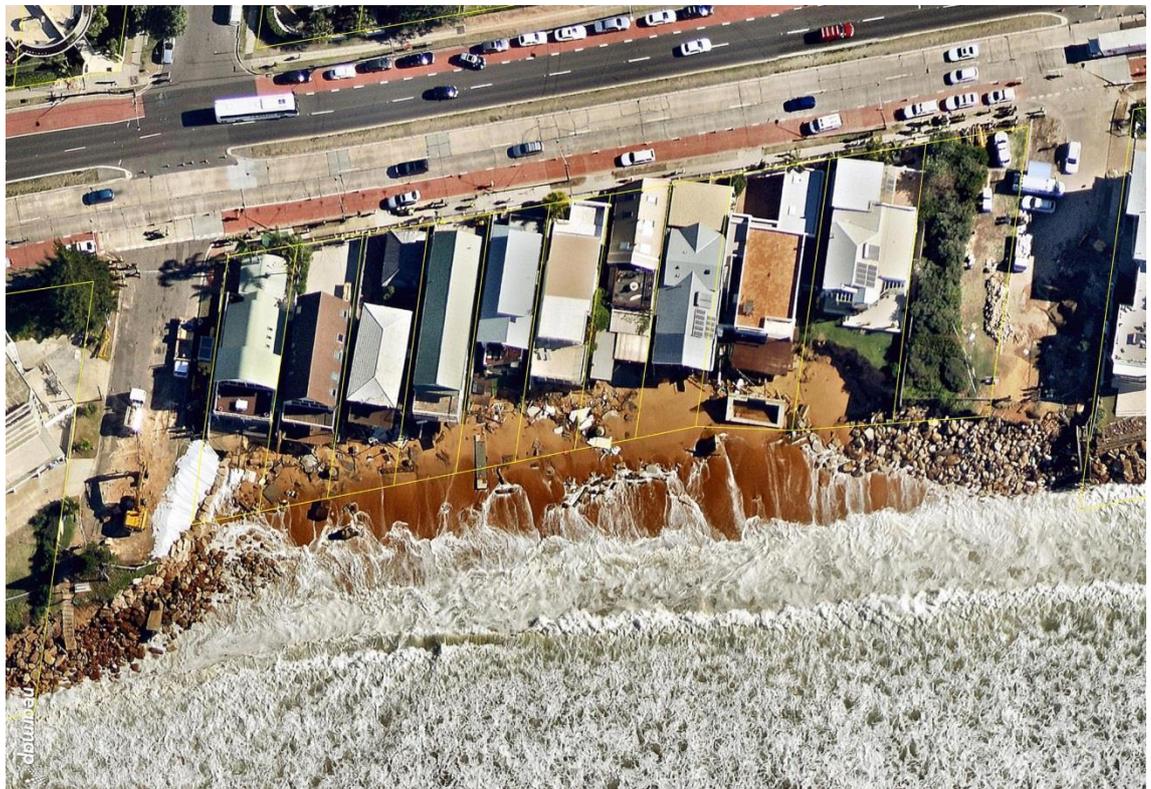
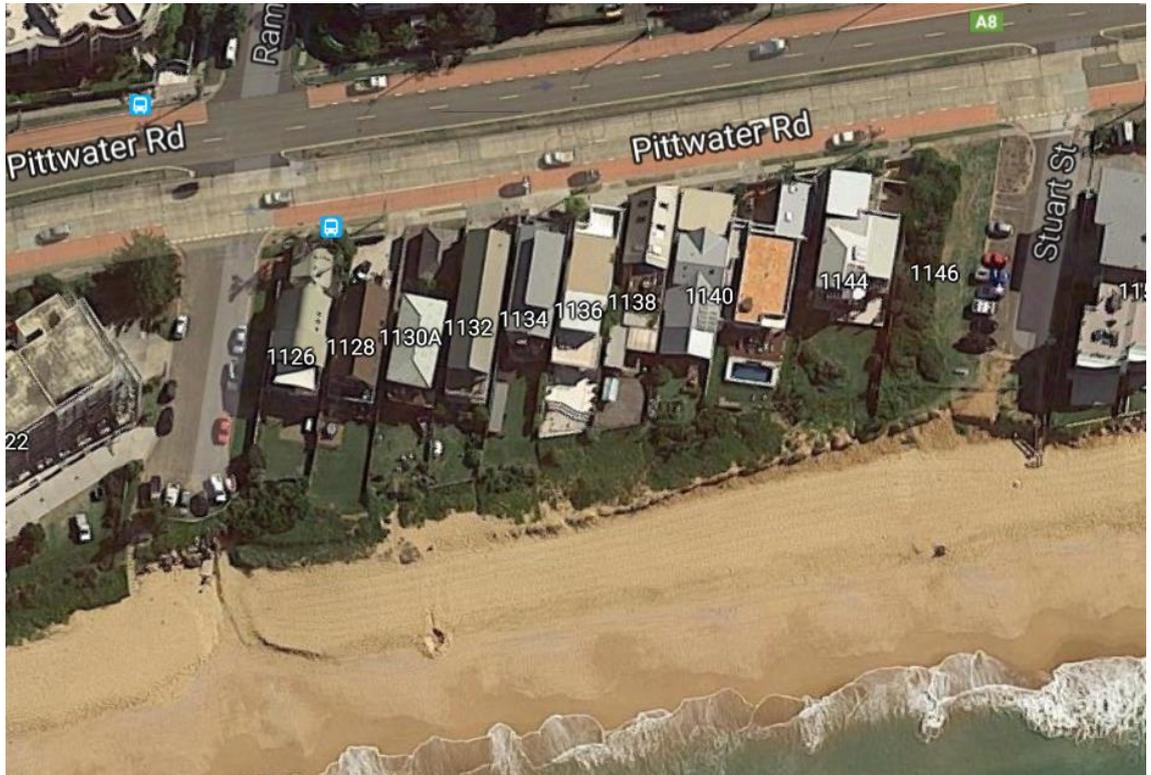
¹ <http://www.environment.nsw.gov.au/coasts/coastreforms-manual.htm>

