Supporting Documentation F.

Cost Benefit Analysis (Bluecoast, 2020b)

City of Newcastle

City of Newcastle

Cost benefit analysis for Stockton Beach coastal management program

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1. INTRODUCTION

1.1 General

A cost benefit analysis (CBA) was undertaken in support of the coastal management program (CMP) being prepared by the City of Newcastle (CN) for the area north of the Stockton Breakwater (northern training wall of the Hunter River) to Meredith Street, Stockton. CN engaged Bluecoast Consulting Engineers (Bluecoast) and their sub-consultants Rhelm to undertake the CBA for the proposed CMP options. After extensive discussion with community and agency stakeholders, CN have identified three coastal management options for Stockton Beach to be assessed in the CBA.

This report sets out the approach and results of the CBA and the associated sensitivity and distribution analysis (partitioning of benefits to affected property and asset owners). The CBA has been prepared in accordance with the Coastal Management Act 2016 and the NSW Coastal Management Manual (the Manual) and consideration of the *Guidelines for using cost-benefit analysis to assess coastal management options* (OEH, 2018).

1.2 Study area

Stockton Beach is in the City of Newcastle Local Government Area (LGA) in the Hunter region of the NSW coast. It is located on a peninsula on the southern end of Stockton Bight. Stockton Bight stretches along 32km from the Hunter River to Birubi Point. The area of Stockton Beach for inclusion in Newcastle CMP will extend from northern breakwall to LGA boundary. Due to time constraints imposed by Ministerial direction to complete a Stockton CMP by 30 June 2020, the current study area has been defined as the area of Stockton Beach between the northern breakwall and Meredith Street, as shown in Figure 1. Key features in the study area are also noted in Figure 1.

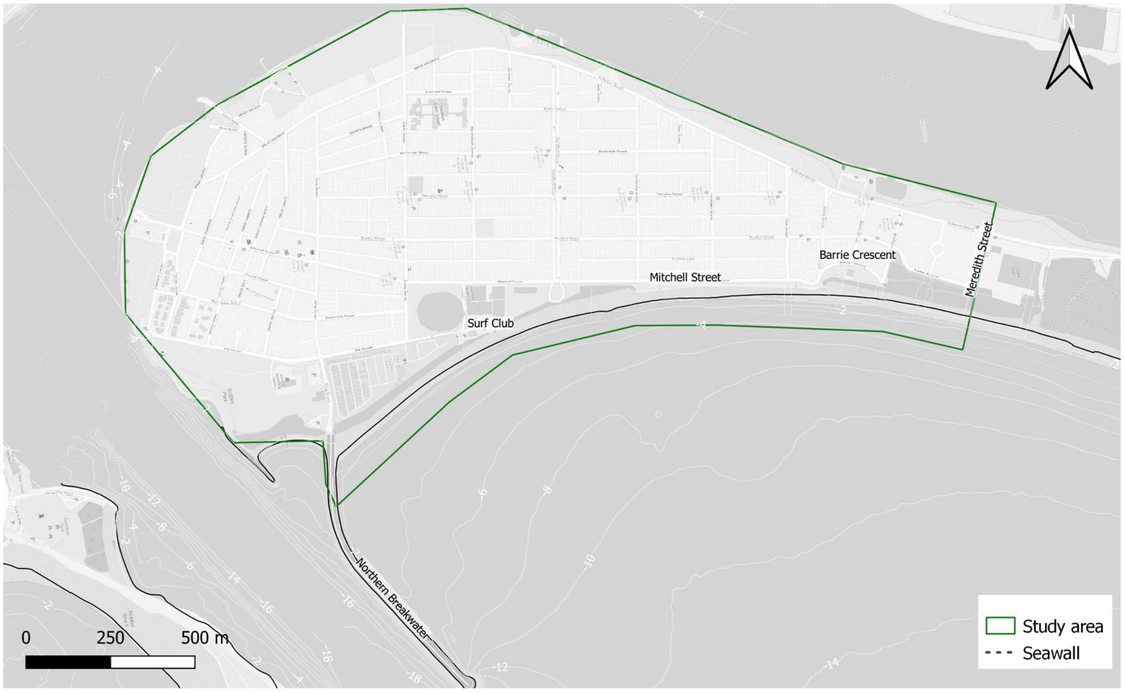

Figure 1: Stockton Beach CMP study area and key features.

1.3 Study objectives and context

CN are looking to address the on-going erosion issues at Stockton Beach. The beach has experienced episodes of erosion over many years and CN has undertaken a series of actions to address this issue over the past decades. As recently as earlier in 2020 storm wave conditions led to significant beach erosion and associated emergency works, damage to property, loss of amenity, closure of Lexis's café and restricted access to the Stockton beachfront.

CN are in the process of developing a CMP in accordance with the Coastal Management Act (2016) and are developing long-term actions to address on-going beach erosion and shoreline recession. It is understood that following the consideration of a range of potential options, CN have identified three broad options including programs of sand nourishment and response to residual risk through protection structures.

The objective of this study is to undertake an economic assessment and evaluation of the coastal protection options outlined in RHDHV (2020), demonstrate their economic feasibility and identify potential options for further development.

