JBP
scientists
and engineers

Clarence Valley Coastline

Coastal Erosion and
Recession Hazard
Assessment

APPENDIX B: EROSION AND
RECESSION TABLES

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Hydrosphere
Consulting

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Revision History

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MO0001 S3.P01 / 27 Sept 2022 Draft for comment		RC
MO0001 S3.P03 / 18 August 2023 Draft	Updated erosion and recession hazard methodology	RC
MO-0001 S3-P04 / 22 August 2023 Draft Report	Minor comments addressed	RC
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Contract

This report describes work commissioned by Robyn Campbell, on behalf of Hydrosphere Consulting Pty Ltd, by a letter dated 15/09/21. Daniel Rodger, Michael Thomson, Emma Walker, Zoe Nehring, and Callan Schonrock of JBP carried out this work.

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Contents

Abbreviations

AEP .... Annual Exceedance Probability

AHD .... Australian Height Datum

CMP .... Coastal Management Program

CVC .... Clarence Valley Council

DEA .... Digital Earth Australia

DEM .... Depth Elevation Model

DoC .... Depth of Closure

EVA .... Extreme Value Analysis

GA .... Geoscience Australia

GPD .... Generalised Pareto Distribution

HAT .... Highest Astronomical Tide

HHWSS .... High High Water Spring Solstice

Hs .... Significant Wave Height

ICOLL .... Intermittently Closed and Open Lakes and Lagoons

IPCC .... Intergovernmental Panel on Climate Change

JBEM .... JBP Beach Evolution Model

LGA .... Local Government Area

LiDAR .... Light Detection and Ranging

NPWS .... National Parks and Wildlife Service

NSW .... New South Whales

OEH .... NSW Office of Environment and Heritage

POT .... Peak Over Threshold

RCP .... Representative Concentration Pathway

SLR .... Sea Level Rise

SSP .... Shared Socio-economic Pathway

SWAN .... Simulating Waves Nearshore

WRL .... NSW Water Research Laboratory

ZRFC .... Zone of Reduced Foundation Capacity

1 Shark Bay

1.1 Recession

Shark Bay beach has been defined by four beach segments following the NSW Beach Profile Database. Figure 1-1 shows the average annual rates of change between 1988 and 2020 from the GA DEA Coastlines rate of change data, with rates and standard deviation for each block shown in Table 1-1. An example triangular distribution for probabilistic modelling is shown in Figure 1-2 for beach block 4.
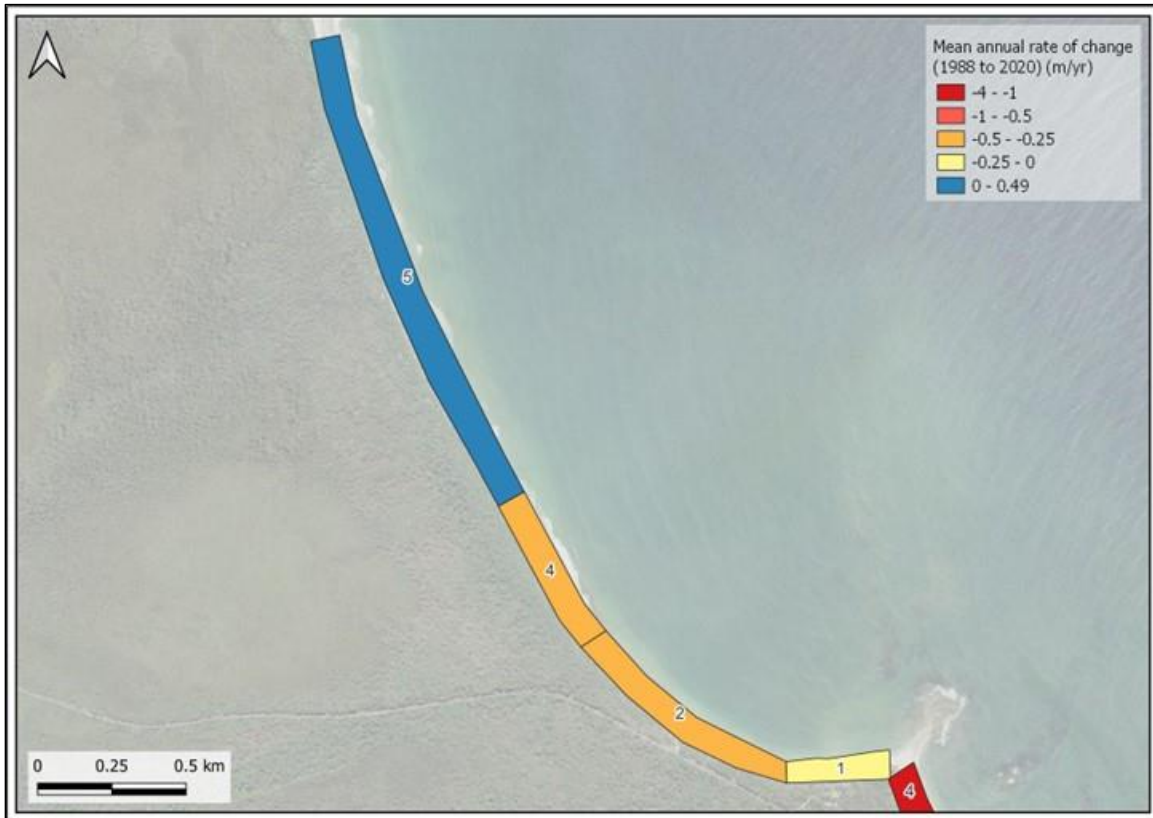

Figure 1-1: Shark Bay beach block mean annual rates of change

Table 1-1: Shark Bay historic annual rates of change

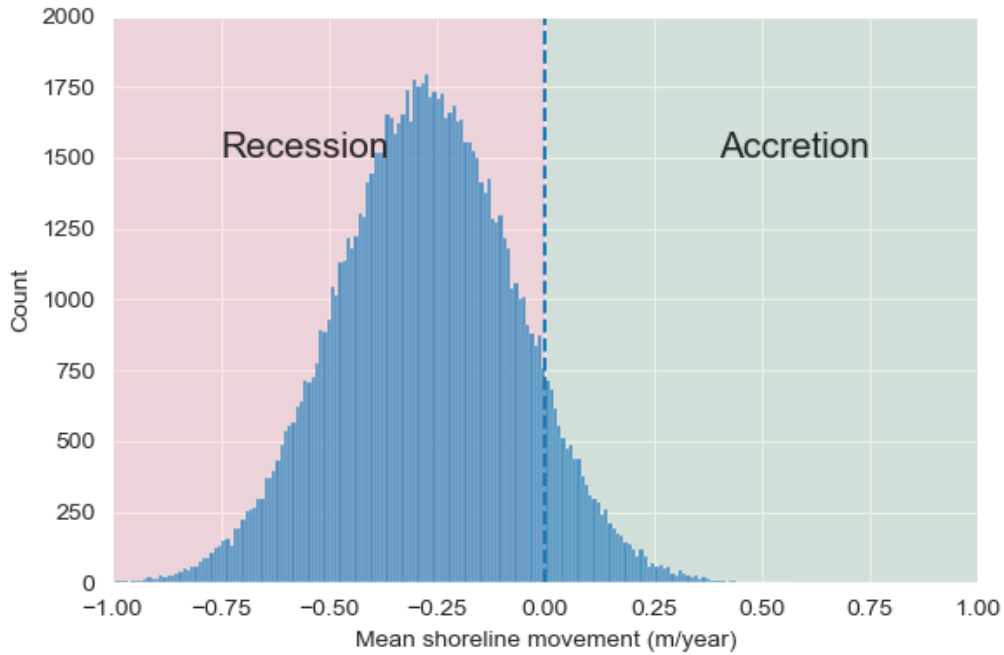| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
1	-0.05	±0.14
2	-0.30	±0.08
4	-0.27	±0.21
5	0.18	±0.22

Figure 1-2: Probabilistic distribution of long-term recession at Shark Bay block 4.

1.2 Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 1-2 and Table 1-3, respectively.

Table 1-2: Shark Bay projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
1	2043	28.4	43.9	71.7
	2073	91.6	142.2	228.5
	2123	149.3	263.0	450.9
2	2043	28.4	43.9	71.7
	2073	91.6	142.2	228.5
	2123	149.3	263.0	450.9
4	2043	21.3	33.2	54.3
	2073	68.4	107.2	178.0
	2123	149.3	263.0	450.9
5	2043	14.2	22.4	36.9
	2073	45.2	72.2	127.4
	2123	76.2	161.1	312.0

Table 1-3: Shark Bay projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
1	2043	33.0	48.8	79.5
	2073	115.2	172.8	272.2
	2123	209.0	363.7	631.1
2	2043	33.0	48.8	79.5
	2073	115.2	172.8	272.2
	2123	209.0	363.7	631.1
4	2043	24.7	36.9	60.1
	2073	86.3	131.2	221.0
	2123	160.8	307.2	514.0
5	2043	16.5	25.0	40.7
	2073	57.4	89.6	169.9
	2123	112.7	250.7	397.0

1.3   Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 1-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992). This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 1-3.

Table 1-4: Shark Bay extreme event-based erosion

Beach block	Exposure factor	50% AEP Erosion (m³/m)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
1	0.58	42	89	129	145
2	0.75	54	114	165	186
3	0.75	54	116	167	189
4	0.69	50	106	154	173
5	0.96	70	148	214	241
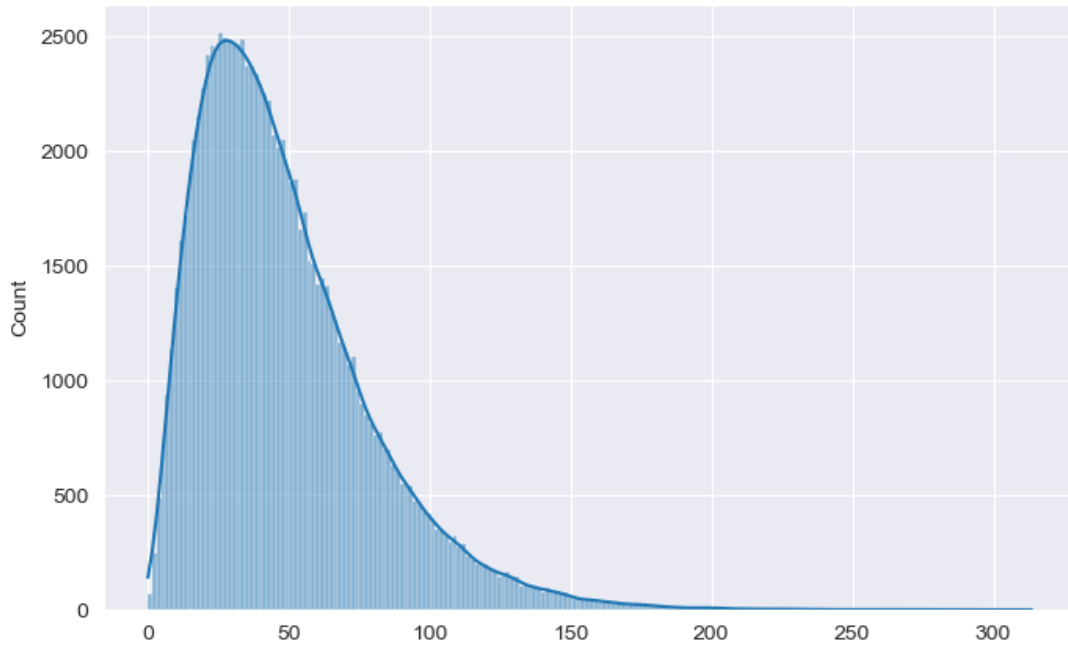
Figure 1-3: Distribution of short-term erosion, and erosion AEPs at Shark Bay Beach Block 3

1.4 Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Shark Bay are shown in Table 1-5 and Table 1-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Shark Bay are shown in Table 1-7 and Table 1-8 for climate change scenarios SSP2 and SSP5, respectively.

The total (non-ZRFC and ZRFC components combined) hazard zone estimates for Shark Bay are shown in Table 1-9 and Table 1-10 for climate change scenarios SSP2 and SSP5, respectively. These have been limited by the alignment of the future projected crenulate shape bay.

Table 1-5: Shark Bay erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	9.7	24.9	38.4	43.9
	2043	26.6	42.7	56.2	61.9
	2073	64.3	85.9	100.9	106.8
	2123	111.8	147.6	167.3	173.7
2	2023	14.1	33.2	48.4	54.6
	2043	35.6	53.8	69.6	75.5
	2073	77.2	97.0	112.0	118.7
	2123	130.7	154.1	166.3	171.2
4	2023	7.8	34.2	50.8	56.4
	2043	33.2	53.0	66.6	72.0
	2073	67.1	86.1	101.4	106.2
	2123	109.7	141.2	163.4	170.9
5	2023	2.9	31.8	43.8	50.8
	2043	7.6	34.4	47.4	55.3
	2073	23.5	44.6	67.0	77.9
	2123	36.5	86.3	130.3	147.5

Table 1-6: Shark Bay erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	9.7	24.9	38.4	43.9
	2043	28.5	44.9	57.7	63.4
	2073	75.7	97.5	113.2	119.1
	2123	147.1	189.1	214.1	221.9
2	2023	14.1	33.2	48.4	54.6
	2043	37.2	55.7	71.2	77.4
	2073	86.4	106.5	122.6	129.6
	2123	154.1	183.1	200.5	205.7
4	2023	7.8	34.2	50.8	56.4
	2043	35.0	54.0	67.1	72.8
	2073	74.6	94.7	109.1	114.2
	2123	133.2	172.8	196.9	207.0
5	2023	2023	2.9	31.8	43.8
	2043	8.9	34.7	47.7	55.3
	2073	30.0	51.4	77.9	88.6
	2123	52.7	117.3	166.3	185.1

Table 1-7: Shark Bay ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	6.6	6.6	6.6	6.4
	2043	6.6	6.6	6.4	6.6
	2073	6.6	6.4	6.4	6.6
	2123	6.9	7.1	7.1	6.9
2	2023	7.3	6.8	6.8	7.1
	2043	6.8	7.1	7.1	7.3
	2073	7.3	6.8	7.1	7.3
	2123	9.5	8.2	8.2	8.2
4	2023	5.4	7.2	7.0	7.0
	2043	7.0	7.0	7.5	7.2
	2073	7.5	7.0	7.5	7.0
	2123	7.0	6.7	7.0	6.7
5	2023	6.3	7.0	6.0	6.0
	2043	7.3	6.5	6.0	6.0
	2073	9.1	6.3	6.0	6.0
	2123	6.5	6.0	5.5	5.5