Figure 1: Aerial view of Collaroy-Narrabeen Beach and surrounds



Source: Coastal Zone Management Plan for Collaroy-Narrabeen Beach and Fishermans Beach, October 2014.

Figure 2: Aerial view of parts of the study area and the exposed existing coastal protection works before (top) and after (bottom) the June 2016 storm events



Source: Google Map data 2016 (before) and Northern Beaches Council (after)

1.2 Coastal management framework

OEH has published a consultation draft of the NSW Coastal Management Manual. The manual outlines mandatory requirements and provides guidance on the preparation, development, adoption and content of a coastal management program. Stage 3 Part B of the manual sets out the use of cost benefit analysis and distributional analysis when selecting the appropriate coastal management strategy. Further, the manual outlines principles for sharing the cost of coastal management, specifically that cost sharing should take account of the beneficiaries of coastal management actions and the relative share of benefits enjoyed by each party.²

The Coastal Zone Management Plan (CZMP) for Collaroy-Narrabeen Beach and Fishermans Beach was adopted by the Council in October 2014 and certified by the NSW Government in November 2015. This plan establishes a framework for the management of beaches in the area and identifies controls to manage future risks from coastal hazards, for example by setting a minimum setback for development on conventional foundations and piled foundations.

Following the storms that occurred in June 2016, the Council released a draft Northern Beaches Coastal Erosion Policy (CEP) which sets out the framework for building and maintaining protection works. Marsden Jacob understands that the CZMP would be amended to take account of the CEP when finalised. The proposed amendments to the CZMP set out the requirements for constructing coastal protection works on public and private land.

The draft CEP states that:³

- a) *Protection works that benefit a private property shall be designed, constructed and maintained (including any sandy offsets) at the expense of the property owner.⁴*
- b) *Any contribution by the Council will be at its absolute discretion and shall not be relied upon by a private property owner in determining what action to take to protect their own property.*

Further, the CEP also states that:⁵

- h) *In exceptional circumstances and where protection works principally benefit private property and also provide a benefit to significant public assets, Government may make a contribution to the works subject to a positive benefit analysis for those assets.*

Marsden Jacob understands that the Northern Beaches Council is seeking to understand how to apportion the cost of building coastal protection works at Collaroy-Narrabeen beach between different stakeholders (public and private) on the basis of the ‘beneficiary pays’ principle, so as to guide the level of any contribution the Council or NSW Government may provide towards the cost of protection works that benefit private properties.