1.4 Statement of assumption and uncertainty

The approach developed herein is reasonable and valid for evaluating coastal management options in the CMP area. However, it is important that decision-makers recognise the assumptions underlining the development of the CBA as well as the uncertainty. These relate to the assessment of coastal hazards, data availability and to the application of the cost benefit analysis. The assumptions that relate to specific future scenarios (i.e. base case and options) are provided in the relevant sections of this report. Set out below are the overarching assumptions and uncertainties.

Assumptions and uncertainty related to coastal hazards and the performance of the options in a dynamic coastal environment:

- Detailed numerical and/or physical modelling of the performance outcomes of the coastal management options have not been undertaken.
- Climate change projection and the future climate at Stockton Beach cannot be predicted precisely.
- All areas to the north of Corroba Oval were not considered within the economic analysis study area (Figure 1) as no foreshore protection (seawall or nourishment) is proposed for this section. For the purposes of the economic analysis it was assumed that the rate of erosion of these sections would not be materially different between the base case (Section 3.2) or project case scenarios (Section 3.3 – Section 3.5).

Assumptions and uncertainty related to the CBA include:

- Benefit transfer approach was adopted to identify reasonable dollar value estimates of non-market costs and benefits for Stockton Beach (e.g. Deloitte, 2016; Pascoe et al., 2017). The use of benefit transfer approaches introduces uncertainty within models as the degree to which the 'transferred' values are representative of actual values of Stockton Beach is not validated. This uncertainty has not been validated. This approach was adopted given the time and scope available for this CBA. The alternative to benefit transfer valuations of non-market goods is the adoption of techniques that are typically time and labour intensive (i.e. revealed preference, stated preference, input-output modelling). No site-specific valuation of

beach usage to assess importance to fisheries, tourism or the regional economy has been undertaken.
- The CBA undertakes an assessment over four time periods (2020, 2040, 2060, 2120). Within each time period the impacts to private and public assets was evaluated across three 'probability of exceedance' levels: 50%, 10% and 1%. The use of only three probabilistic points requires the interpolation and extrapolation of risk and costs within and beyond these horizons, introducing further uncertainty within the model. This approach was adopted given the time and scope available for this CBA. A higher degree of certainty within the model could be achieved through running a greater range of exceedance levels and assessment timeframes.
- The CBA does not currently include consideration of inundation impacts associated with storm surge events. Inundation avoidance can form a significant component of coastal protection work benefits and the CBA is considered conservative in this regard. This approach was undertaken as the inundation results were not available within given the CBA development timeframe.
- This CBA aims to quantify the important benefits and costs for the specified community in monetary terms. This includes social and environmental impacts as well as economic impacts. However, it is not possible to quantify all impacts and, where this is the case, the document highlights what has not been quantified and valued. The remaining impacts have then been described qualitatively. To test robustness of the CBAs and account for some uncertainties outlined above, sensitivity testing was conducted on the quantified results.

Given these high order uncertainties, where relevant the CBA has adopted conservative assumptions to attempt to minimise the risk of over estimation of project benefits and false justification of project feasibility. The further range of more detailed assumptions adopted within the CBA are outlined as relevant within Section 5.

2. BACKROUND INFORMATION

2.1 Coastal management issues to be addressed by CMP

Stockton Beach currently experiences significant erosion and inundation following large storm events, leaving several CN assets at risk, and requiring installation of a range of temporary (e.g. sandbagging) and permanent protection measures. These risks are recognised in the Coastal Zone Management Plan 2018 (CZMP) that was prepared under the Coastal Protection Act (1979). However, as this Act has now been repealed and planning and management of coastal regions within NSW is now managed under the Coastal Management Act (2016), Councils are required to prepare Coastal Management Programs (CMPs) to manage their coastal assets. The CMP is currently in preparation, and this economic analysis forms a component therein, assisting in the evaluation of management options.

Specifically, it has been identified that the management options identified for Stockton Beach within the CZMP, while potentially effective in addressing the hazards currently realised at the beach, do not include consideration of a solution to the long-term erosion hazard. The erosion hazard has been quantified by Bluecoast ,2020 and coastal management options were identified by Royal HaskoningDHV (RHDHV, 2020). The key coastal management issues identified in the Stage 1 report of the CMP included:

- Beach erosion and shoreline recession: on-going loss of sediment within the compartment.
- Protection of assets.
- Management options not impacting on the northern coastline.

Ongoing community consultation is captured through a variety of mediums including the establishment of the Stockton Community Liaison Group (CLG) in 2018 which is continuing to provide valuable input into the CMP process.

2.2 Socio-economic profile of Stockton

The residential suburb of Stockton is located on the peninsula at the southern end of the larger embayed section of sandy coast known as Stockton Bight. The suburb comprises 360 hectares of land area and a population of 4,179 with a population density of 12.32 per hectare (CN, 2019). The Mitchell Street seawall, which was constructed between Pembroke Street and Stone Street in 1989, is largely protecting residential development and infrastructure west of the beach along the central section of Stockton. This section comprises primarily residential development with public recreation areas (Dalby Oval) south of the Mitchell Street seawall (CN, 2019).