Table 1-8: Shark Bay ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	6.6	6.6	6.6	6.4
	2043	6.6	6.4	6.4	6.9
	2073	6.6	6.4	6.9	6.6
	2123	7.1	6.4	6.6	6.6
2	2023	7.3	6.8	6.8	7.1
	2043	6.8	7.1	7.1	7.3
	2073	7.1	6.8	8.7	9.8
	2123	8.2	8.7	9.2	9.5
4	2023	5.4	7.2	7.0	7.0
	2043	7.2	7.0	7.5	7.2
	2073	7.2	8.0	7.0	7.0
	2123	6.7	6.7	6.2	6.2
5	2023	6.3	7.0	6.0	6.0
	2043	7.8	6.5	6.0	6.0
	2073	7.3	6.0	6.0	6.0
	2123	6.0	5.5	5.5	5.2

Table 1-9: Shark Bay total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	16.4	31.6	45.1	50.3
	2043	33.2	49.4	62.7	68.6
	2073	71.0	92.3	107.3	113.4
	2123	118.7	154.7	174.4	180.6
2	2023	21.5	39.9	55.2	61.7
	2043	42.4	60.9	76.6	82.9
	2073	84.5	103.8	119.0	126.1
	2123	140.2	162.2	174.5	179.3
4	2023	13.1	41.5	57.8	63.4
	2043	40.1	59.9	74.1	79.2
	2073	74.6	93.1	108.9	113.2
	2123	116.6	147.9	**148***	**148***
5	2023	9.1	38.8	49.8	56.8
	2043	14.9	40.9	53.4	61.3
	2073	32.6	50.8	73.0	83.9
	2123	43.0	92.3	135.8	**152***
*limited by parabolic shoreline model - refer to maps					

Table 1-10: Shark Bay total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	16.4	31.6	45.1	50.3
	2043	35.1	51.3	64.1	70.2
	2073	82.4	103.9	120.1	125.8
	2123	154.3	195.6	220.7	228.5
2	2023	21.5	39.9	55.2	61.7
	2043	44.0	62.8	78.3	84.8
	2073	93.5	113.3	131.2	139.4
	2123	162.2	191.8	209.8	215.2
4	2023	13.1	41.5	57.8	63.4
	2043	42.3	61.0	74.6	80.0
	2073	81.9	102.7	116.1	121.2
	2123	139.9	**148***	**148***	**148***
5	2023	9.1	38.8	49.8	56.8
	2043	16.7	41.2	53.7	61.3
	2073	37.3	57.3	83.9	94.6
	2123	58.7	122.8	**152***	**152***
*limited by parabolic shoreline model - refer to maps					

2 Woody Bay, Iluka

2.1 Recession

The beach has been represented by three beach blocks. Figure 2-1 shows the average annual rate of change, with rates and standard deviation for each block shown in Table 2-1. An example triangular distribution for probabilistic modelling is shown in Figure 2-2 for beach block 3.
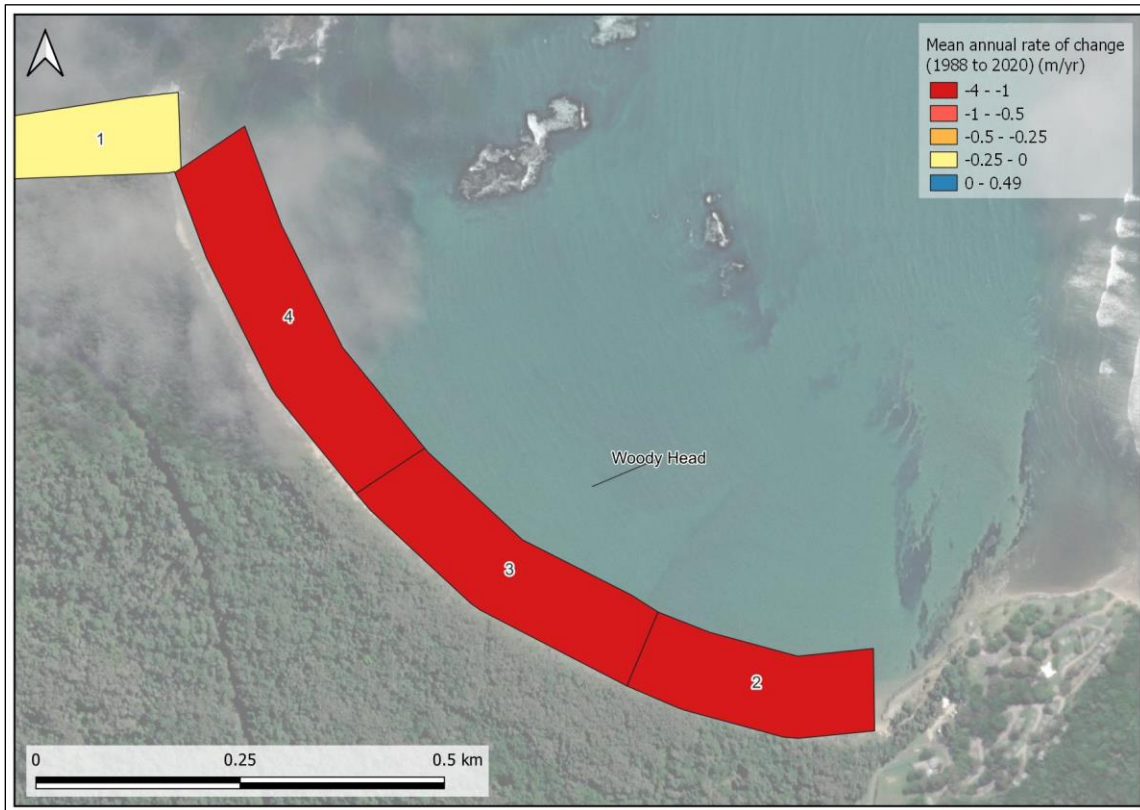

Figure 2-1: Woody Bay beach block mean annual rates of change

Table 2-1: Woody Bay historic annual rates of change

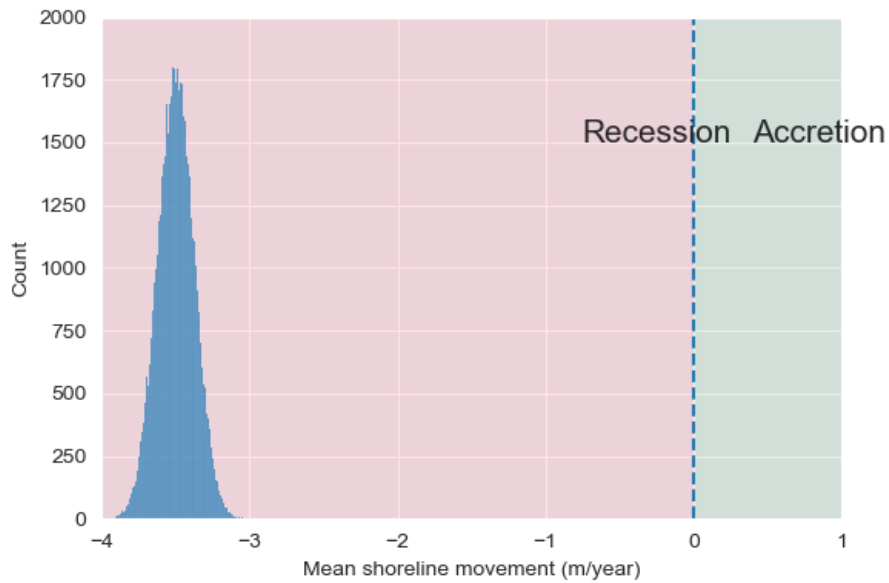| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
2	-2.89	± 0.08
3	-3.50	± 0.13
4	-3.59	± 0.17

Figure 2-2: Probabilistic distribution of long-term recession at Woody Bay beach block 3

2.2 Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 2-2 and Table 2-3, respectively.

Table 2-2: Woody Head projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m^3/m)	50th percentile SLR erosion (m^3/m)	100th percentile SLR erosion (m^3/m)
2	2043	38.4	59.4	91.0
	2073	115.5	167.6	257.3
	2123	174.6	294.9	487.1
3	2043	38.4	59.4	91.0
	2073	115.5	167.6	257.3
	2123	174.6	294.9	487.1
4	2043	38.4	59.4	91.0
	2073	115.5	167.6	257.3
	2123	174.6	294.9	487.1

Table 2-3: Woody Head projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
2	2043	45.0	65.5	98.7
	2073	139.7	198.7	305.1
	2123	236.2	397.5	627.4
3	2043	45.0	65.5	98.7
	2073	139.7	198.7	305.1
	2123	236.2	397.5	627.4
4	2043	45.0	65.5	98.7
	2073	139.7	198.7	305.1
	2123	236.2	397.5	627.4

2.3 Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 2-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992). This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 2-3.

Table 2-4: Woody Head extreme event-based erosion

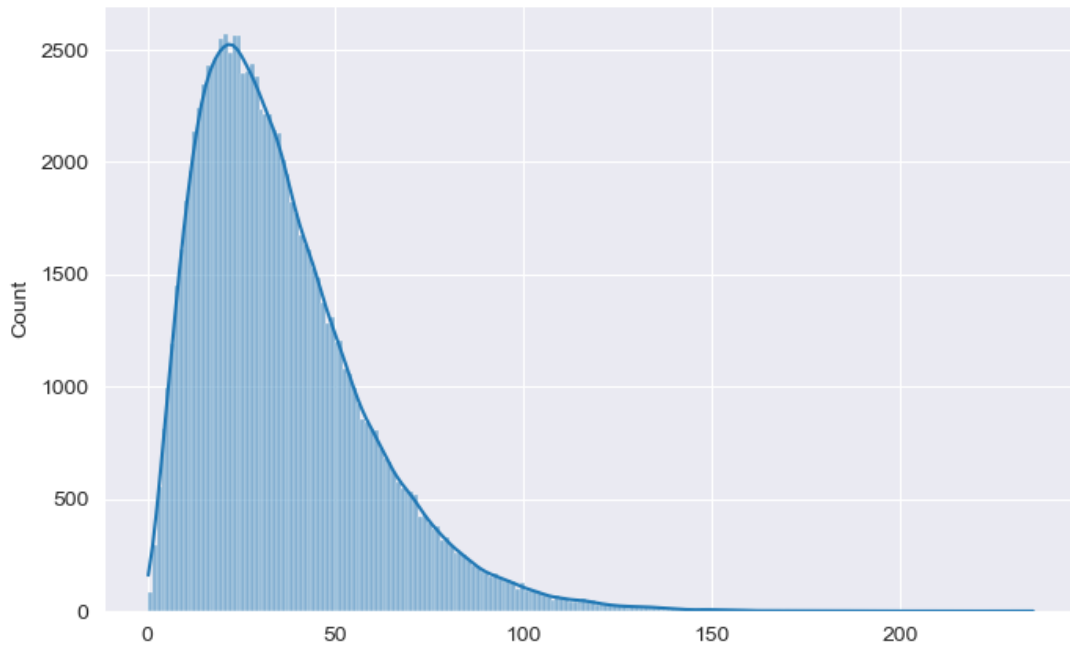| Beach block	Exposure factor	50% AEP Erosion (m³/m)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
2	0.42	30	64	92	104
3	0.43	31	66	96	108
4	0.45	32	69	99	112

Figure 2-3: Distribution of short-term erosion, erosion AEPs for Woody Bay Beach Block 3

2.4 Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Woody Bay are shown in Table 2-5 and Table 2-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Woody Bay are shown in Table 2-7 and Table 2-8 for climate change scenarios SSP2 and SSP5, respectively.

The total (non-ZRFC and ZRFC components combined) estimates for Woody Bay are shown in Table 2-9 and Table 2-10 for climate change scenarios SSP2 and SSP5, respectively. These have been limited by the alignment of the future projected crenulate shape bay.

Table 2-5: Woody Bay erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	9.1	23.5	35.8	40.9
	2043	88.0	102.2	113.5	117.7
	2073	203.0	215.5	223.3	226.3
	2123	295.1	316.0	327.3	330.5
3	2023	5.6	18.5	29.0	33.4
	2043	89.4	101.7	111.3	115.7
	2073	216.8	235.3	246.7	249.6
	2123	346.5	369.2	381.9	385.7
4	2023	10.1	22.9	33.6	38.0
	2043	99.9	111.6	120.8	124.2
	2073	224.0	242.8	256.2	261.0
	2123	452.6	512.8	545.6	557.4

Table 2-6: Woody Bay erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	9.1	23.5	35.8	40.9
	2043	90.5	104.7	116.4	121.1
	2073	210.3	224.1	231.7	234.3
	2123	312.5	337.8	347.9	351.3
3	2023	5.6	18.5	29.0	33.4
	2043	91.4	103.7	113.7	117.8
	2073	225.6	246.7	254.3	256.9
	2123	363.3	390.9	403.7	407.8
4	2023	10.1	22.9	33.6	38.0
	2043	101.8	113.3	122.2	125.9
	2073	232.1	254.5	268.2	273.0
	2123	491.8	559.9	600.5	616.2

Table 2-7: Woody Bay ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	5.9	5.9	5.9	5.9
	2043	6.1	6.1	6.1	6.4
	2073	8.1	8.6	8.8	8.6
	2123	7.8	9.1	9.6	9.1
3	2023	6.2	6.4	6.4	6.4
	2043	6.7	6.4	6.2	6.4
	2073	6.4	9.7	8.5	8.5
	2123	7.7	8.2	8.5	8.5
4	2023	6.4	6.4	6.4	6.4
	2043	7.0	7.3	7.3	7.3
	2073	6.4	6.4	6.7	7.3
	2123	5.3	5.6	5.3	5.3

Table 2-8: Woody Bay ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	5.9	5.9	5.9	5.9
	2043	6.1	6.1	6.1	6.4
	2073	8.1	8.6	8.6	8.6
	2123	9.1	8.3	8.8	9.1
3	2023	6.2	6.4	6.4	6.4
	2043	6.7	6.4	6.2	6.4
	2073	6.7	8.5	8.5	8.6
	2123	8.3	8.2	8.5	8.8
4	2023	6.4	6.4	6.4	6.4
	2043	7.3	7.3	7.3	7.3
	2073	6.2	6.7	7.8	8.1
	2123	5.3	5.3	5.0	4.8

Table 2-9: Woody Bay total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	15.0	29.4	41.7	46.8
	2043	94.1	108.3	119.6	124.0
	2073	**211***	**211***	**211***	**211***
	2123	**211***	**211***	**211***	**211***
3	2023	11.7	24.9	35.5	39.8
	2043	96.1	108.1	117.5	122.2
	2073	223.3	244.9	**246.8***	**246.8***
	2123	**246.8***	**246.8***	**246.8***	**246.8***
4	2023	16.5	29.4	40.0	44.5
	2043	106.8	118.9	128.1	131.5
	2073	230.5	249.2	262.9	268.2
	2123	**436.8***	**436.8***	**436.8***	**436.8***
*limited by parabolic shoreline model					

Table 2-10: Woody Bay total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	15.0	29.4	41.7	46.8
	2043	96.6	110.8	122.6	127.5
	2073	**211***	**211***	**211***	**211***
	2123	**211***	**211***	**211***	**211***
3	2023	11.7	24.9	35.5	39.8
	2043	98.1	110.2	119.8	124.2
	2073	232.3	**246.8***	**246.8***	**246.8***
	2123	**246.8***	**246.8***	**246.8***	**246.8***
4	2023	16.5	29.4	40.0	44.5
	2043	109.1	120.5	129.5	133.1
	2073	238.3	261.2	276.1	281.1
	2123	**436.8***	**436.8***	**436.8***	**436.8***
*limited by parabolic shoreline model					

3 Whiting Beach

3.1 Recession

Whiting Beach has been split into two sections, an eastern block (Yamba 7) and a western block (Yamba 8). The eastern block at Whiting is exposed to wave action from offshore swell entering the estuary (described below). The western section is exposed to tidal processes only, due to its orientation and sheltered location within the estuary. An example normal distribution for probabilistic modelling is shown in Figure 3-2 for block 8.