² <http://www.environment.nsw.gov.au/resources/coasts/150872-draft-manual-part-b-stage3.pdf>, p 36. Accessed 28 September 2016.

³ Northern Beaches Council, Northern Beaches Coastal Erosion Policy 2016, p 5.

⁴ This position is consistent with the CZMP which states that property owners are responsible for protecting their properties from the impacts of coastal processes.

⁵ Northern Beaches Council, Northern Beaches Coastal Erosion Policy 2016, p 5.

1.3 Coastal erosion / recession probability lines

As previously discussed, the Council engaged Royal Haskoning DHV and Horton Coastal Engineering Pty Ltd ('engineering consultants') to prepare the CZMP for Collaroy-Narrabeen Beach and Fishermans Beach, and the preferred design and alignment for coastal protection works at Collaroy-Narrabeen Beach.

The engineering consultants modelled coastal erosion / recession probability lines that underpin this distributional analysis. Appendix B of this report has been provided by the engineering consultants and provides information on how the probability lines have been derived.

2. Approach

In estimating the benefits from coastal protection works (proposed rubble mound wall), we were informed by the erosion / recession probability lines undertaken by the Council's engineering consultants. We then calculated the present value of the expected benefits over a 60 year time frame, these present values were then used to estimate the distribution of benefits between stakeholder groups. This chapter explains the scope of our analysis and our approach.

2.1 Scope

Marsden Jacob was engaged by the Council to conduct a distribution analysis of coastal protection works, including the following:

- outline the benefits from coastal protection works in either financial or proportional terms between properties and assets located adjacent to Collaroy-Narrabeen Beach
- identify the stakeholders affected by coastal protection works
- demonstrate how any benefits vary spatially, both north to south and east to west, and temporally (if relevant)
- attribute financial or proportional benefit resulting from coastal protection works to stakeholder groups.

The timeframe for the distributional analysis is 60 years, reflecting the engineering consultants' advice on the design life of the properties adjacent to the Collaroy-Narrabeen Beach. It is noted that the engineering works are anticipated to have a design life that would exceed 60 years, however, the analysis reflects the design life of the adjacent properties and infrastructure.

As we are not conducting a cost benefit analysis, we do not consider the cost of coastal protection works. As discussed in Chapter 1, the CEP provides that protection works that benefit a private property should be funded by the property owner. Therefore, in assessing the impact of coastal protection works, we focus on the benefits, or avoided costs, and the distribution of those benefits.

2.2 Stakeholders/beneficiaries

Land ownership in the study area is split between private, Council, and Crown Land as shown in Figure 3. Other assets that would benefit from coastal protection works include roads, stormwater and sewer pipelines, gas pipelines, electricity cables and poles, and telecommunication cables.

Figure 3: Land ownership in the study area



Source: Coastal Zone Management Plan for Collaroy-Narrabeen Beach and Fishermans Beach, October 2014.

The stakeholders relevant for the distributional analysis include:

- residential property owners
- commuters (users of Pittwater Road)
- beach users (could be Australian residents or overseas tourists)
- Northern Beaches Council
- Crown Land – NSW Government
- Roads and Maritime Services – NSW Government
- Sydney Water Corporation
- Telstra Corporation
- Ausgrid
- Jemena.

We understand that in some parts of the study area, the proposed protection works would occupy Crown Land. As such, the impact on Crown Land from protection works could be considered an additional cost of the proposed works. This cost would be considered in a cost-benefit analysis but is outside the scope of a benefits distribution analysis.

2.3 Method

2.3.1 Defining the base case and scenario case

We assess the benefits arising from coastal protection works by comparing the base case to the scenario case.

Under the base case, we assumed:

- Minimal protection would be provided by existing coastal protection works, except for recently constructed protection works at 1 Frazer Street, Collaroy, and 1186 Pittwater Road, Narrabeen that have been constructed to a standard that is consistent with the coastal protection works that are currently being considered. For these properties, equivalent protection is assumed to be provided in the base case and scenario case.
- No additional coastal protection works would be constructed over the next 60 years.
- The construction method employed for the residential properties is assumed to remain unchanged over the analysis period. This means properties with conventional foundations are not redeveloped and instead built on piled foundations. This is a simplifying assumption because it is not possible to predict which properties will be redeveloped and built on piled foundations over the analysis period.