The southern section of Stockton is primarily residential and accommodates the beach front Stockton Beach Holiday Park. Community facilities exist along the former hind dune areas of the beach, including the Stockton Surf Life Saving Club, Lexie's café and Lynn Oval.

The beach is popular for primarily locals and visitors from the Hunter Valley for activities including swimming, fishing, nippers, beach going and surfing. Visitation data for Stockton Beach is limited but it is estimated that approximately 100,000 people currently utilise the beach annually[1]. In addition, no beach user survey information (e.g. frequency, duration, purposes, expenditure, etc.) was available for this study. Visitors from Australia and international visitors regularly stayi at Stockton Beach Holiday Park. Indeed, the Holiday Park is the only caravan/motorhome, camping park close to the Newcastle CBD, Stockton and Newcastle beaches. The surf club hosts surf carnivals and surf boat carnivals and the Royal Australian Airforce (RAAF), who have a base nearby at Williamtown, have an annual surf boat carnival with teams from all over Australia attending. The Northside Boardriders club host surfing events and Surfest also holds the team's event at Stockton Beach.

Community consultation activities undertaken by CN have identified strong opinions regarding Stockton Beach, including:

- The beach is highly valued and represents a critical asset to the local community.
- The preference to maintain a clean beach area providing enough width for recreational space, including uses such as Nippers, and which supports the current foreshore amenity and character.
- Stockton has a strong surf culture with a desire to maintain surf amenity nearby the residential areas.
- The preference to ensure any nourishment programs utilise sand that matches the existing visual profile of Stockton Beach.

[1] Based on 2013/14 30-week beach user counts, grown in proportion to local growth rates (approx. 1% p.a.) to 2020 values.

- The preference to maintain beach connectivity along the entirety of the beach. The available socio-economic data and community concerns regarding beach development were utilised in establishing assumptions adopted within the economic model developed for the CBA.

2.3 Environmental values

The local community at Stockton has a strong connection to the beach and the foreshore area. Beach amenity is critical for locals and visitors the like to pursue their endeavours. The key environmental values include:

- A dune system and vegetation seaward of the Stockton Beach Holiday Park.
- Dune systems along the coast north of the former Hunter Water Corporation site (310 Fullerton Street).
- An urbanised area along the central section of Stockton Beach with exotic grasses and planted landscape species (CN, 2019).

2.4 Data used in CBA

A summary of the datasets available for this study is presented in Table 1.

Table 1: Overview of datasets used in this study.

ID	Description	Source	Dates
Economic data			
Land values	Land parcels, including land valuation and sales from the past 5 years (where available)	CN	2016-2020
Council assets	CN asset database	CN	2020
Buildings	Laser-scanning outlines	CN	2020
Revenue/ spending	Holiday park revenue, coastal management spending	CN	2020
Coastal hazards			
Topography and bathymetry	LiDAR at 5m resolution	DPIE	2018
	High-resolution UAV derived topography	CN	2019, 2020
	Beach photogrammetry	DPIE	1953 to 2018
	Various hydrographic surveys	DPIE, Umwelt Pty Ltd, CN, Port of Newcastle	1816 to 2019
Aerial imagery	High resolution, rectified aerial imagery	Nearmap	2020

3. CBA OPTIONS

3.1 Introduction

The base case and three options to be assessed in this CBA have been developed by the City of Newcastle and their consultant Royal HaskoningDHV (RHDHV). These options are described in RHDHV's (2020) technical note entitled *RHDHV input information for a Cost Benefit Analysis for Stockton Beach*, dated 18 June 2020 and provided in **Appendix A**. **Appendix A** has been prepared by RHDHV directly for CN. The views and opinions expressed in **Appendix A** are those of the authors and do not necessarily reflect the opinions of Bluecoast.

Figure 2 and Figure 3 provide a map that show the key features of the management options. An overview of all project cases assessed is provided in Table 2. Broadly, the discrete options consist of:

- **Base case** – involves the continued delivery of the actions in the certified Newcastle Coastal Zone Management Plan (CZMP). The main element of this is the maintenance of the two existing rock revetments, at the SLSC and fronting Mitchell Street and the provision of emergency works as required. Combined these structures extend over 717 linear metres of the shoreline.
- **Option 1** – involves mass beach nourishment along with the construction of 'Stage 1' coastal protection structures. The extent of Stage 1 structures varies between project cases considered as part of the sensitivity analysis. Table 3 provides a summary of the extent of structures applied in each case. In Figure 2 and Figure 3, the nourishment areas are shown as nearshore placement boxes. This assumes the nourishment sand will be placed by a dredger (e.g. a Trailer Hopper Suction Dredger) using rainbowing (see Figure 4) and bottom dumping. These processes are described in RHDHV, 2020.
- **Option 2** – involves the construction of Stage 1 and Stage 2 coastal protection structures and beach nourishment for a defined beach area objective. Stage 2 works would be constructed, when triggered by further erosion adding further coastal protection structures and a short rock groyne as outlined in Table 3. Beach nourishment under this option is aimed at providing a minimum annual average beach width of 5m at the narrowest point along the CMP area measured at 1.5m AHD (approximately 1m above mean high water (MHW) to account for wave runup) accommodating a volume for a 1-year ARI storm each year. This was calculated to equate to an ongoing nourishment of 112,000m^3 of native beach sand supplied on an annual basis (RHDHV, 2020).
- **Option 3** – involves the construction of the Stage 1 and Stage 2 coastal protection structures as outlined in Table 3 as well as a relatively modest amount of beach nourishment. The sand quantities for beach nourishment were based on what would be realistically obtainable from available terrestrial sources of sand.