Figure 3-1: Whiting Beach mean annual rate of change

Table 3-1: Whiting Beach historic annual rates of change

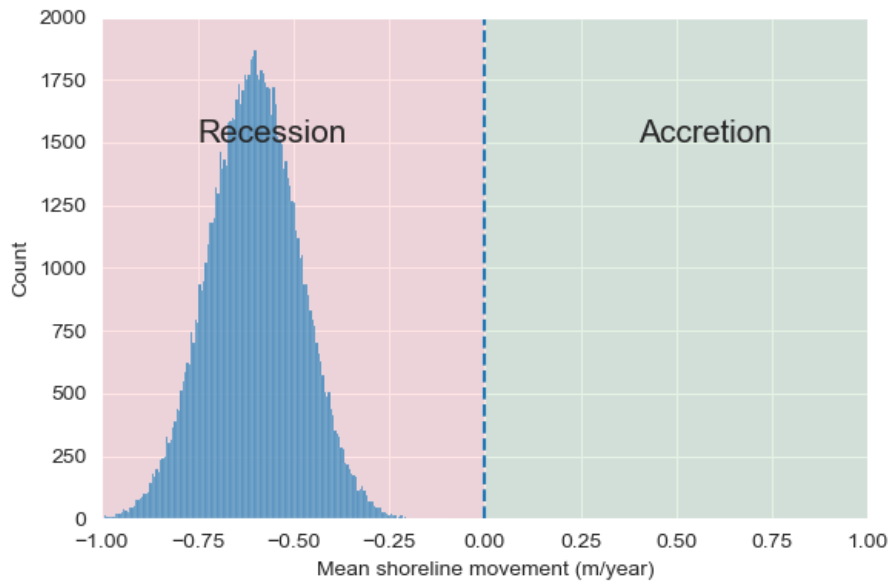| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
7	-1.03	±0.11
8	-0.60	±0.12

Figure 3-2: Probabilistic distribution of long-term recession at Whiting beach block 8.

3.2 Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 3-2 and Table 3-3, respectively.

Table 3-2: Whiting Beach projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
7	2043	2.3	5.7	14.4
	2073	3.4	18.6	59.6
	2123	21.3	75.4	129.7
8	2043	2.3	5.7	14.4
	2073	3.4	18.6	59.6
	2123	21.3	75.4	129.7

Table 3-3: Whiting Beach projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
7	2043	0.2	2.2	13.3
	2073	10.0	31.7	79.1
	2123	49.8	107.7	151.7
8	2043	0.2	2.2	13.3
	2073	10.0	31.7	79.1
	2123	49.8	107.7	151.7

3.3   Additional erosion analysis

New analysis was undertaken to consider the potential for swell waves to penetrate through the harbour breakwalls and cause erosion. This approach is detailed within the main report Coastal Erosion and Recession Hazard Mapping (JBP 2023). The nearshore waves were extracted at the -2m AHD depth contour at the beach and used to adjust the event-based erosion probability distribution. Beach block 8 is not impacted by short-term erosion, only long-term processes. Table 3-4 shows the estimated erosion widths. The distribution of short-term erosion and erosion AEPs are shown in Figure 3-3.

Table 3-4: Extreme event-based erosion at Whiting Beach (based on residual swell waves)

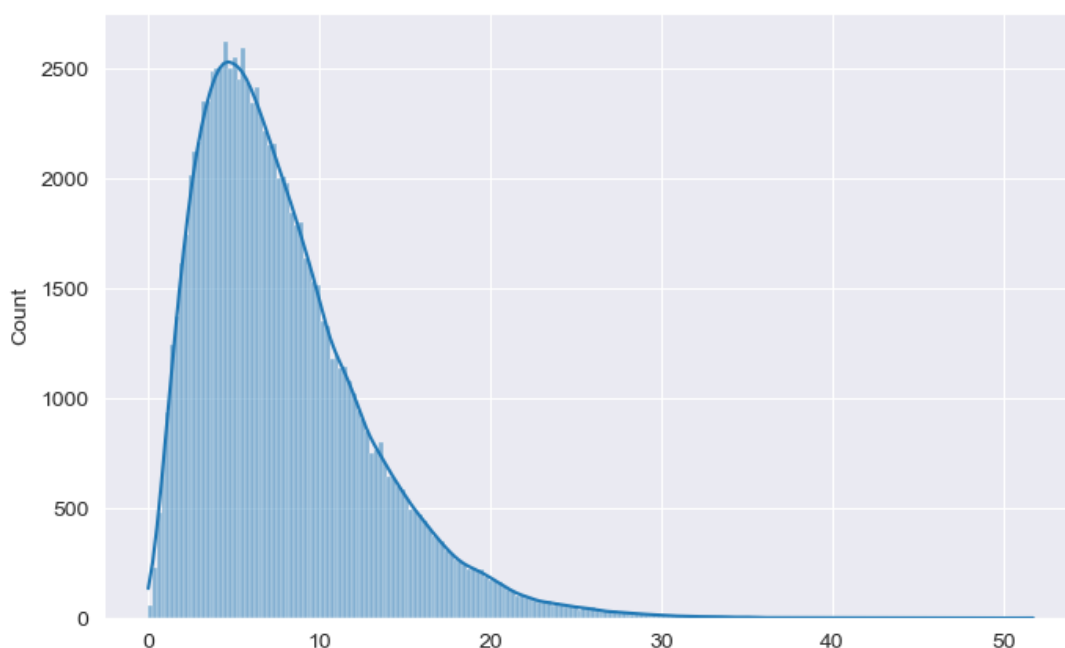| Beach block	Exposure factor	50% AEP Erosion (m^3/m)	10% AEP Erosion (m^3/m)	2% AEP Erosion (m^3/m)	1% AEP Erosion (m^3/m)
7	0.10	7	15	21	24
8	0.00	0	0	0	0

Figure 3-3: Distribution of short-term erosion, erosion AEPs for Whiting Beach block 7.

3.4   Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Whiting Beach are shown in Table 3-5 and Table 3-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Whiting Beach are shown in Table 3-7 and Table 3-8 for climate change scenarios SSP2 and SSP5, respectively.

The hazard zone estimates for Whiting Beach is shown in Table 3-9 and Table 3-10 for climate change scenarios SSP2 and SSP5, respectively. These have been limited by the extent of Hickey Island.

Table 3-5: Whiting Beach erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
7	2023	0.0	0.0	1.3	3.1
	2043	24.0	27.4	31.0	32.8
	2073	106.2	381.0	395.5	399.3
	2123	505.2	533.4	547.3	552.5
8	2023	0.0	0.0	0.0	0.0
	2043	18.9	24.7	28.5	30.5
	2073	87.3	120.1	139.2	145.5
	2123	248.1	316.7	341.0	357.9

Table 3-6: Whiting Beach erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
7	2023	0.0	0.0	1.3	3.1
	2043	23.5	26.6	29.7	31.5
	2073	114.5	391.6	403.0	406.6
	2123	514.0	540.1	553.5	558.2
8	2023	0.0	0.0	0.0	0.0
	2043	17.3	22.8	26.6	28.3
	2073	103.6	139.1	158.7	165.6
	2123	285.8	339.3	399.8	834.5

Table 3-7: Whiting Beach ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
7	2023	4.9	7.2	8.0	8.3
	2043	4.4	4.4	4.9	4.9
	2073	4.7	5.4	5.4	5.4
	2123	5.4	5.9	6.5	6.7
8	2023	7.1	7.1	7.1	7.1
	2043	4.4	3.9	3.8	3.6
	2073	3.9	4.0	3.9	4.0
	2123	3.6	3.7	3.0	3.1

Table 3-8: Whiting Beach ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
7	2023	4.9	7.2	8.0	8.3
	2043	4.4	4.7	4.9	4.9
	2073	4.4	5.2	5.2	5.2
	2123	5.4	5.9	7.0	7.2
8	2023	7.1	7.1	7.1	7.1
	2043	4.5	4.1	4.0	3.8
	2073	3.9	3.9	3.9	3.9
	2123	3.7	3.0	2.7	5.8

Table 3-9: Whiting Beach total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
7	2023	4.9	7.2	9.3	11.4
	2043	28.4	31.8	35.9	37.7
	2073	110.9	386.4	400.9	404.8
	2123	440*	440*	440*	440*
8	2023	7.1	7.1	7.1	7.1
	2043	23.4	28.5	32.3	34.1
	2073	91.2	124.0	143.1	149.6
	2123	251.7	320.4	343.9	361.0
*limited by estuary - refer to maps					

Table 3-10: Whiting Beach total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
7	2023	4.9	7.2	9.3	11.4
	2043	27.9	31.3	34.6	36.4
	2073	118.9	396.8	408.1	411.7
	2123	440*	440*	440*	440*
8	2023	7.1	7.1	7.1	7.1
	2043	21.8	26.9	30.5	32.1
	2073	107.5	143.0	162.6	169.6
	2123	289.5	342.2	402.5	500*
*limited by estuary - refer to maps					

4 Yamba Beaches (Pippi Beach)

4.1 Recession

The headland at Yamba includes small pocket beaches of Convent Beach, Main Beach, and Turners Beach, as well as the south-east facing Pippi Beach between Barri Point and Yamba Point. The east-facing pocket beaches in this section are controlled by rocky headlands, with Turners Beach controlled by Clarence Head and the southern Clarence River breakwall and as a result has not been included in this assessment. Convent Beach and Main Beach have also not been included in this assessment as it was determined through consult with Council that slope stability of high-crested cliffs will be the primary hazard at these locations, which will be considered in a separate assessment.

Pippi Beach have been defined by four beach segments. Figure 4-1 shows the average annual rate of change between 1988 and 2020 from the GA DEA Coastlines dataset and nearshore wave roses, with rates and standard deviations shown in Table 4-1. An example normal distribution for probabilistic modelling is shown in Figure 4-2 for block 2.

Figure 4-1: Pippi beach blocks mean annual rates of change

Table 4-1: Pippi beach historic annual rates of change

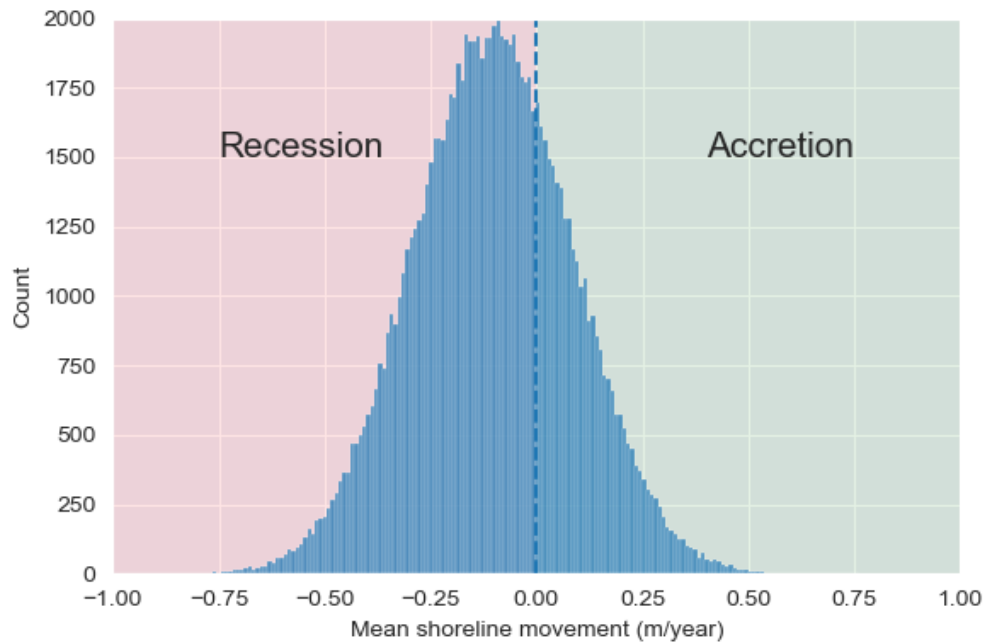| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
1	-0.03	± 0.14
2	-0.10	± 0.19
3	-0.07	± 0.31
4	-0.04	± 0.26

Figure 4-2: Probabilistic distribution of long-term recession at Pippi beach block 2

4.2   Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 4-2 and Table 4-3, respectively.

Table 4-2: Pippi Beach projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m^3/m)	50th percentile SLR erosion (m^3/m)	100th percentile SLR erosion (m^3/m)
1	2043	7.8	12.3	21.1
	2073	25.2	44.4	90.1
	2123	88.4	190.2	427.5
2	2043	7.8	12.3	21.1
	2073	25.2	44.4	90.1
	2123	88.4	190.2	427.5
3	2043	7.8	12.3	21.1
	2073	25.2	44.4	90.1
	2123	88.4	190.2	427.5
4	2043	7.8	12.3	21.1
	2073	25.2	44.4	90.1
	2123	88.4	190.2	427.5

Table 4-3: Pippi Beach projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
1	2043	9.1	13.9	23.6
	2073	33.3	58.7	118.0
	2123	136.4	305.3	660.3
2	2043	9.1	13.9	23.6
	2073	33.3	58.7	118.0
	2123	136.4	305.3	660.3
3	2043	9.1	13.9	23.6
	2073	33.3	58.7	118.0
	2123	136.4	305.3	660.3
4	2043	9.1	13.9	23.6
	2073	33.3	58.7	118.0
	2123	136.4	305.3	660.3

4.3   Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 4-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992). This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 2-3.