In the scenario case, we assumed that coastal protection works, in the form of a rubble mound wall, would be constructed along the beach from the Council reserve at 1068 Pittwater Road Collaroy (near Fielding Street) to 2 Devitt Street Narrabeen. We assumed that the constructed coastal protection works would provide protection against erosion from coastal processes over 60 years under the assumptions outlined in Appendix B.

Under both the base case and the scenario case, we assumed no redevelopment of existing properties in the study area.

2.3.2 Assessing the benefits

The benefits from coastal protection works include:

- avoided loss of land value
- avoided loss of properties
- avoided loss of infrastructure assets such as stormwater pipes and telecommunication cables
- avoided travel related costs (Pittwater Road remains open to traffic, so traffic does not have to detour via Wakehurst Parkway)
- avoided clean up costs associated with storm damage
- avoided loss of dune breaches
- impacts on beach and dune amenity.

To assess the avoided loss of land values and properties, we developed a database based on information provided by the Council and publicly available information sources. The database includes the following information for each property:

- location
- unimproved value (as per Council's records)
- capital improved value and redevelopment cost estimates
- land area
- building type
- conventional or piled foundation
- building setback distance.⁶

Total benefits or avoided costs are calculated from the following formula:

$$EV(C) = \sum_{i=1 \text{ to } n} C_i p_i = C_1 p_1 + C_2 p_2 + C_3 p_3 \dots$$

Where:

- **C** is the land value, value of the built asset, roads and services that is at risk
- **p** is probability of the land or built asset being impacted by shoreline erosion in any one year
- **n** is the number of affected properties.

The Council, based on work by their engineering consultants, provided us with the land erosion impacts associated with probabilities of 0.5%, 1%, 2.5%, 10% and 20%. This data was provided for Year 0, 20, 40 and 60 years. We interpolated the impacts from land erosion for each year over the 60 year period, and then calculated the present value⁷ of benefits over a 60 year period. These present values were then used to estimate the distribution of benefits between stakeholder groups.

⁶ Measured as the average distance of the back edge of the building from the seaward property boundary.

⁷ The present value of benefits describes how much a benefit that occurs in the future is worth today. The further away in the future that a benefit occurs, the less it is worth today because this value is discounted at the assumed discount rate.

2.3.3 Key assumptions

Under the base case, we assumed:

- Shoreline recession extending into private properties will impact on the land value of those properties, proportional to the extent of land lost to recession.
- When shoreline recession reaches the seaward edge of un-piled buildings it is assumed that the asset value is lost.
- The value of piled buildings is assumed to decline in proportion to the area of land under the building that is lost to recession.

Under both the base case and the scenario case, we assumed no incremental impact on beach amenity.

More details on our assumptions are provided below and in Appendix A.

Loss of built asset values

Residential buildings that are impacted by shoreline erosion fall into two main categories:

- **Unpiled** buildings (with conventional foundations) that have not been constructed to withstand coastal processes.
- **Piled** buildings that have been constructed to withstand coastal processes.

Buildings not constructed to withstand coastal processes (unpiled buildings) are assumed to be uninhabitable if the existing building footprint falls within a modelled erosion / recession probability line, as per the engineers modelling. The cost of this impact is calculated as the expected value of the built asset.

Piled houses are built to withstand wave forces on the piling. Therefore, a piled house is assumed to remain habitable when the land on which it is situated is impacted by erosion. However, piled houses are still likely to lose value over time under the base case. This is because, as a property gradually loses land over time through coastal erosion, the desirability of that property – both its land and house – will diminish. This is assumed to be reflected in a loss of market value of the building which is roughly in proportion to the loss of the land value on which the building is situated.

Property owners are also assumed to experience costs associated with restoring access and services when the properties are impacted by erosion associated with storm events. The costs of restoring services, including power, water, sewerage and access are estimated to be approximately \$10,800 per restoration. For the purpose of this analysis we have treated these costs with respect to unpiled buildings and piled buildings in the same way as the value of the built asset.