Table 2: Overview of nine project cases and four associated cost sensitivity tests.

Description	Option 1				Option 2			Option 3	
	O1a	O1b	O1c	O1d	O2	O2b	O2c	O3a	O3b
Initial nourishment campaign									
Total initial nourishment volume – native	1.8Mm^3 **	2.4Mm^3	1.8Mm^3	2.4Mm^3	210,000m^3 **	610,000m^3	610,000m^3	80,000m^3 **	20,000m^3 **
Source	Terrestrial	Marine (offshore)	Hunter River (South Arm)	Marine (offshore)	Terrestrial	Marine (offshore)	Hunter River (South Arm)	Terrestrial	Terrestrial
Method	Trucks, back passing pipeline and earthmoving equipment	Dredge (TSHD with rainbowing capability)	Dredge (CSD with pumping ashore capability)	Dredge (TSHD)	Trucks, back passing pipeline and earthmoving equipment	Dredge (TSHD)	Dredge (CSD)	Trucks, and earthmoving equipment	Trucks, and earthmoving equipment
Placement area	Upper beach (sub aerial), Holiday Park & Dalby Oval	Surf zone and lower profile	Upper beach	Surf zone and lower profile	Upper beach (sub aerial), Holiday Park & Dalby Oval	Surf zone and lower profile	Upper beach	Upper beach (sub aerial), Holiday Park & Dalby Oval	Upper beach (sub aerial), Holiday Park & Dalby Oval
Maintenance nourishment campaign									
Annual nourishment volume	112,000m^3/yr**	112,000m^3/yr	112,000m^3/yr	112,000m^3/yr	112,000m^3/yr**	112,000m^3/yr	112,000m^3/yr	80,000m^3/yr **	20,000m^3/yr **
Renourishment period (years)	5	10	5	10	1	5	5	1	1
Nourishment volume	560,000m^3**	1.12Mm^3	560,000m^3	1.12Mm^3	112,000m^3**	560,000m^3	560,000m^3	80,000m^3 **	20,000m^3 **
Cost sensitivity included:				4 cases		Results of this case are report in Section 5.2.	Results of this case are report in Section 5.2.		

Description	Option 1				Option 2			Option 3	
	O1a	O1b	O1c	O1d	O2	O2b	O2c	O3a	O3b
Summary of structures									
Stage 1 linear meters of works	458m	458m	458m	225m	458m	458m	458m	458m	225m
Stage 2 linear meters of works	na	na	na	na	995m	995m	995m	995m	1,186m
Griffith Avenue car park structure	Not included	Not included	Not included	Not included	Included	Included	Included	Included	Not included
Griffith Avenue car park groyne	Not included	Not included	Not included	Not included	Included	Included	Included	Included	Not included

***Nourishment volumes converted to native sand volumes using the specified overfill factor of 2.5 in RHDHV (2020).*

Table 3: Overview of Stage 1 and Stage 2 structures.

Description	Original		Revised	
	Stage 1	**Stage 2**	**Stage 1**	**Stage 2**
Total linear meters of proposed terminal erosion protection works (vertical seawall with rock scour protection at the toe)	458m	995m	225m	1,186m
Minimum width between beach erosion scarp and protection line used as trigger for construction works to commence	-	25m	-	20m
Barrie Crescent/Griffith Avenue car park vertical seawall	Included	-	Not included	-
Barrie Crescent/Griffith Avenue car park groyne	Included	-	Not included	-
Applied to:	Option 1a Option 1b Option 1c Option 2 Option 3	Option 2 Option 3	Option 1d Option 3b	Option 3b