Table 4-4:   Pippi Beach extreme event-based erosion

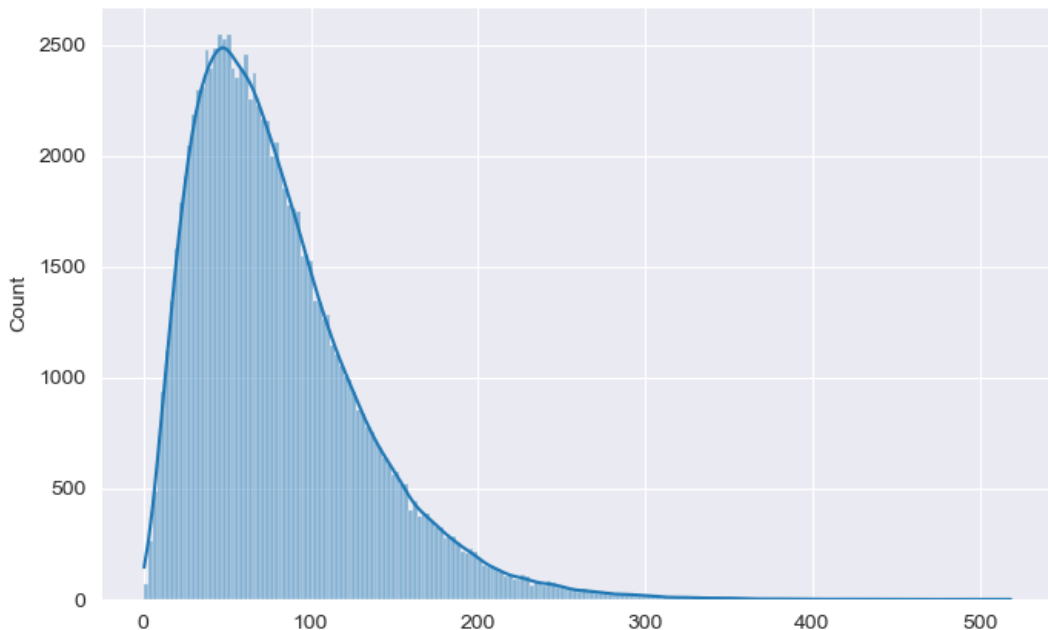| Beach block	Exposure factor	50% AEP Erosion (m³/m)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
1	0.97	70	148	215	242
2	0.97	70	148	215	242
3	0.99	71	151	219	247
4	0.84	60	128	185	209

Figure 4-3: Distribution of short-term erosion, erosion AEPs for Yamba Beach Block 2

4.4 Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Pippi Beach are shown in Table 4-5 and Table 4-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Pippi Beach are shown in Table 4-7 and Table 4-8 for climate change scenarios SSP2 and SSP5, respectively.

The hazard zone estimates for Pippi Beach are shown in Table 4-9 and Table 4-10 for climate change scenarios SSP2 and SSP5, respectively.

Table 4-5: Pippi Beach erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	19.0	41.9	54.8	59.0
	2043	25.8	46.8	58.2	62.8
	2073	39.7	58.2	70.9	75.8
	2123	75.0	97.4	109.1	113.3
2	2023	11.5	35.9	48.7	52.6
	2043	24.4	44.3	54.5	58.2
	2073	41.6	60.0	72.3	76.7
	2123	74.9	106.1	123.9	128.3
3	2023	16.3	40.0	54.6	59.7
	2043	28.9	55.7	72.0	80.6
	2073	44.6	94.3	109.1	112.8
	2123	91.1	156.2	175.4	181.7
4	2023	11.1	30.2	41.1	45.0
	2043	19.8	37.1	47.3	51.5
	2073	31.4	54.9	67.8	71.8
	2123	64.6	98.0	133.4	133.4

Table 4-6: Pippi Beach erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	19.0	41.9	54.8	59.0
	2043	26.3	47.3	58.5	63.1
	2073	43.4	61.1	74.3	78.9
	2123	92.3	115.2	128.1	132.8
2	2023	11.5	35.9	48.7	52.6
	2043	24.9	44.8	55.0	58.4
	2073	44.5	62.1	74.7	78.8
	2123	92.7	124.9	139.6	144.9
3	2023	16.3	40.0	54.6	59.7
	2043	29.4	56.0	72.3	81.1
	2073	47.7	96.3	109.7	113.4
	2123	106.0	167.1	184.0	190.2
4	2023	11.1	30.2	41.1	45.0
	2043	20.0	37.6	47.8	52.0
	2073	35.4	57.9	69.8	73.7
	2123	81.9	133.4	133.4	133.4

Table 4-7: Pippi Beach ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	8.3	10.7	11.0	12.2
	2043	9.7	10.0	11.9	13.4
	2073	10.7	11.9	13.9	13.4
	2123	13.6	12.4	11.7	11.2
2	2023	8.6	12.0	10.7	10.5
	2043	11.0	11.0	10.5	10.7
	2073	11.3	11.3	11.8	12.3
	2123	11.8	15.5	13.4	13.9
3	2023	8.6	8.9	8.3	9.1
	2043	8.6	8.6	15.7	15.7
	2073	9.4	13.4	10.6	11.4
	2123	14.3	20.9	27.1	27.7
4	2023	9.7	10.1	10.6	11.4
	2043	9.4	10.1	11.9	11.9
	2073	10.1	11.6	10.9	10.4
	2123	10.9	6.2	0.0	0.0

Table 4-8: Pippi Beach ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	8.5	10.7	11.0	12.4
	2043	9.7	10.0	12.2	13.4
	2073	10.7	12.7	13.6	13.2
	2123	12.4	11.2	10.0	9.5
2	2023	8.6	12.0	10.7	10.5
	2043	11.3	11.0	10.5	11.0
	2073	11.0	11.8	11.8	12.6
	2123	12.8	13.4	13.7	14.2
3	2023	8.6	8.9	8.3	9.1
	2043	8.6	8.6	15.7	16.0
	2073	9.4	12.9	10.9	11.7
	2123	10.9	24.3	27.4	27.1
4	2023	9.7	10.1	10.6	11.4
	2043	9.7	10.1	12.1	11.9
	2073	9.7	10.9	10.6	10.1
	2123	9.2	0.0	0.0	0.0

Table 4-9: Pippi Beach total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	27.3	52.6	65.8	71.1
	2043	35.6	56.8	70.2	76.2
	2073	50.4	70.2	84.8	89.2
	2123	88.7	109.9	120.8	124.5
2	2023	20.2	47.9	59.5	63.1
	2043	35.4	55.3	65.0	68.9
	2073	52.9	71.2	84.1	89.1
	2123	86.7	121.5	137.3	142.3
3	2023	24.9	48.8	62.8	68.8
	2043	37.4	64.3	87.7	96.3
	2073	54.0	107.7	119.7	124.3
	2123	105.4	177.1	202.5	209.4
4	2023	20.8	40.3	51.7	56.4
	2043	29.2	47.3	59.1	63.4
	2073	41.6	66.6	78.7	82.2
	2123	75.5	104.2	133.4	133.4

Table 4-10: Pippi Beach total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	27.3	52.6	65.8	71.1
	2043	36.1	57.2	70.6	76.5
	2073	54.1	73.8	87.9	92.1
	2123	104.7	126.4	138.1	142.3
2	2023	20.2	47.9	59.5	63.1
	2043	36.1	55.8	65.5	69.4
	2073	55.5	73.9	86.4	91.4
	2123	105.6	138.3	153.3	159.1
3	2023	24.9	48.8	62.8	68.8
	2043	38.0	64.6	88.0	97.1
	2073	57.1	109.1	120.5	125.1
	2123	116.8	191.4	211.4	217.4
4	2023	20.8	40.3	51.7	56.4
	2043	29.7	47.8	59.9	63.8
	2073	45.0	68.8	80.4	83.9
	2123	91.1	133.4	133.4	133.4

5 Angourie (Spooky Head)

5.1 Recession

Spooky Beach has been represented as one beach segment (Angourie 3). Figure 5-1 shows the average annual rate of change between 1988 and 2020 from the GA DEA Coastlines dataset and nearshore wave roses, with rates and standard deviations shown in Table 5-1. An example triangular distribution for probabilistic modelling is shown in Figure 5-2 for block 3.

Figure 5-1: Angourie blocks mean annual rates of change.

Table 5-1: Angourie beach historic annual rates of change

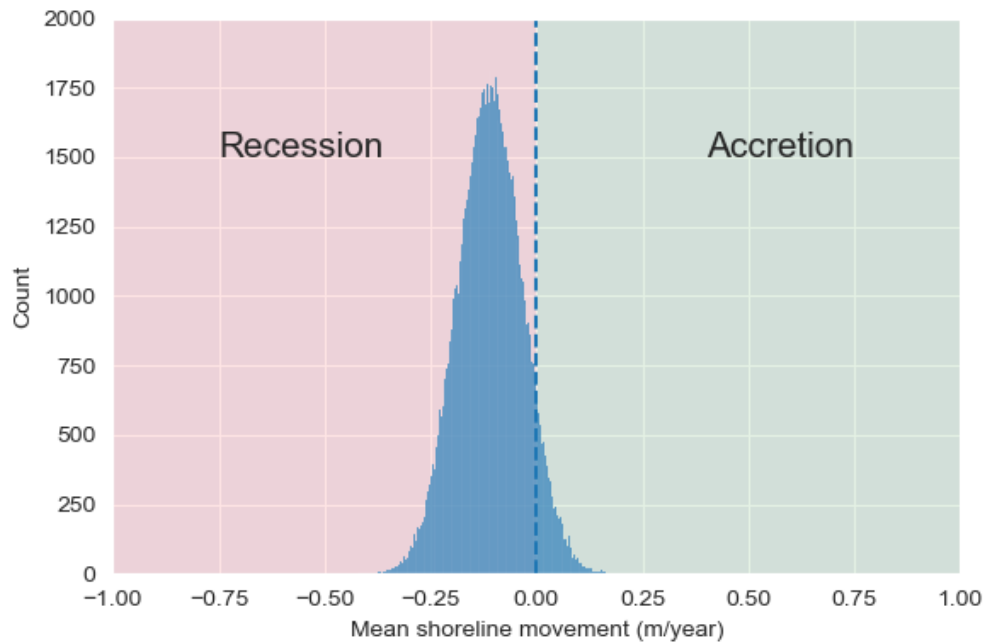| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
3	-0.11	±0.08

Figure 5-2: Probabilistic distribution of long-term recession at Angourie beach block 3.

5.2 Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 5-2 and Table 5-3, respectively.

Table 5-2: Angourie projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
3	2043	5.0	8.1	13.7
	2073	15.5	26.6	55.2
	2123	50.3	200.2	429.4

Table 5-3: Angourie projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
3	2043	5.9	9.2	15.2
	2073	20.3	34.7	115.2
	2123	132.0	319.0	676.8

5.3   Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 5-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992). This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 5-3.

Table 5-4:   Angourie extreme event-based erosion

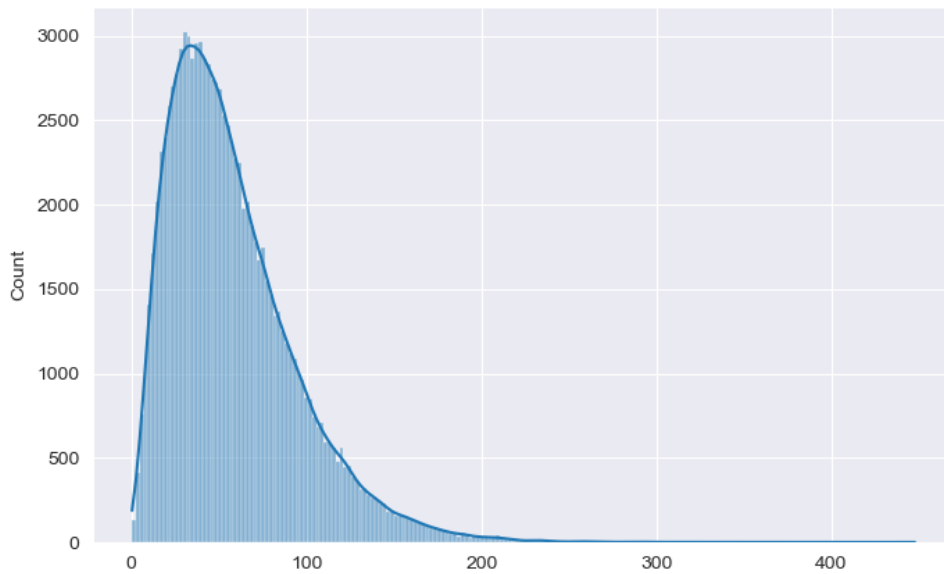| Beach block	Exposure factor	50% AEP Erosion (m³/m)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
3	0.7	50.47672	107.1413	155.3027	175

Figure 5-3: Distribution of short-term erosion, erosion AEPs for Angourie Beach Block 3

5.4   Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Angourie Beach are shown in Table 5-5 and Table 5-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Angourie Beach are shown in Table 5-7 and Table 5-8 for climate change scenarios SSP2 and SSP5, respectively.

The hazard zone estimates for Angourie are shown in Table 5-9 and Table 5-10 for climate change scenarios SSP2 and SSP5, respectively.