Impact on beach amenity

As agreed with the Council and the engineering consultants, we assumed there would be no loss to beach amenity as the beach will be renewed naturally over a relatively short timeframe following a storm event, and there are other beaches nearby. Thus there is no incremental impact on beach amenity for the scenario case as compared to the base case.

2.3.4 Unquantified benefits

There are a number of unquantifiable public benefits that may result from the implementation of coastal protection works. To assist in assessing the range of impacts that may result from coastal protection at Collaroy-Narrabeen Beach, the Council commissioned the Manly Hydraulics Laboratory (MHL) in association with the Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering to review the concept design and concept alignment of the proposed coastal protection works for Collaroy-Narrabeen Beach, south of Devitt Street Narrabeen. The review includes an analytical assessment of the relative impacts on coastal processes within the Collaroy-Narrabeen Beach embayment.

This review found that the proposed coastal protection improvement works will be designed and constructed to meet conventional coastal engineering standards, and while some damage may still be expected during major coastal storm events beyond the adopted design conditions, this is expected to be in a far more controlled and acceptable/planned manner. The proposed coastal protection improvement works, therefore, are expected to provide improved public access and vastly improved serviceability and public safety with the proposed alignment established to maximise the public beach amenity as far as practicable in comparison to the existing ad-hoc works.

Additionally, in relation to visual amenity, the review found that visual amenity would be improved in terms of uniformity of appearance, access and public safety during eroded beach conditions. Therefore, the overall visual impacts compared with the status quo from the proposed works are expected to be positive.

Our analysis also assumed that owners of piled houses do not pay for dune replenishment (sand replacement) after an erosion event, because there is uncertainty around whether property owners would undertake dune replenishment or would instead rely upon natural dune replenishment processes.

3. Results

In this chapter, we outline the estimated benefits across the relevant stakeholders from coastal protection works. We also present the benefits across stakeholders as a proportion of the total value of benefits.

3.1 Key findings

The key findings from the benefit distribution analysis are:

- About 94% of the benefits from coastal protection works accrue to residents along the study area at Collaroy-Narrabeen Beach.
- The Council would share about 6% of the benefits from coastal protection works.
- Utilities and telecommunications would share little of the benefits from coastal protection works.
- Benefits to Pittwater Road from coastal protection works are minimal as impacts from coastal process occur towards the end of the 60 year analysis period.
- The use of different discount rates does not materially change the proportion of benefits between stakeholder groups.

3.2 Benefit distribution

As can be seen from Table 1, residents in the study area share the majority of the benefits from coastal protection works.

Table 1: Distribution of benefits between stakeholder groups

Stakeholder groups	% of total benefits
Council	6.2
Roads and Maritime Services	0
Sydney Water	0.2
Jemena	0
Optus	0
Telstra	0
Ausgrid	-
Residential property owners	93.6
Total	100.0

Source: Marsden Jacob analysis.

In relation to Pittwater Road, impacts from coastal process occur mostly towards the end of the 60 year analysis period under the base case scenario, where coastal protection is not built. Specifically:

- Year 0: no impact under any of the probability lines.

- Year 20: approximately 650m² of Pittwater Road and footpath is impacted by the 0.5% probability line. No impacts under other probability lines.
- Year 40: approximately 2800m² of Pittwater Road and footpath is impacted by the 0.5% probability line and 900m² of road and footpath impact by the 1% probability line. No impacts under other probability lines.
- Year 60: approximately 11,000m² of Pittwater Road and footpath is impacted by the 0.5% probability line, 4,100m² of road and footpath is affected by the 1% probability line and 750m² by the 2.5% probability line. No impacts under other probability lines.

The distribution of benefits across infrastructure owners is shown in Table 2.