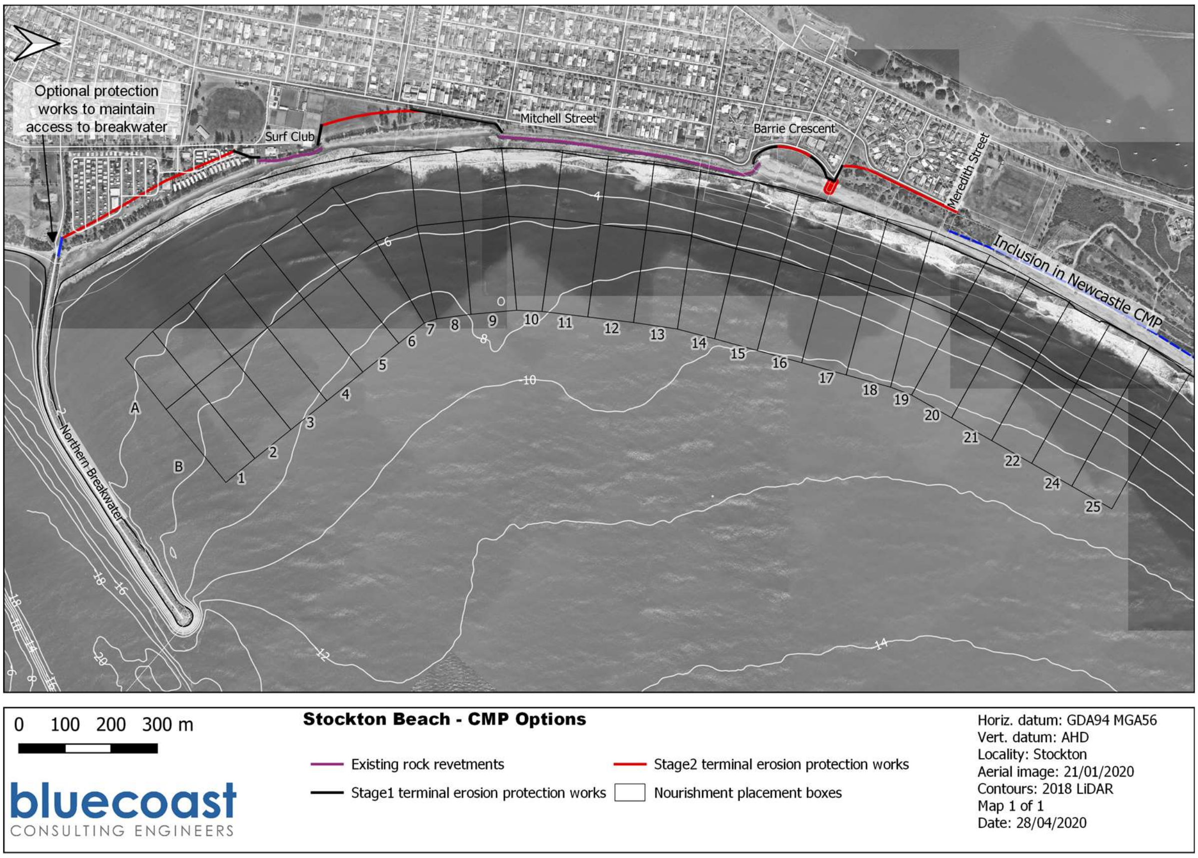

Figure 2: Stockton Beach CMP options (RHDHV, 2020) and preliminary nourishment placement boxes.

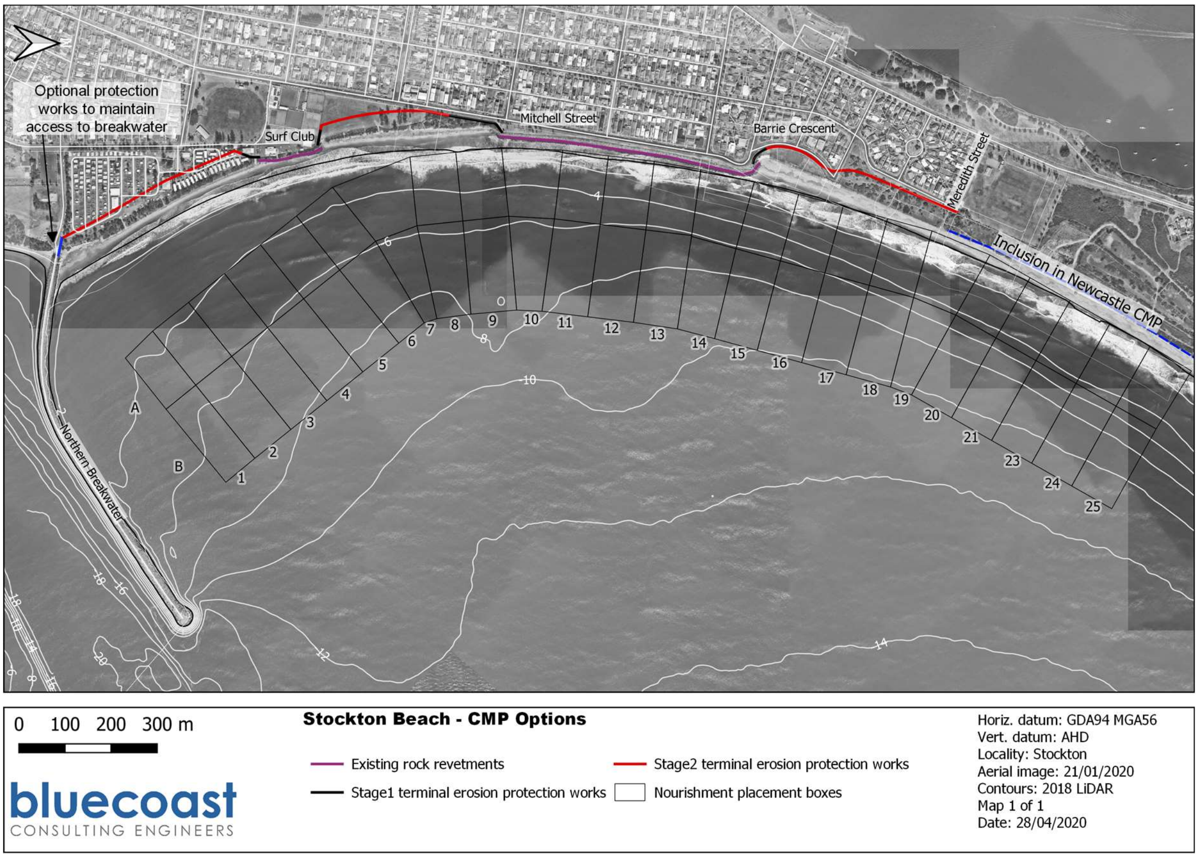

Figure 3: Revised Stockton Beach CMP options (RHDHV, 2020) and preliminary nourishment placement boxes.