Table 5-5: Angourie erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	23.8	26.8	29.8	31.8
	2043	26.0	29.5	34.2	36.2
	2073	30.4	38.7	43.1	44.5
	2123	55.8	79.0	92.8	96.1

Table 5-6: Angourie erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	23.8	26.8	29.8	31.8
	2043	26.0	29.5	34.2	36.2
	2073	32.6	41.1	44.7	46.4
	2123	76.5	98.6	107.2	109.7

Table 5-7: Angourie ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	7.7	13.0	13.3	12.4
	2043	12.2	13.5	11.0	10.2
	2073	13.0	10.2	12.4	13.5
	2123	20.4	22.9	18.8	18.8

Table 5-8: Angourie ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	7.7	13.0	13.3	12.4	7.7
	12.2	13.5	11.0	10.2	12.2
	11.9	10.8	14.4	20.2	11.9
	22.1	19.1	20.4	21.0	22.1

Table 5-9: Angourie total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	31.5	39.8	43.1	44.2
	2043	38.1	43.1	45.3	46.4
	2073	43.4	48.9	55.5	58.0
	2123	76.2	101.9	111.6	114.9

Table 5-10: Angourie total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	31.5	39.8	43.1	44.2
	2043	38.1	43.1	45.3	46.4
	2073	44.5	51.9	59.1	66.6
	2123	98.6	117.7	127.6	130.7

6 Brooms Head Beach

6.1 Recession

Brooms Head Beach has been defined by three segments. The row of private residences along Ocean Road at the entrance to Lake Cakora have been mapped as part of segment 2. Figure 6-1 shows the average annual rate of change, with rates and standard deviation for each block shown in Table 6-1. An example triangular distribution for probabilistic modelling is shown in Figure 6-2 for beach block 2.
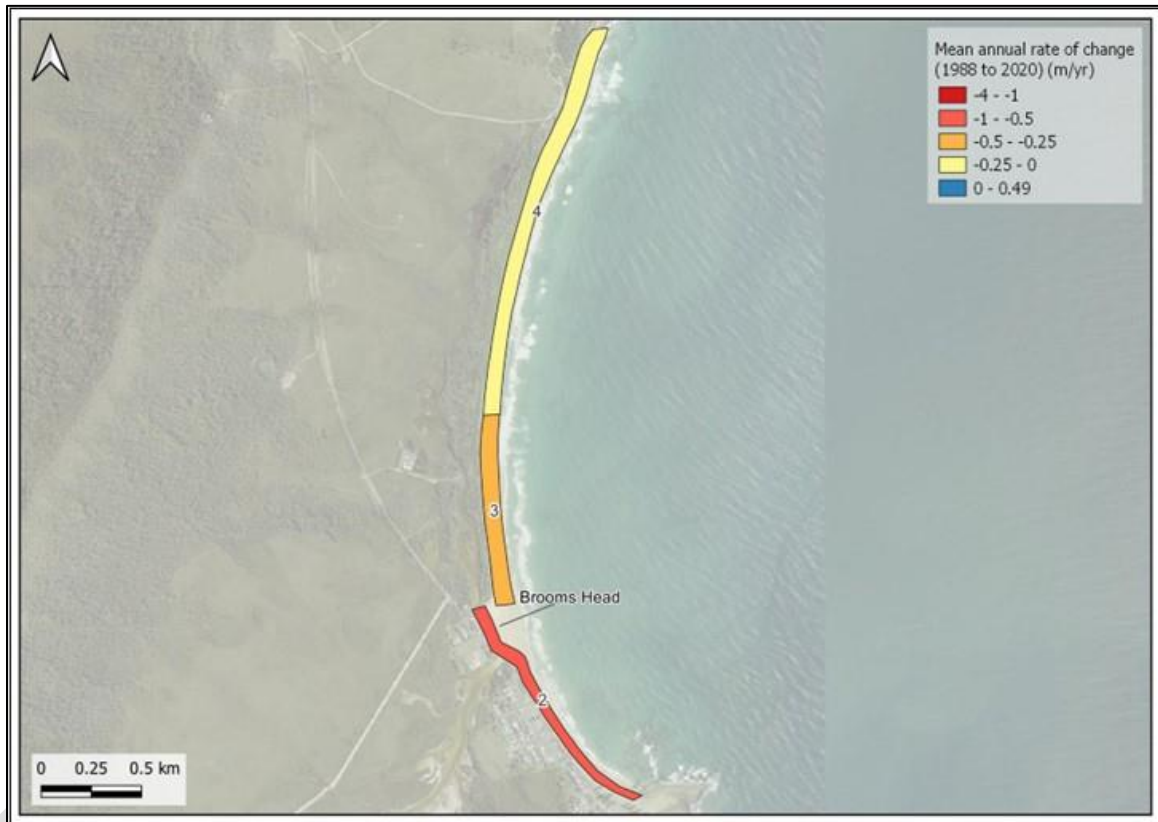

Figure 6-1: Brooms Head beach blocks mean annual rates of change

Table 6-1: Brooms Head historic annual rates of change

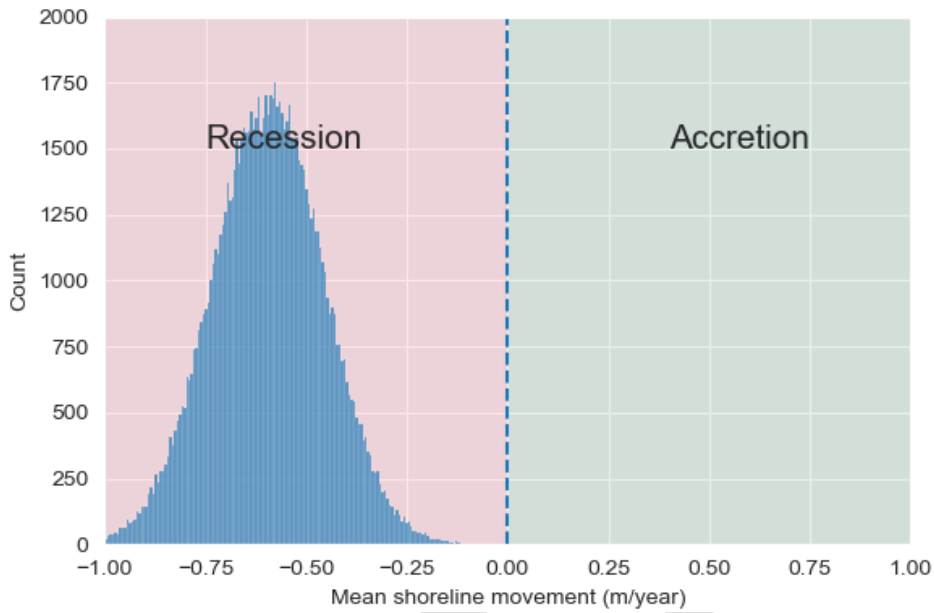| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
1	-0.26	± 0.07
2	-0.60	± 0.14
3	-0.49	± 0.13
4	-0.15	± 0.09

Figure 6-2: Probabilistic distribution of long-term recession for Brooms Head beach block 2

6.2   Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 6-2 and Table 6-3, respectively.

Table 6-2: Brooms Head projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m^3/m)	50th percentile SLR erosion (m^3/m)	100th percentile SLR erosion (m^3/m)
2	2043	6.5	10.6	17.8
	2073	13.1	23.9	53.8
	2123	25.5	68.6	144.1
3	2043	7.2	11.5	19.1
	2073	14.0	25.3	58.5
	2123	27.1	76.9	174.6
4	2043	7.9	12.3	20.4
	2073	15.0	26.7	63.1
	2123	28.7	85.2	205.1

Table 6-3: Brooms Head projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m^3/m)	50th percentile SLR erosion (m^3/m)	100th percentile SLR erosion (m^3/m)
2	2043	7.7	11.8	19.9
	2073	17.6	32.4	72.5
	2123	45.9	109.2	316.4
3	2043	8.4	12.8	21.2
	2073	18.9	34.1	81.9
	2123	48.7	129.1	303.7
4	2043	9.1	13.7	22.6
	2073	20.1	35.9	91.4
	2123	51.4	149.1	291.1

6.3 Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 6-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992). This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 6-3.

Table 6-4: Brooms Head extreme event-based erosion

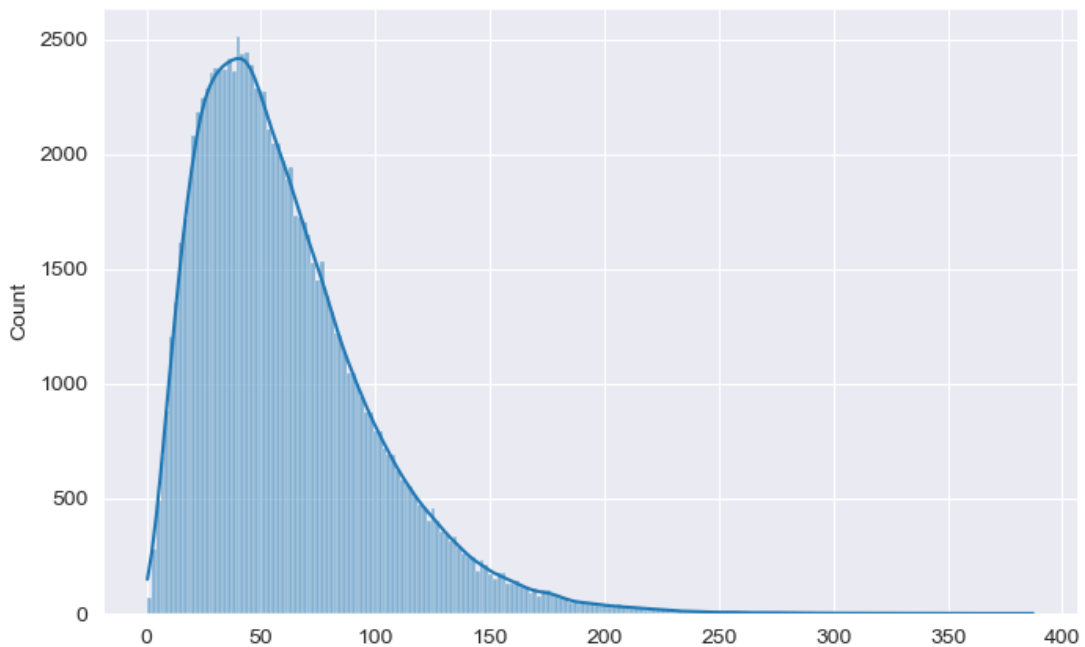| Beach block	Exposure factor	50% AEP Erosion (m³/m)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
2	0.73	53	112	163	183
3	0.98	71	151	218	246
4	0.98	71	151	218	246

Figure 6-3: Distribution of short-term erosion, erosion AEPs for Brooms Head Beach Block 2

6.4   Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Brooms Head Beach are shown in Table 6-5 and Table 6-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Brooms Head Beach are shown in Table 6-7 and Table 6-8 for climate change scenarios SSP2 and SSP5, respectively.

The hazard zone estimates for Brooms Head Beach are shown in Table 6-9 and Table 6-10 for climate change scenarios SSP2 and SSP5, respectively.

Table 6-5: Brooms Head erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	12.4	32.2	49.2	56.0
	2043	29.7	50.0	67.3	74.1
	2073	56.5	78.9	102.1	113.1
	2123	118.5	171.4	220.0	236.8
3	2023	17.7	29.6	49.5	68.6
	2043	32.0	65.9	133.3	154.3
	2073	122.3	181.8	207.6	217.9
	2123	234.8	311.3	345.1	355.9
4	2023	19.3	33.5	46.7	52.2
	2043	25.0	39.7	53.2	59.0
	2073	33.7	50.1	64.5	70.5
	2123	56.6	81.3	103.2	112.6

Table 6-6: Brooms Head erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	12.4	32.2	49.2	56.0
	2043	30.3	50.6	68.1	75.5
	2073	59.7	82.8	106.6	117.4
	2123	161.5	253.6	366.1	394.0
3	2023	17.7	29.6	49.5	68.6
	2043	32.5	67.4	135.0	155.5
	2073	130.7	185.9	210.9	221.2
	2123	254.4	336.0	368.2	379.4
4	2023	19.3	33.5	46.7	52.2
	2043	25.5	39.9	53.4	58.7
	2073	36.3	53.2	68.1	74.6
	2123	68.8	99.2	123.7	135.5

Table 6-7: Brooms Head ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	6.2	6.5	6.2	6.2
	2043	6.5	6.2	5.9	5.7
	2073	6.2	5.7	5.1	5.1
	2123	5.1	4.5	4.8	4.5
3	2023	6.9	6.7	4.8	2.9
	2043	6.5	3.1	4.8	5.7
	2073	4.8	6.7	6.5	6.5
	2123	6.2	6.5	6.5	7.0
4	2023	8.4	8.4	7.9	7.5
	2043	8.2	8.2	7.5	7.7
	2073	8.4	7.7	7.2	7.0
	2123	7.5	6.7	6.5	6.0

Table 6-8: Brooms Head ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	6.2	6.5	6.2	6.2
	2043	6.5	6.2	5.9	5.7
	2073	6.2	5.4	5.1	5.1
	2123	4.8	4.5	3.7	5.7
3	2023	6.9	6.7	4.8	2.9
	2043	6.2	3.1	5.0	5.7
	2073	4.8	6.7	6.5	6.5
	2123	5.3	6.7	6.7	7.0
4	2023	8.4	8.4	7.9	7.5
	2043	8.2	8.2	7.5	7.7
	2073	8.2	7.5	7.2	7.0
	2123	7.2	6.5	5.3	5.8

Table 6-9: Brooms Head total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	18.7	38.7	55.4	62.2
	2043	36.2	56.3	73.2	79.7
	2073	62.8	84.5	107.2	118.3
	2123	123.7	176.0	224.9	241.3
3	2023	24.6	36.3	54.2	71.4
	2043	38.5	69.0	138.1	160.1
	2073	127.1	188.5	214.0	224.3
	2123	241.0	317.8	351.6	362.9
4	2023	27.7	41.9	54.6	59.7
	2043	33.2	47.9	60.6	66.7
	2073	42.1	57.8	71.7	77.5
	2123	64.0	88.1	109.7	118.6

Table 6-10: Brooms Head total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	18.7	38.7	55.4	62.2
	2043	36.8	56.8	74.1	81.1
	2073	65.9	88.2	111.7	122.5
	2123	166.3	258.1	369.8	399.7
3	2023	24.6	36.3	54.2	71.4
	2043	38.7	70.5	140.0	161.3
	2073	135.5	192.5	217.4	227.7
	2123	259.7	342.7	374.9	386.4
4	2023	27.7	41.9	54.6	59.7
	2043	33.7	48.1	60.9	66.4
	2073	44.5	60.6	75.3	81.6
	2123	76.0	105.6	129.0	141.3

7 Sandon

7.1 Recession

Sandon Beach has been defined by three beach segments with a fourth (Sandon X) for the village. Figure 7-1 shows the average annual rate of change, with rates and standard deviation for each block shown in Table 7-1. An example distribution for probabilistic modelling is shown in Figure 7-2 for Sandon X (Village).

Figure 7-1: Sandon beach blocks mean annual rates of change

Table 7-1: Sandon historic annual rates of change

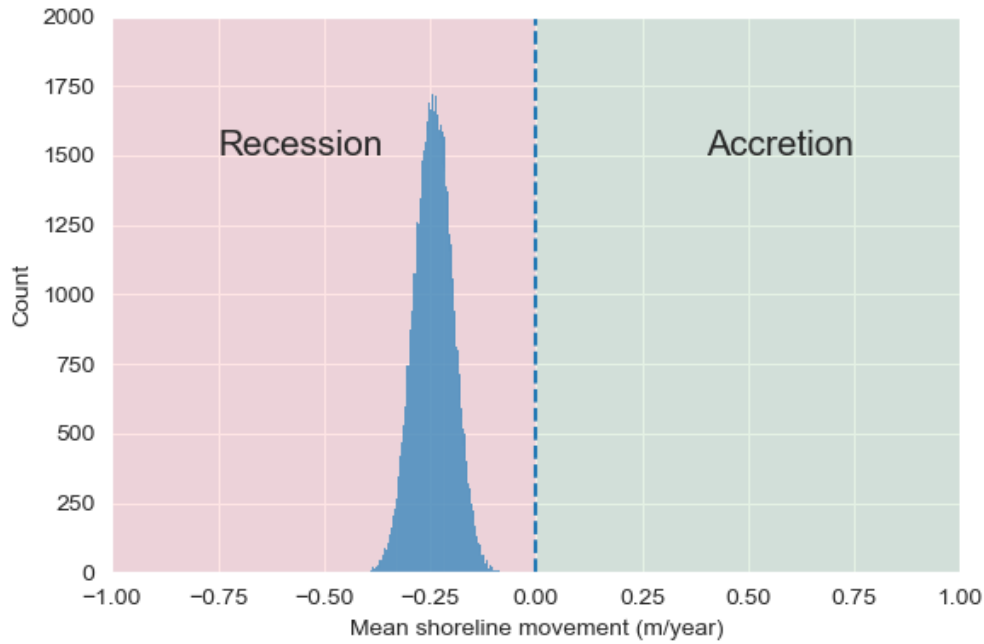| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
5	-0.08	± 0.17
7	-0.07	± 0.19
X (Village)	-0.24	±0.05

Figure 7-2: Probabilistic distribution of long-term recession at Sandon X (Village)

7.2 Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 7-2 and Table 7-3, respectively

Table 7-2: Sandon projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
5	2043	19.7	30.1	50.3
	2073	64.1	117.2	217.8
	2123	233.4	380.9	563.8
7	2043	18.1	25.7	40.2
	2073	51.7	87.1	166.0
	2123	178.8	364.1	655.9
X (Village)	2043	0.0	0.0	0.0
	2073	0.0	0.7	7.4
	2123	1.0	11.2	33.0

Table 7-3: Sandon projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
5	2043	22.5	33.8	56.2
	2073	86.4	152.9	264.5
	2123	315.6	485.3	685.3
7	2043	20.4	28.3	44.5
	2073	66.0	113.5	212.8
	2123	264.9	536.4	856.9
X (Village)	2043	0.0	0.1	0.2
	2073	0.0	2.2	12.2
	2123	5.5	22.7	47.9

7.3   Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 7-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992).   This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 7-3.