Table 2: Distribution of benefits for Council properties, roads and services

Asset	Asset owner	% of total benefits
Council properties		
2 Devitt Street Narrabeen	Council	0.1%
1198 Pittwater Road	Council	0.8%
1146 Pittwater Road Collaroy	Council	0.3%
1102 Pittwater Road	Council	0.7%
1068 Pittwater Road	Council	3.4%
Roads		
Pittwater Road	Roads and Maritimes Services	0.0%
Footpaths and other roads	Council	0.7%
Services		
Stormwater pipes, pits	Council	0.2%
Water mains	Sydney Water	0.2%
Sewerage mains	Sydney Water	0.0%
Stormwater pipes, pits	Roads and Maritime Services	0.0%
Gas pipe	Jemena	0.0%
Telecommunication cable	Optus	0.0%
Telecommunication cable	Telstra	0.0%
Electricity cable	Austgrid	0.0%

3.3 Sensitivity analysis

We conducted sensitivity analysis on the results using different discount rates. The share of benefits by stakeholder group does not change materially from using different discount rates, see Table 3.

Table 3: Sensitivity of results using different discount rates

Stakeholder groups	% of total benefits	% of total benefits	% of total benefits
	7% discount rate	4% discount rate	10% discount rate
Council	6.2	5.9	6.6
Roads and Maritime Services	0	0	0
Sydney Water	0.2	0.2	0.2
Jemena	0	0	0
Optus	0	0	0
Telstra	0	0	0
Ausgrid	0	0	0
Residential property owners	93.6	93.9	93.2
Total	100.0	100.0	100.0

Source: Marsden Jacob analysis.

Appendix A: Model Assumptions

Table 4: General assumptions

Category	Value	Source
Discount rate	7%	NSW Treasury guidelines
Evaluation period	FY 2017 to FY 2077	
Base year	\$ 2016	
Roads and footpaths	\$340 / sq meter	The Council
Stormwater pipes (Council)	\$1,954 / meter	Based on IPART's report, adjusted for inflation. https://www.ipart.nsw.gov.au/Home/Industries/Local-Government/Reviews/Benchmark-Costs/Benchmark-costs-for-local-infrastructure-contributions?qDh=2
Stormwater pits (Council)	\$5,725 / unit	Based on IPART's report, adjusted for inflation. https://www.ipart.nsw.gov.au/Home/Industries/Local-Government/Reviews/Benchmark-Costs/Benchmark-costs-for-local-infrastructure-contributions?qDh=2
Stormwater gross pollutant traps (Council)	\$87,514 / unit	Based on IPART's report, adjusted for inflation. https://www.ipart.nsw.gov.au/Home/Industries/Local-Government/Reviews/Benchmark-Costs/Benchmark-costs-for-local-infrastructure-contributions?qDh=2
Sewer mains (Sydney Water)	\$3,303 / meter	https://www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/investigation-legislative-requirements-water-metropolitan-water-sydney-water-corporation-pricing-investigation-commencing-from-1-july-2016/consultants-report-atkins-cardno-sydney-water-corporation-expenditure-review-december-2015.pdf
Water mains (Sydney Water)	\$3,053 / meter	https://www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/investigation-legislative-requirements-water-metropolitan-water-sydney-water-corporation-pricing-investigation-commencing-from-1-july-2016/consultants-report-atkins-cardno-sydney-water-corporation-expenditure-review-december-2015.pdf
Stormwater pipes (Roads and Maritime Services)	\$1,954 / meter	Based on IPART's report, adjusted for inflation. https://www.ipart.nsw.gov.au/Home/Industries/Local-Government/Reviews/Benchmark-Costs/Benchmark-costs-for-local-infrastructure-contributions?qDh=2
Stormwater pits (Roads and Maritime Services)	\$5,725 / unit	Based on IPART's report, adjusted for inflation. https://www.ipart.nsw.gov.au/Home/Industries/Local-Government/Reviews/Benchmark-Costs/Benchmark-costs-for-local-infrastructure-contributions?qDh=2
Gas pipeline (Jemena)	\$200 / meter	http://www.esc.vic.gov.au/wp-content/uploads/esc/bc/bc4d9cee-e9c7-47f8-88ed-df413275e239.pdf
Fibre/cable	\$115 / meter	Based on:

Category	Value	Source
(Optus)		http://www.nbnco.com.au/content/dam/nbnco2/documents/nbn-corporate-plan-2017.pdf
Cable (Telstra)	\$115/ meter	Based on: http://www.nbnco.com.au/content/dam/nbnco2/documents/nbn-corporate-plan-2017.pdf
Cables (Ausgrid)	\$100 / meter	http://www.ausgrid.com.au/Common/Custom-er-Services/Homes/Private-Poles-Home/Repair-costs.aspx#.WAA0qWea2Um

Appendix B: Coastal erosion/ recession probability lines (prepared by Horton Coastal Engineering Pty Ltd)

Appendix B was prepared by Horton Coastal Engineering Pty Ltd.