As noted in RHDHV's (2020) technical note, Option 1 and Option 2 involve significant quantities of beach nourishment from terrestrial sources. Existing extraction limits from licensed sand quarries in the local region and practical limitations associated with transporting and placing sand on Stockton Beach using trucks and earth moving equipment have however been acknowledged. It is considered that these actions are not currently feasible, although this may alter in the future. Option 3 involves a lower quantity of terrestrial sourced beach nourishment that is legally and technically feasible at the present time. In addition to the above assessment, the future feasibility of mass nourishment using marine sand sources has been included within the CBA through a series of cost and scope of work sensitivity scenarios within Option 1 (Option 1b, 1c and 1d) as described below. CN advised that despite marine sand sources being currently unfeasible, they were to be assessed in the CBA due to the preference of beach nourishment. CN's intention was to also establish the framework to pursue other actions as they become available in the future.

This section describes the identification and quantification of costs and benefits associated with the base case and each of the options. It should be read in conjunction with RHDHV's (2020) technical notes (see **Appendix A**) as a detailed description of the options is not repeated herein.

3.2 Base case – Business as usual

A business as usual base case was assumed for the comparator as part of the CBA. The base case assumes the on-going implementation of all actions as listed under the current CZMP 2018 Part A (Stockton) as the gradual realisation of erosion in accordance with the hazard mapping and associated loss of assets at risk as detailed in Section 4.1.2.

It is noted that all actions listed within the CZMP would still be required to be undertaken as part of all project case scenarios and, therefore, have been excluded from the analysis as the works will effectively net off against each other. The one exception to this is the current forecast budget for emergency works response (e.g. sandbagging) at specific locations that have been identified as being redundant under project cases. This currently represents an expense of $200,000 p.a to CN. The provision of any of the options will avoid the need for this expenditure.

3.3 Option 1 – Mass nourishment and essential protection

RHDHV indicate that terrestrial sand is currently the only available source (RHDHV, 2020). The mass nourishment option and all other options have therefore been developed using this sand as the standard supply source. As previously discussed, it is CN's direction to have Options 1 to 3 considered within the Stockton CMP cost benefit analysis. Recognising that alternative marine sand sources may become available, a range of alternative cost estimate have been developed based on the sand source, vessel sizes, methodology and volumes required. Specifically, the standard option and three additional variants were identified, including:

- **Option 1a**: Mass beach nourishment and essential protection works as above with nourishment sand sourced from a **terrestrial** source.
- **Option 1b**: Mass beach nourishment and essential protection works as above with nourishment sand sourced from an **offshore marine** source.
- **Option 1c**: Mass beach nourishment and essential protection works as above with nourishment sand sourced from a **Hunter River** source.
- **Option 1d**: Mass beach nourishment as under Option 1b, however, the delivery of this is delayed until year one and only Stage 1 essential protection works are included. Before this (i.e. for the first 12-months), works adopted for Option 3b (Section 3.5) were assumed to be implemented.

A summary of the key inputs and assumptions for each variant is provided in Table 4. The costs for Option 1a and 1c have been based on those outlined in RHDHV (RHDHV, 2020). For Option 1b and 1d the nourishment costs were based on the rational and estimates provided in **Appendix B**, noting the assumptions of:

- Native Stockton Beach sand with grain size D50 = 0.35 - 0.40mm.
- Nourishment sand source is assumed to be within 5NM of the nearshore placement zone.
- Assumed placement is all nearshore but as close as possible to the shore for:
    - 75% rainbowed (see example in Figure 4).
    - 25% is bottom dumped.
- 5 or 10 yearly repeated nourishments in the order of 1.0M m^3.
- Budgetary estimates provided by potential contractors based on limited information available and subject to confirmation by a tendering process.

Figure 4: A TSHD rainbowing sand onto the nearshore area of the beach as part of beach nourishment works (source: City of Gold Coast).

Table 4: Option 1 key inputs and assumptions for each variant.