Table 7-4: Sandon extreme event-based erosion

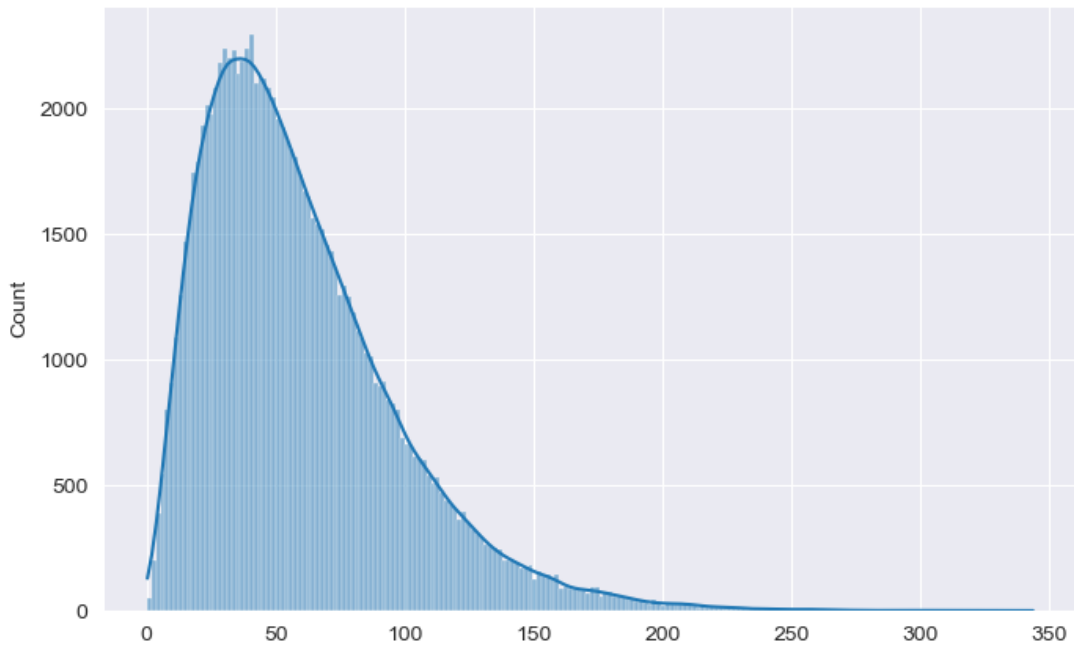| Beach block	Exposure factor	50% AEP Erosion (m³/m)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
5	0.72	52	111	160	181
6	0.94	68	144	209	236
7	0.99	71	151	219	246
X (Village)	0.40	29	61	89	100

Figure 7-3: Distribution of short-term erosion, erosion AEPs for Sandon Beach Block 5

7.4 Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Sandon Beach are shown in Table 7-5 and Table 7-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Sandon Beach are shown in Table 7-7 and Table 7-8 for climate change scenarios SSP2 and SSP5, respectively.

The hazard zone estimates for Sandon Beach are shown in Table 7-9 and Table 7-10 for climate change scenarios SSP2 and SSP5, respectively. These have been limited by the alignment of the Sandon River estuary behind the campground.

Table 7-5: Sandon erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
5	2023	10.8	27.6	38.0	41.6
	2043	23.4	36.6	45.8	50.0
	2073	46.1	65.2	82.2	89.8
	2123	141.4	568.7	590.8	597.5
7	2023	18.0	38.0	53.3	60.3
	2043	27.6	49.0	62.5	66.1
	2073	49.7	67.0	74.0	76.6
	2123	88.2	128.9	148.7	165.2
X (Village)	2023	11.7	20.0	26.4	29.3
	2043	17.6	25.2	31.9	34.5
	2073	25.7	33.8	40.5	43.3
	2123	41.4	51.4	58.8	61.9

Table 7-6: Sandon erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
5	2023	10.8	27.6	38.0	41.6
	2043	24.5	37.1	46.7	51.2
	2073	54.0	76.4	95.7	104.1
	2123	453.5	597.2	616.0	622.4
7	2023	18.0	38.0	53.3	60.3
	2043	28.3	49.3	62.9	67.0
	2073	54.1	70.2	76.9	79.5
	2123	123.3	177.1	233.5	254.0
X (Village)	2023	11.7	20.0	26.4	29.3
	2043	17.6	25.2	31.7	34.8
	2073	26.2	34.3	41.2	43.8
	2123	43.3	53.3	60.7	63.6

Table 7-7: Sandon ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
5	2023	8.7	8.4	7.3	7.3
	2043	9.0	7.6	7.0	7.0
	2073	7.0	6.2	6.2	6.2
	2123	5.0	7.8	8.1	8.4
7	2023	7.9	12.7	15.4	11.8
	2043	8.4	13.9	10.8	10.1
	2073	14.7	9.6	8.4	7.9
	2123	7.0	7.4	5.3	5.5
X (Village)	2023	7.6	7.6	7.4	7.4
	2043	7.6	7.6	7.6	7.6
	2073	7.6	7.6	7.4	7.4
	2123	7.4	7.4	7.1	7.1

Table 7-8: Sandon ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
5	2023	8.7	8.4	7.3	7.3
	2043	9.0	7.6	7.0	6.7
	2073	6.7	6.4	5.9	5.9
	2123	2.5	8.4	8.4	8.7
7	2023	7.9	12.7	15.4	11.8
	2043	8.4	14.2	10.8	9.6
	2073	15.4	9.1	8.2	7.7
	2123	8.4	5.5	5.5	5.5
X (Village)	2023	7.6	7.6	7.4	7.4
	2043	7.6	7.6	7.4	7.6
	2073	7.6	7.6	7.4	7.4
	2123	7.4	7.4	7.1	7.1

Table 7-9: Sandon total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
5	2023	19.5	36.0	45.3	48.9
	2043	32.4	44.1	52.8	57.0
	2073	53.1	71.3	88.4	96.0
	2123	146.4	**315***	**315***	**315***
7	2023	25.9	50.7	68.7	72.1
	2043	36.0	62.9	73.3	76.2
	2073	64.4	76.6	82.4	84.6
	2123	95.2	136.3	153.9	170.7
X (Village)	2023	19.3	27.6	33.8	36.7
	2043	25.2	32.8	39.5	42.1
	2073	33.3	41.4	47.8	50.7
	2123	48.8	58.8	65.9	69.0
*limited by estuary - refer to maps					

Table 7-10: Sandon total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
5	2023	19.5	36.0	45.3	48.9
	2043	33.5	44.7	53.7	57.9
	2073	60.7	82.8	101.6	110.0
	2123	**315***	**315***	**315***	**315***
7	2023	25.9	50.7	68.7	72.1
	2043	36.8	63.4	73.8	76.6
	2073	69.4	79.3	85.0	87.2
	2123	131.7	182.6	239.0	259.5
X (Village)	2023	19.3	27.6	33.8	36.7
	2043	25.2	32.8	39.0	42.4
	2073	33.8	41.9	48.6	51.2
	2123	50.7	60.7	67.8	70.7
*limited by estuary - refer to maps					

8   Minnie Water

8.1   Recession

The beach has been represented as a single beach segment. Figure 8-1 shows the average annual rate of change, with rates and standard deviation for each block shown in Table 8-1. An example distribution for probabilistic modelling is shown in Figure 8-2.
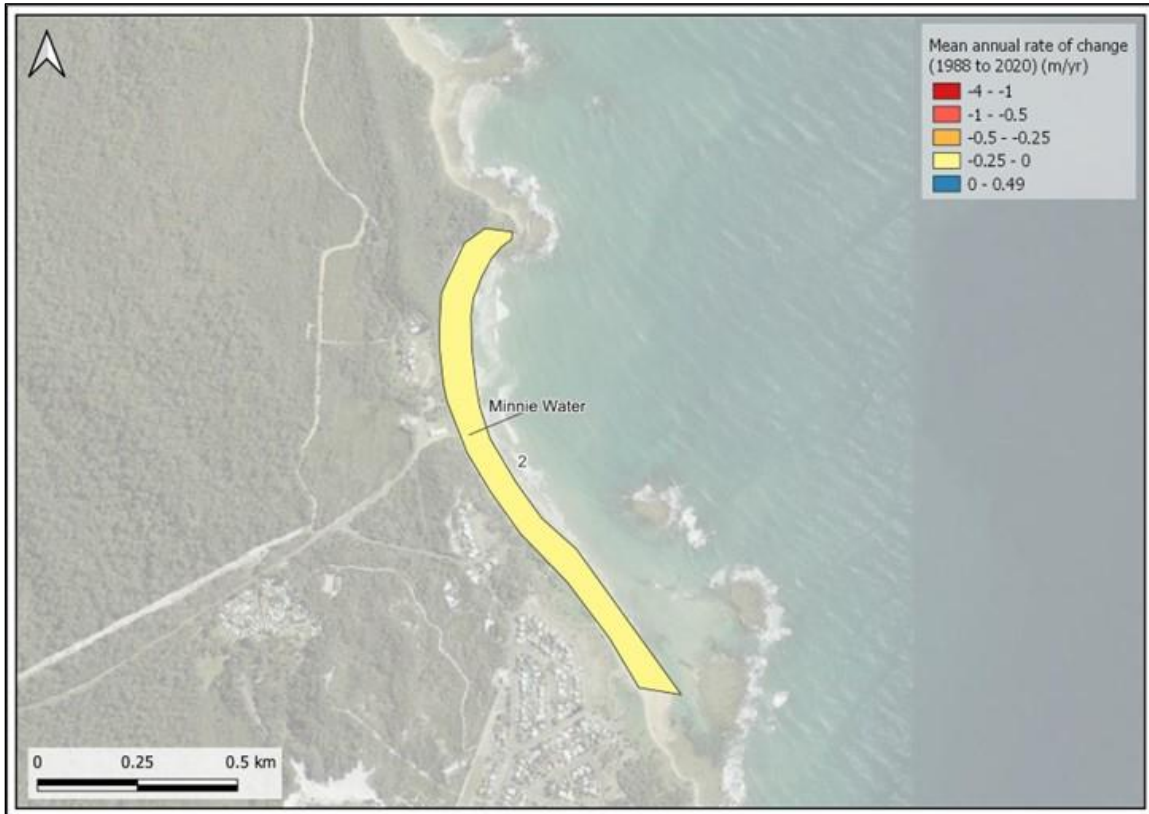

Figure 8-1: Minnie Water beach blocks mean annual rates of change

Table 8-1: Minnie Water historic annual rates of change

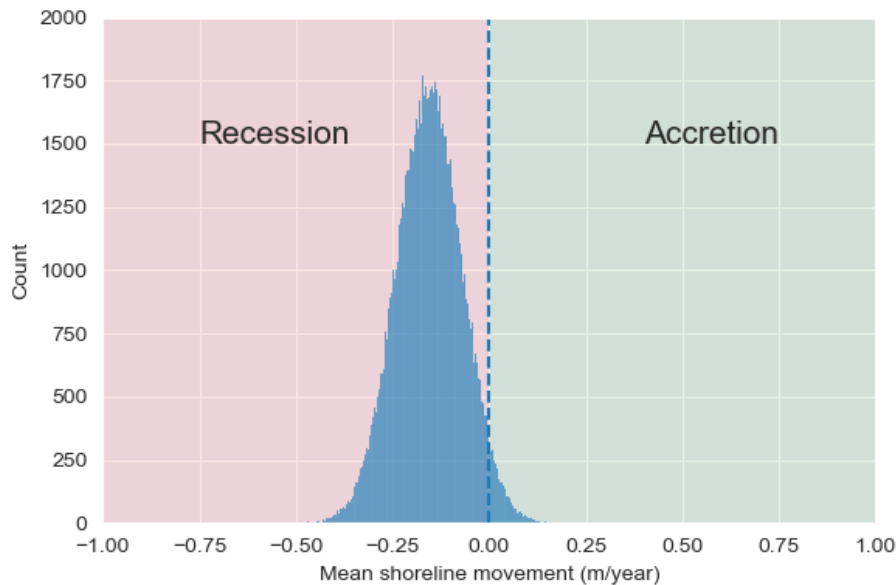| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
2	-0.16	± 0.09

Figure 8-2: Probabilistic distribution of long-term recession at Minnie Water Block 2

8.2   Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 8-2 and Table 8-3, respectively.

Table 8-2: Minnie Water projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m^3/m)	50th percentile SLR erosion (m^3/m)	100th percentile SLR erosion (m^3/m)
3	2043	15.7	21.7	32.2
	2073	36.9	59.4	138.1
	2123	116.1	300.8	676.7

Table 8-3: Minnie Water projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m^3/m)	50th percentile SLR erosion (m^3/m)	100th percentile SLR erosion (m^3/m)
3	2043	17.5	23.7	35.2
	2073	46.5	77.9	192.8
	2123	209.5	489.8	996.1

8.3   Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 8-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992). This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 8-3.