A total of 20 coastal erosion/recession probability lines have been applied in considering the benefits of coastal protection at Collaroy-Narrabeen Beach. The lines were developed using the same or similar assumptions as applied in the CZMP, namely:

- relationship between storm demand and Average Recurrence Interval (ARI) as per Figure L1 of the CZMP, with a reduction in storm demand due to the effect of the existing protection works of 20%, except as discussed in the two points below
- no reduction in storm demand due to the effect of existing protection works south of The Breakers (1096 Pittwater Road), between Stuart Street and Ramsay Street exclusive, at 1154 and 1156 Pittwater Road, at 1218 Pittwater Road to 2a Goodwin Street inclusive, and north of Marquesas (11 Ocean Street)
- 10% reduction in storm demand due to the effect of existing protection works from north of The Breakers to south of 1104 Pittwater Road
- no consideration for the potential for any built structures (on either piled or conventional foundations) to mitigate the erosion/recession extent
- base profile date of 2006
- 50% probability for long term recession due to net sediment loss of 0.05m/year
- sea level rise derived from IPCC, including regional sea level rise variation, assuming that the 4 representative concentration pathways were equally likely
- 50% probability for the inverse slope of the active beach profile of 30
- long term recession due to sea level rise calculated using the Bruun Rule
- adjustment for beach rotation inherent in the 2006 base profiles
- 50% probability for future beach rotation and uncertainty of 5m over 60 years
- lines located at the landward edge of the Zone of Slope Adjustment.

In the CZMP, only a 60 year planning was considered, applying at 2074. The lines utilised for this benefit distribution assessment have been produced for 4 planning periods, namely Year 0 (now, 2016), Year 20 (2036), Year 40 (2056) and Year 60 (2076). In the CZMP, probability lines were developed assuming a cumulative probability of erosion and recession over a 60-year planning period. In this benefit distribution assessment, event based probabilities have been used.

The sea level rise and future beach rotation and uncertainty values that were applied at Year 20, Year 40 and Year 60 (ie at 2076) are listed below. The Year 60 sea level rise is slightly different to that applied in the CZMP as it applies at 2076, and not 2074 as in the CZMP.

Table 5: Sea level rise and beach rotation

Year	50% probability sea level rise (m)	50% probability future beach rotation and uncertainty (m)
20	0.14	1.7
40	0.27	3.3
60	0.42	5.0

The storm event Annual Exceedance Probabilities (AEPs) and corresponding Average Recurrence Intervals (ARIs) are provided below.

Table 6: Storm event probabilities and years

Storm event (AEP) %	Storm event (ARI) years
20	5
10	10
2.5	40
1.0	100
0.5	200

The erosion/recession probability lines are provided below in Figure 4 to Figure 7:

Figure 4: Year 0 erosion / recession probability lines

Year 0 Lines (at 2016)



Legend

	20 AEP Storm Event
	10 AEP Storm Event
	2.5 AEP Storm Event
	0.1 AEP Storm Event
	0.5 AEP Storm Event

Figure 5: Year 20 erosion / recession probability lines

Year 20 lines (2036)



Legend

	20 AEP Storm Event
	10 AEP Storm Event
	2.5 AEP Storm Event
	0.1 AEP Storm Event
	0.5 AEP Storm Event

Figure 6: Year 40 erosion / recession probability lines

Year 40 Lines (at 2056)



Legend

	20 AEP Storm Event
	10 AEP Storm Event
	2.5 AEP Storm Event
	0.1 AEP Storm Event
	0.5 AEP Storm Event

Figure 7: Year 60 erosion / recession probability lines

Year 60 lines (2076)



Legend

	20 AEP Storm Event
	10 AEP Storm Event
	2.5 AEP Storm Event
	0.1 AEP Storm Event
	0.5 AEP Storm Event