Parameter	Option 1a	Option 1b	Option 1c	Option 1d
Initial nourishment campaign				
Total initial nourishment volume – native	1.8M m^3	2.4M m^3	1.8 M m^3	2.4M m^3
Source	Terrestrial	Marine (offshore)	Hunter River (South Arm)	Marine (offshore)
Method (transport and placement)	Trucks, back passing pipeline and earthmoving equipment	Dredge (e.g. TSHD with rainbowing capability)	Dredge (e.g. CSD with pumping ashore capability)	Dredge (e.g. TSHD with rainbowing capability)
Placement area (cross shore & alongshore)	Upper beach (sub aerial)	Surf zone and lower profile	Upper beach	Surf zone and lower profile
Year of works	1	1	1	2
Average increase in beach width – year of works completion	36	48	36	48
Maintenance nourishment campaign				
Annual nourishment volume	112,000m^3/yr	112,000m^3/yr	112,000m^3/yr	112,000m^3/yr

Parameter	Option 1a	Option 1b	Option 1c	Option 1d
Renourishment period (years)	5 years	10 years	5 years	10 years
Nourishment volume*	560,000 m^3	1.12 M m^3	560,000 m^3	1.12 M m^3
Indicative increase in beach width – average over nourishment period	30	42	30	42
Structures				
Stage 1 vertical seawalls	Original	Original	Original	Revised
Maintenance of seawalls	Reduced relative to base case	Reduced relative to base case	Reduced relative to base case	Reduced relative to base case

*where terrestrial sources are used a 2.5 overfill adjustment factor is required to be applied to the reported values (RHDHV (2020)

3.3.1 Protection of assets

The risks associated with beach nourishment for the purpose of providing coastal erosion protection to backshore assets at Stockton Beach are discussed in detail in **Appendix C**. Broadly, two sand placement quantities and renourishment periods have been considered in the CBA. A simplistic analysis comparing the two strategies is outlined in Table 5. Based on the simplified analysis the risk profile for backshore assets at Stockton Beach is expected to be lower for the higher initial quantity and longer renourishment period. This scenario is also more economical in terms of sand delivery due to the lower mobilisation/demobilisation costs. An even lower risk profile could be realised if a higher initial quantity is provided with regular annual increments delivered thereafter. This would be feasible if a local vessel were utilised to source and place the sand.

Table 5: Mass nourishment risk profile comparison for Option 1.

Parameter	Lower initial quantity	Higher initial quantity
Initial nourishment volume (m^3)	1,800,000	2,400,000
Renourishment period (years)	5	10
Alongshore length (m) along 0m AHD contour plus an additional 200m based on RHDHV (2020a)	2,200	2,200
Length (m) along the -8m AHD contour plus 200m	2,000	2,000
Protection benefits (i.e. above base case) provided by the nourishment immediately following the works		
Nourishment volume per linear meter of nearshore compartment (i.e. full coastal profile) in year 0 (m^3/m)	857	1,143
Effective nourishment volume above AHD (i.e. sub-aerial storm demand) available in year 0 (m^3/m)[1]	286	381
Additional effective Average Recurrence Interval (ARI) storm demand provided in year 0[4]	>500-year (photogrammetry Block A)	>500-year (photogrammetry Block A)

Parameter	Lower initial quantity	Higher initial quantity
	~80-year (photogrammetry Block C)	>100-year (photogrammetry Block C)
Protection benefits (i.e. above base case) provided by the nourishment at the end of the renourishment period		
Long term (full coastal profile) sand loss rate ($m^3/m/yr$) [2]	46.2	46.2
Nourishment volume per linear meter of nearshore compartment (i.e. full coastal profile) at the end of the nourishment period (m^3/m)[3]	626	681
Effective nourishment volume above AHD (i.e. sub aerial storm demand) available in the last year of the nourishment period (m^3/m)[1]	209	227
Additional effective ARI storm demand provided in the last year of the nourishment period[4]	>200-year (photogrammetry Block A) ~45-year (photogrammetry Block C)	>200-year (photogrammetry Block A) ~50-year (photogrammetry Block C)

Notes:

1. This is based on the typical proportion of 33% of the total nourishment volume being the effective volume above AHD (Carley and Cox, 2017).
2. This is based on the long-term volumetric rate of sand loss over the full profile of 112,000m^3/yr between the northern breakwater and the Hunter Water site. An additional allowance for loss due to sea level rise has been included to account for the flattening of the profile due to Bruun rule-based slope re-adjustment.
3. Nourishment sand is also assumed to be lost at the long-term historic rate with an additional allowance for sea level rise. Accelerated losses because of the nourishment sand itself have not been included.
4. This is the additional sub-aerial sandy buffer provided by the beach nourishment works. The existing sub-aerial beach, in unprotected areas of the shoreline, would also provide some coastal protection function. Storm demands are based on the values provided in Bluecoast (2020) with consideration of seawall end effects after Carley et al. (2010).

Sand placed in the surf zone by rainbowing and bottom dumping is assumed to provide an immediate positive coastal protection benefit based on the increased volume in the coastal profile. Referring to the nourishment boxes in Figure 2 it can be seen that sand can be directly rainbowed to the inner surf zone and/or sub-aerial beach along most of the CMP area. This will result in an immediate beach widening and associated benefits being delivered. In the southern corner, the shallower coastal profile means rainbowing is not effective at delivering sand to the sub-aerial beach. Along this southern corner it has been assumed that sand will redistribute across the profile with a proportion of the sand move moving onto the sub-aerial beach and widening the beach in a relatively short period (i.e. less than 3 months).

3.4 Option 2 – Beach amenity sand nourishment and protection (staged)

This option includes construction of terminal protection structures at currently unprotected areas along the entire stretch north of the training wall to Meredith Street, a total length of 1,453m. Given the requirement to maintain a useable beach, a total beach nourishment volume of 375,000m^3/ year of terrestrial sand is proposed to be placed on the upper beach. Sand placement would occur at the

Holiday Park as well as Dalby Oval frontage. A summary of the key inputs and assumptions for this option is presented in Table 6.