Table 8-4: Minnie Water extreme event-based erosion

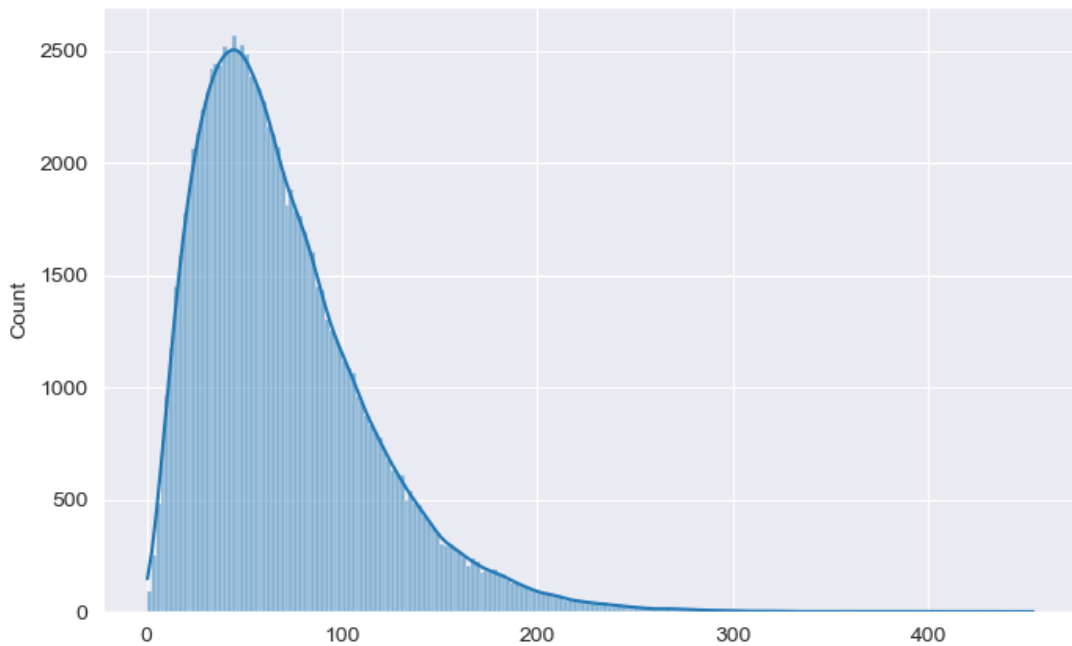| Beach block	Exposure factor	50% AEP Erosion (m³/m)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
2	0.84	61	129	186	210

Figure 8-3: Distribution of short-term erosion, erosion AEPs for Minnie Water Beach Block 2

8.4 Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Minnie Water are shown in Table 8-5 and Table 8-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Minnie Water are shown in Table 8-7 and Table 8-8 for climate change scenarios SSP2 and SSP5, respectively.

The hazard zone estimates for Minnie Water are shown in Table 8-9 and Table 8-10 for climate change scenarios SSP2 and SSP5, respectively.

Table 8-5: Minnie Water erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	14.8	31.7	40.2	43.5
	2043	27.1	38.3	46.9	50.7
	2073	40.7	52.6	60.4	63.5
	2123	80.4	98.8	107.6	110.2

Table 8-6: Minnie Water erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	14.8	31.7	40.2	43.5
	2043	27.6	38.6	47.1	50.7
	2073	44.5	56.9	64.7	67.3
	2123	98.8	118.5	130.2	134.5

Table 8-7: Minnie Water ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	13.3	12.9	14.8	15.2
	2043	12.4	14.5	15.5	15.2
	2073	14.8	15.2	15.0	15.2
	2123	15.7	13.3	11.9	11.4

Table 8-8: Minnie Water ZFRC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	13.3	12.9	14.8	15.2
	2043	12.1	14.5	15.2	15.2
	2073	15.2	15.0	15.2	15.5
	2123	13.3	10.9	12.6	12.9

Table 8-9: Minnie Water total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	28.1	44.5	55.0	58.8
	2043	39.5	52.8	62.3	65.9
	2073	55.4	67.8	75.4	78.8
	2123	96.1	112.1	119.5	121.6

Table 8-10: Minnie Water total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
2	2023	28.1	44.5	55.0	58.8
	2043	39.7	53.1	62.3	65.9
	2073	59.7	71.9	80.0	82.8
	2123	112.1	129.5	142.8	147.3

9 Diggers Camp

9.1 Recession

The beach has been represented as a single beach segment. Figure 8-1 shows the average annual rate of change, with rates and standard deviation for each block shown in Table 8-1Table 8-1. An example distribution for probabilistic modelling is shown in Figure 9-2 for beach block 1.
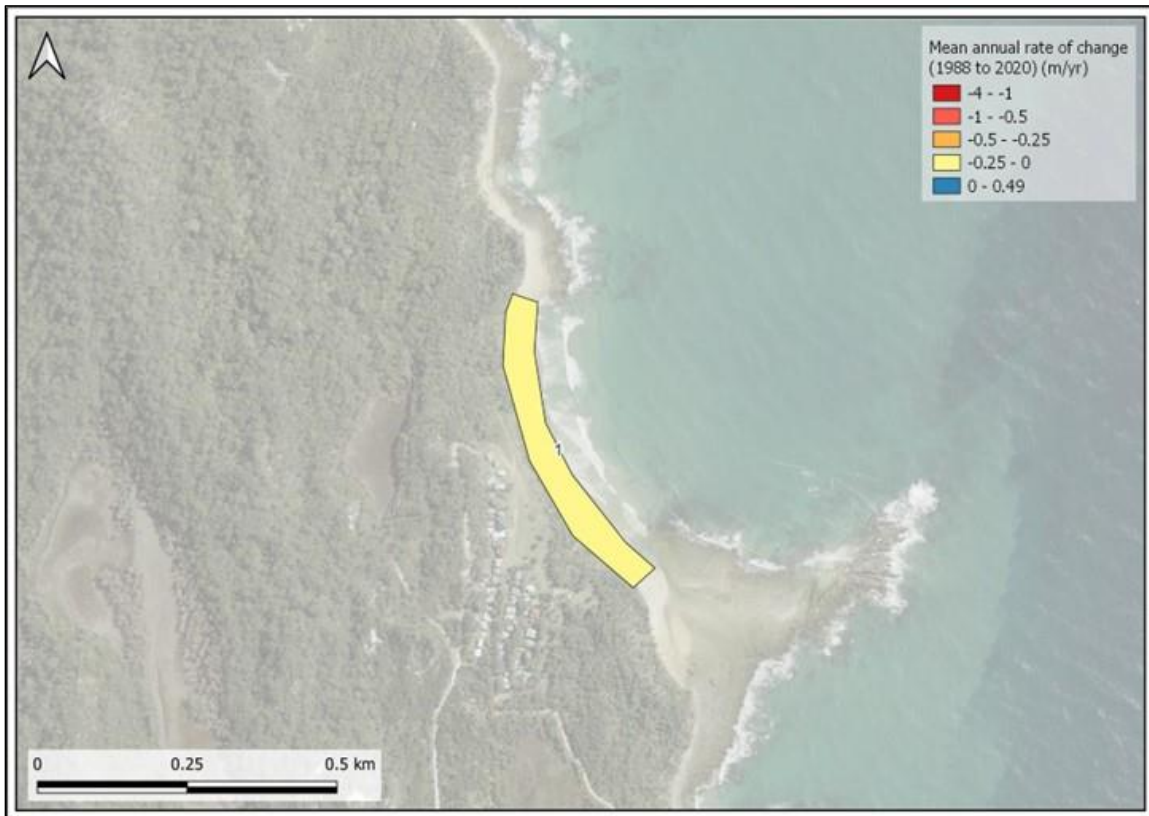

Figure 9-1: Diggers Camp beach blocks mean annual rates of change.

Table 9-1: Diggers Camp historic annual rates of change

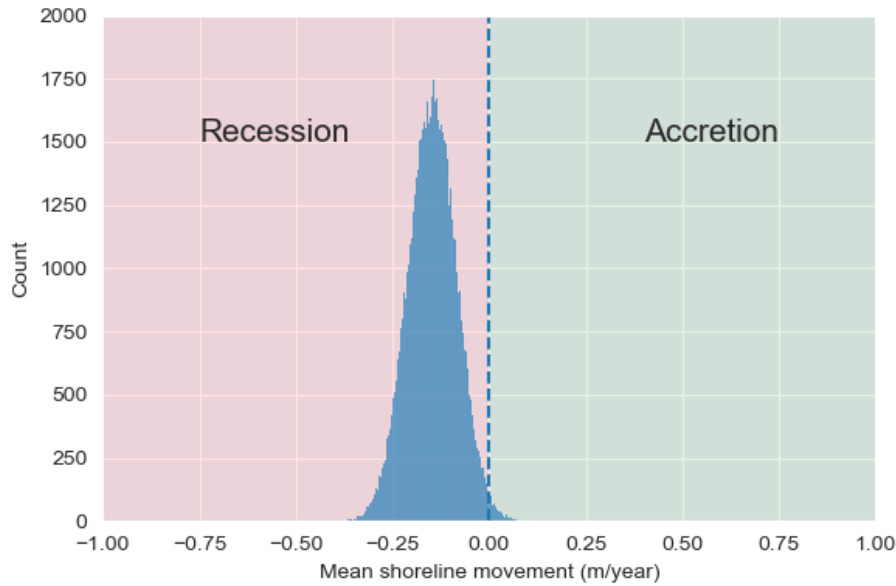| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
1	-0.15	± 0.06

Figure 9-2: Probabilistic distribution of long-term recession at Diggers Camp Block 1.

9.2   Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 8-2 and Table 8-3, respectively.

Table 9-2: Diggers Camp projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
1	2043	2.3	5.7	14.4
	2073	15.5	25.2	228.3
	2123	217.4	457.8	888.4

Table 9-3: Diggers Camp projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
1	2043	3.1	7.2	17.3
	2073	25.3	158.0	295.8
	2123	342.1	673.4	1293.3

9.3   Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 9-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992). This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 9-3

Table 9-4: Diggers Camp extreme event-based erosion

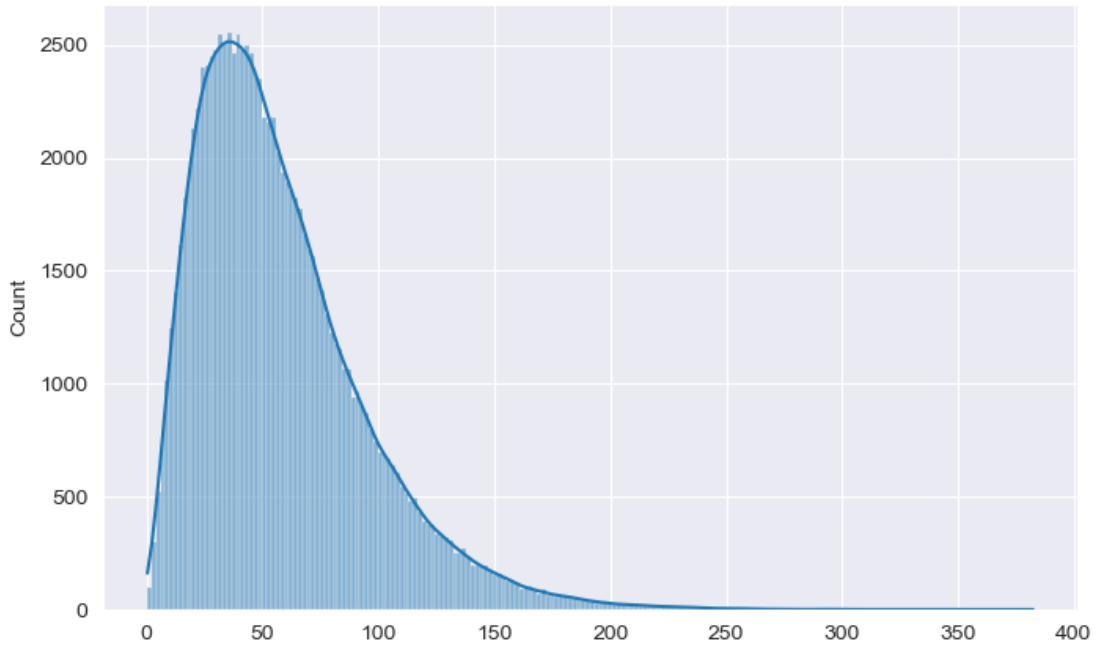| Beach block	Exposure factor	50% AEP Erosion (m³)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
1	0.70	50	107	155	175

Figure 9-3: Distribution of short-term erosion, erosion AEPs for Diggers Camp Beach Block 1.

9.4 Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Diggers Camp are shown in Table 9-5 and Table 9-6 for climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Diggers Camp are shown in Table 9-7 and Table 9-8 for climate change scenarios SSP2 and SSP5, respectively.

The hazard zone estimates for Diggers Camp are shown in Table 9-9 and Table 9-10 for climate change scenarios SSP2 and SSP5, respectively.

Table 9-5: Diggers Camp erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	44.0	48.0	51.0	52.3
	2043	45.0	49.0	52.0	53.3
	2073	51.3	56.8	60.3	61.6
	2123	76.7	86.2	90.8	92.3

Table 9-6: Diggers Camp erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	44.0	48.0	51.0	52.3
	2043	45.2	49.0	52.0	53.3
	2073	55.8	61.3	64.6	65.8
	2123	87.5	121.2	127.5	128.2

Table 9-7: Diggers Camp ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	18.9	25.2	26.9	27.4
	2043	20.9	25.9	27.2	27.9
	2073	26.9	28.2	28.4	28.2
	2123	50.8	49.3	48.3	48.1

Table 9-8: Diggers Camp ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	18.9	25.2	26.9	27.4
	2043	21.4	25.9	27.2	27.9
	2073	28.2	28.2	28.2	28.9
	2123	49.1	24.9	22.9	23.1

Table 9-9: Diggers Camp total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	62.8	73.1	77.9	79.7
	2043	65.8	74.9	79.2	81.2
	2073	78.2	85.0	88.7	89.7
	2123	127.5	135.5	139.1	140.3

Table 9-10: Diggers Camp total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
1	2023	62.8	73.1	77.9	79.7
	2043	66.6	74.9	79.2	81.2
	2073	84.0	89.5	92.8	94.8
	2123	136.5	146.1	150.4	151.4

10 Wooli Beach

10.1 Recession

The beach has been defined by five beach blocks. Figure 10-1 shows the average annual rate of change, with rates and standard deviation for each block shown in Table 10-1. An example distribution for probabilistic modelling is shown in Figure 6-1 for beach block 5.
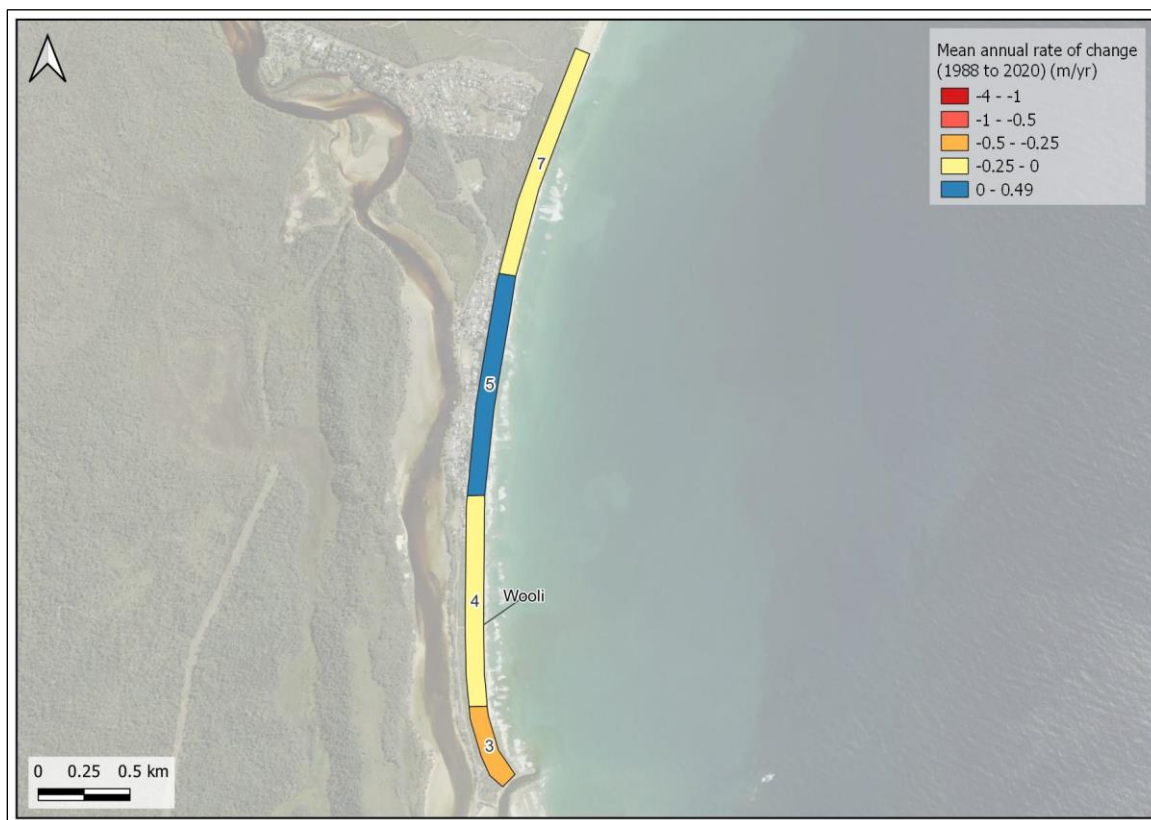

Figure 10-1: Wooli beach blocks mean annual rates of change

Table 10-1: Wooli historic annual rates of change

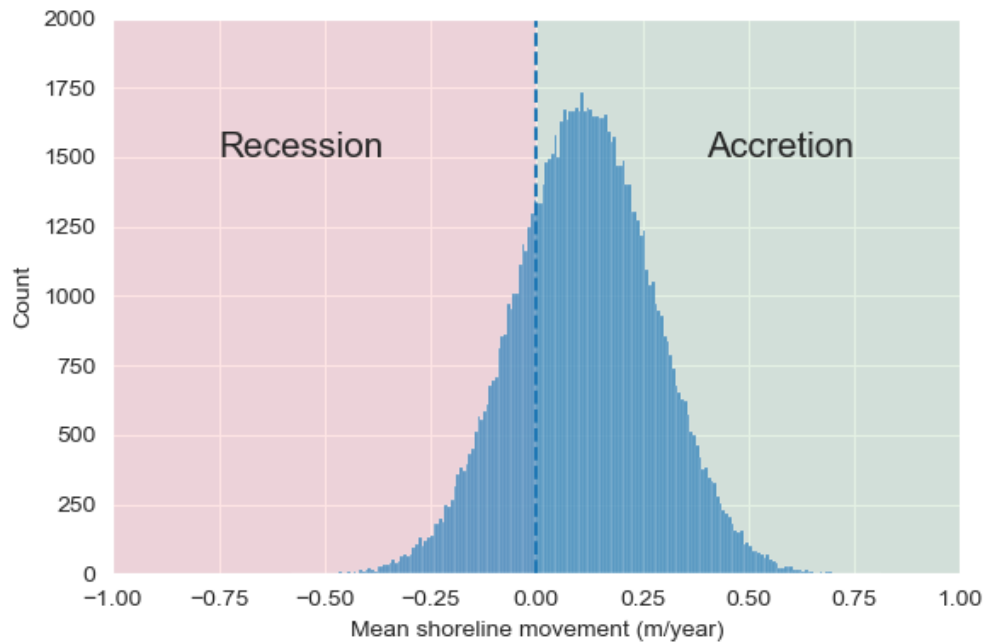| Beach block	Mean rate of change (m/year)	Standard deviation (m/year)
3	-0.32	± 0.16
4	-0.02	± 0.16
5	0.11	± 0.17
7	-0.08	± 0.08

Figure 10-2: Probabilistic distribution of long-term recession at Wooli Beach block 5.

10.2 Sea level rise erosion

Each beach block has been subjected to probabilistic, volumetric sea level rise modelling. The results of the modelling representing the 0th, 50th, and 100th percentiles of projected sea level rise erosion for each future planning period (2043, 2073, and 2123) under SSP2 (RCP4.5) and SSP5 (RCP8.5) scenarios are shown in Table 10-2 and Table 10-3, respectively.

Table 10-2: Wooli projected sea level rise erosion - SSP2

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
3	2043	21.8	36.8	62.8
	2073	78.4	128.1	226.5
	2123	230.5	380.0	568.8
4	2043	23.2	39.6	68.9
	2073	88.5	148.5	258.7
	2123	272.2	425.4	621.3
5	2043	24.7	42.3	75.1
	2073	98.6	168.9	290.9
	2123	313.9	470.8	673.7
7	2043	36.4	51.4	77.1
	2073	95.0	149.2	256.7
	2123	276.8	416.8	594.2

Table 10-3: Wooli projected sea level rise erosion - SSP5

Beach block	Planning horizon (year)	0th percentile SLR erosion (m³/m)	50th percentile SLR erosion (m³/m)	100th percentile SLR erosion (m³/m)
3	2043	26.0	41.4	70.0
	2073	100.6	161.2	273.8
	2123	313.6	482.2	714.0
4	2043	27.8	44.8	77.7
	2073	115.2	187.4	309.6
	2123	358.9	532.0	762.9
5	2043	29.5	48.2	85.3
	2073	129.8	213.7	345.3
	2123	404.1	581.7	811.7
7	2043	41.1	56.1	83.9
	2073	117.4	187.5	305.1
	2123	357.9	511.6	722.4

10.3   Event-based erosion

Event-based erosion is based on a volumetric 'gamma distribution' of potential storm loss and the beach unit exposure factor, with results shown in Table 10-4. An additional Zone of Reduced Foundational Capacity (ZRFC) width has been applied to each eroded storm width based on the approach developed by Nielsen et al. (1992). This is an additional Factor of Safety approach applied to estimate the extent of dune instability behind the slumped profile. The distribution of short-term erosion and erosion AEPs are shown in Figure 10-3.

Table 10-4: Wooli extreme event-based erosion

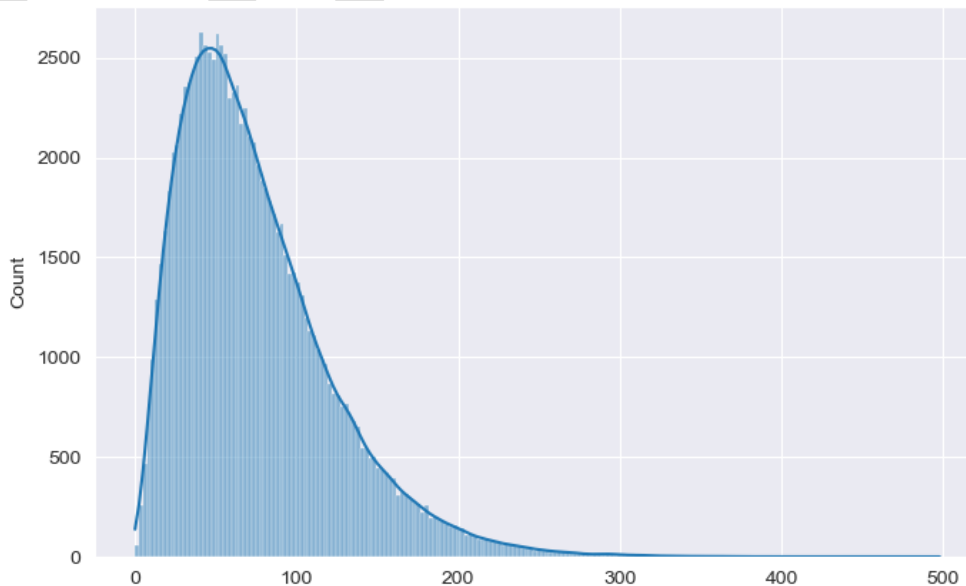| Beach block	Exposure factor	50% AEP Erosion (m³/m)	10% AEP Erosion (m³/m)	2% AEP Erosion (m³/m)	1% AEP Erosion (m³/m)
3	0.90	65	138	200	226
4	0.87	62	133	192	217
5	0.86	62	131	190	214
7	0.90	65	137	199	224

Figure 10-3: Distribution of short-term erosion, erosion AEPs at Wooli Beach Block 3

10.4 Total erosion and recession zone

The non-ZRFC component of the hazard zone estimates for Wooli Beach are shown in Table 10-5 and Table 10-6 climate change scenarios SSP2 and SSP5, respectively. The ZRFC component of the hazard zone estimates for Wooli Beach are shown in Table 10-7 and Table 10-8 for climate change scenarios SSP2 and SSP5, respectively.

The hazard zone estimates for Wooli Beach are shown in Table 10-9 and Table 10-10 for climate change scenarios SSP2 and SSP5, respectively.

Table 10-5: Wooli erosion and recession hazard width - ZRFC component excluded - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	19.7	41.9	54.8	59.8
	2043	36.9	53.2	66.3	72.4
	2073	64.0	86.6	357.7	373.8
	2123	420.7	489.4	494.1	495.9
4	2023	15.9	36.0	46.0	50.1
	2043	31.1	44.9	54.7	58.8
	2073	54.2	71.7	85.5	92.7
	2123	134.1	384.0	385.8	386.3
5	2023	19.5	36.4	45.8	48.2
	2043	28.9	43.2	49.9	52.8
	2073	47.0	62.9	81.0	90.0
	2123	94.3	529.4	566.1	575.0
7	2023	21.0	42.9	52.4	55.0
	2043	42.2	53.2	60.3	64.4
	2073	59.8	76.4	99.2	108.4
	2123	153.9	206.8	235.4	245.4

Table 10-6: Wooli erosion and recession hazard width - ZRFC component excluded - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	19.7	41.9	54.8	59.8
	2043	38.4	54.2	67.4	74.2
	2073	72.4	98.7	379.1	391.2
	2123	472.0	497.3	502.3	504.1
4	2023	15.9	36.0	46.0	50.1
	2043	32.4	46.0	56.0	59.8
	2073	60.6	362.4	96.8	106.3
	2123	382.9	386.0	387.8	388.3
5	2023	19.5	36.4	45.8	48.2
	2043	30.1	44.1	50.9	53.5
	2073	51.9	71.9	95.3	105.4
	2123	136.8	562.4	589.5	596.4
7	2023	21.0	42.9	52.4	55.0
	2043	43.2	53.9	61.1	65.2
	2073	65.2	89.7	113.7	123.7
	2123	196.3	244.8	274.5	285.5

Table 10-7: Wooli ZRFC component - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	7.1	8.2	7.1	6.8
	2043	8.7	7.1	6.6	6.6
	2073	6.6	5.5	5.5	5.8
	2123	6.3	13.4	24.5	26.6
4	2023	10.0	9.2	9.0	8.7
	2043	10.0	9.0	8.5	8.2
	2073	8.7	6.9	6.2	5.9
	2123	2.6	14.1	15.9	16.2
5	2023	11.6	10.9	8.2	8.2
	2043	11.8	8.4	8.0	7.7
	2073	8.2	6.5	6.8	6.0
	2123	6.3	8.7	8.9	9.2
7	2023	9.2	10.0	7.4	7.2
	2043	10.2	7.4	6.6	6.4
	2073	6.6	6.1	6.1	5.9
	2123	5.6	6.4	6.4	6.1

Table 10-8: Wooli ZRFC component - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	7.1	8.2	7.1	6.8
	2043	8.4	7.4	6.6	6.8
	2073	6.6	3.7	5.8	6.1
	2123	26.3	27.6	30.8	31.9
4	2023	10.0	9.2	9.0	8.7
	2043	9.8	9.0	8.5	8.2
	2073	8.2	23.6	5.7	5.4
	2123	13.1	15.9	17.2	17.7
5	2023	11.6	10.9	8.2	8.2
	2043	12.1	8.2	7.7	7.7
	2073	7.7	6.5	6.3	6.0
	2123	6.0	8.7	7.0	0.0
7	2023	9.2	10.0	7.4	7.2
	2043	10.0	7.2	6.6	6.1
	2073	6.1	6.4	5.9	5.9
	2123	6.4	6.1	6.1	6.1

Table 10-9: Wooli total erosion and recession hazard width - SSP2

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	26.9	50.0	61.9	66.6
	2043	45.5	60.3	72.9	79.0
	2073	70.5	92.1	124.3	**125***
	2123	**125***	**125***	**125***	**125***
4	2023	25.9	45.2	55.0	58.8
	2043	41.1	53.9	63.2	67.0
	2073	62.9	78.6	91.7	98.6
	2123	**150***	**150***	**150***	**150***
5	2023	31.1	47.3	54.0	56.4
	2043	40.8	51.6	57.9	60.5
	2073	55.2	69.5	87.8	96.0
	2123	100.6	171.0	192.5	**200***
7	2023	30.2	52.9	59.8	62.1
	2043	52.4	60.6	67.0	70.8
	2073	66.5	82.6	105.3	114.2
	2123	159.5	213.2	241.8	251.5
* limited due to estuary.					

Table 10-10: Wooli total erosion and recession hazard width - SSP5

Beach block	Planning horizon (year)	50% exceedance probability (m)	10% exceedance probability (m)	2% exceedance probability (m)	1% exceedance probability (m)
3	2023	26.9	50.0	61.9	66.6
	2043	46.9	61.6	74.0	81.1
	2073	79.0	102.4	**125***	**125***
	2123	**125***	**125***	**125***	**125***
4	2023	25.9	45.2	55.0	58.8
	2043	42.1	55.0	64.5	68.1
	2073	68.8	86.4	102.5	111.7
	2123	**150***	**150***	**150***	**150***
5	2023	31.1	47.3	54.0	56.4
	2043	42.2	52.3	58.6	61.3
	2073	59.6	78.4	101.5	111.4
	2123	150.0	171.0	192.5	**200***
7	2023	30.2	52.9	59.8	62.1
	2043	53.2	61.1	67.7	71.3
	2073	71.3	96.1	119.6	129.6
	2123	202.7	251.0	280.0	291.6
* limited due to estuary.					

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