Table 6: Option 2 key inputs and assumptions.

Parameter	Option 2
Nourishment campaign	
Total initial nourishment volume – native beach material	210,000 m^3**
Source	Terrestrial
Method (transport and placement)	Trucks, back passing pipeline and earthmoving equipment
Placement area (cross shore & alongshore)	Upper beach (sub aerial), Holiday Park & Dalby Oval frontage
Approximate ARI protection afforded based on storm demand	1-year ARI
Maintenance nourishment campaign	
Annual nourishment volume – native beach material	112,000 m^3 **
Renourishment period (years)	1 year
Structures	
Stage 1 vertical seawalls	Included (original)
Stage 2 Vertical seawalls^^	Included (original)
Maintenance of seawalls	Reduced relative to base case

**Nourishment volumes converted to native sand volumes using the specified overfill factor of 2.5 in RHDHV (2020).
^^Stage 2 was assumed to be developed from 2027

3.5 Option 3 – Available sand nourishment and protection (staged)

As per Option 2, this option includes construction of terminal protection structures at currently unprotected areas along the entire stretch north of the training wall to Meredith Street, a total length of 1,453m. Given the requirement to maintain a useable beach and the logistically feasible sand volumes, a total beach nourishment volume of 200,000m^3/ year of terrestrial sand is proposed to be placed on the upper beach. Sand placement would occur at the Holiday Park and Dalby Oval frontages. An additional sensitivity case (Option 3b) was also undertaken which consisted of the revised Stage 1 structures and a reduced nourishment quantity. A summary of the key inputs and assumptions for Option 3 is presented in Table 7.

Table 7: Option 3 key inputs and assumptions.

Parameter	Option 3	Option 3b
Nourishment campaign		
Total initial nourishment volume – native	80,000 m^3**	20,000 m^3**
Source	Terrestrial	Terrestrial
Method (transport and placement)	Trucks and earthmoving equipment	Trucks and earthmoving equipment
Placement area (cross shore & alongshore)	Upper beach (sub aerial), Holiday Park frontage	Upper beach (sub aerial), Holiday Park frontage
Approximate ARI protection afforded based on storm demand	1-year ARI	Not calculated
Maintenance nourishment campaign		
Annual nourishment volume – native beach material	80,000 m^3**	20,000 m^3**
Renourishment period (years)	1 year	1 year
Structures		
Stage 1 vertical seawalls	Original	Revised
Stage 2 Vertical seawalls^^	Original	Revised
Maintenance of seawalls	Reduced relative to base case	Reduced relative to base case

**Nourishment volumes were converted to native sand volumes using the specified overfill factor of 2.5 in RHDHV (2020).
^^Stage 2 was assumed to be developed from 2027

4. CBA METHODOLOGY

4.1 Approach

The economic assessment considers the comparative costs and benefits of each of the three management options (and variations therein) against the base case scenario as outlined in Section 3.

The economic merit of each option was determined by comparing the present value of the change in net economic benefits (compared with the base case) less the change in capital and operational and maintenance costs (compared with the base case). The key benefits incorporated within this cost benefit analysis (CBA) assessment were in the form of:

- Maintained beach area and associated non-use and use values.
- Reduced loss or property and land to both private landowners and CN.

4.1.1 Model assumptions

For the purposes of this assessment several assumptions have been made to facilitate evaluation of project performance, these include:

- A discount rate of seven per cent per annum has been applied.
- The initial nourishment works for all options has been assumed to be undertaken in 2021 with 2022 representing the first full year of operation and benefits.
- Stage 2 structural works were assumed to be completed by 2028, with 2029 representing the first year of associated benefits.
- A benefit evaluation period of 50 years from the first full year of operation was adopted.
- The base year of assessment was assumed to be 2020 and all values are in 2020 dollars.

4.1.2 Shoreline recession and erosion

In conjunction with the CBA a probabilistic erosion hazard assessment is being undertaken by Bluecoast. The approach and adopted input parameters to the probabilistic modelling are discussed in Bluecoast (2020). In summary, appropriate ranges of long-term recession, sea level rise and beach profiles were adopted to produce probability density curves that fed into a Monte-Carlo simulation of over one million scenarios.

Storm erosion was assessed for beach profiles along DPIE's NSW photogrammetry locations (Figure 5) using the Wedge Failure Plan Model described in Nielsen et al. (1992) which provides setbacks for a series of foundation stability zones. For the purpose of this study, the Zone of Reduced Foundation Capacity (ZRFC) was adopted as the erosion hazard extent, which is the estimated unstable zone of a dune following a coastal erosion event in which it is not acceptable to locate foundations for coastal buildings and infrastructure. The results from the probabilistic hazard modelling provide probabilities of exceedance (PoE) for shoreline recession and erosion setbacks for every year in a 100-year planning horizon. As an example, the calculated 1% PoE (or Annual Exceedance Probability - AEP) erosion hazard lines for the base case (Option 1) are presented in Figure 5.

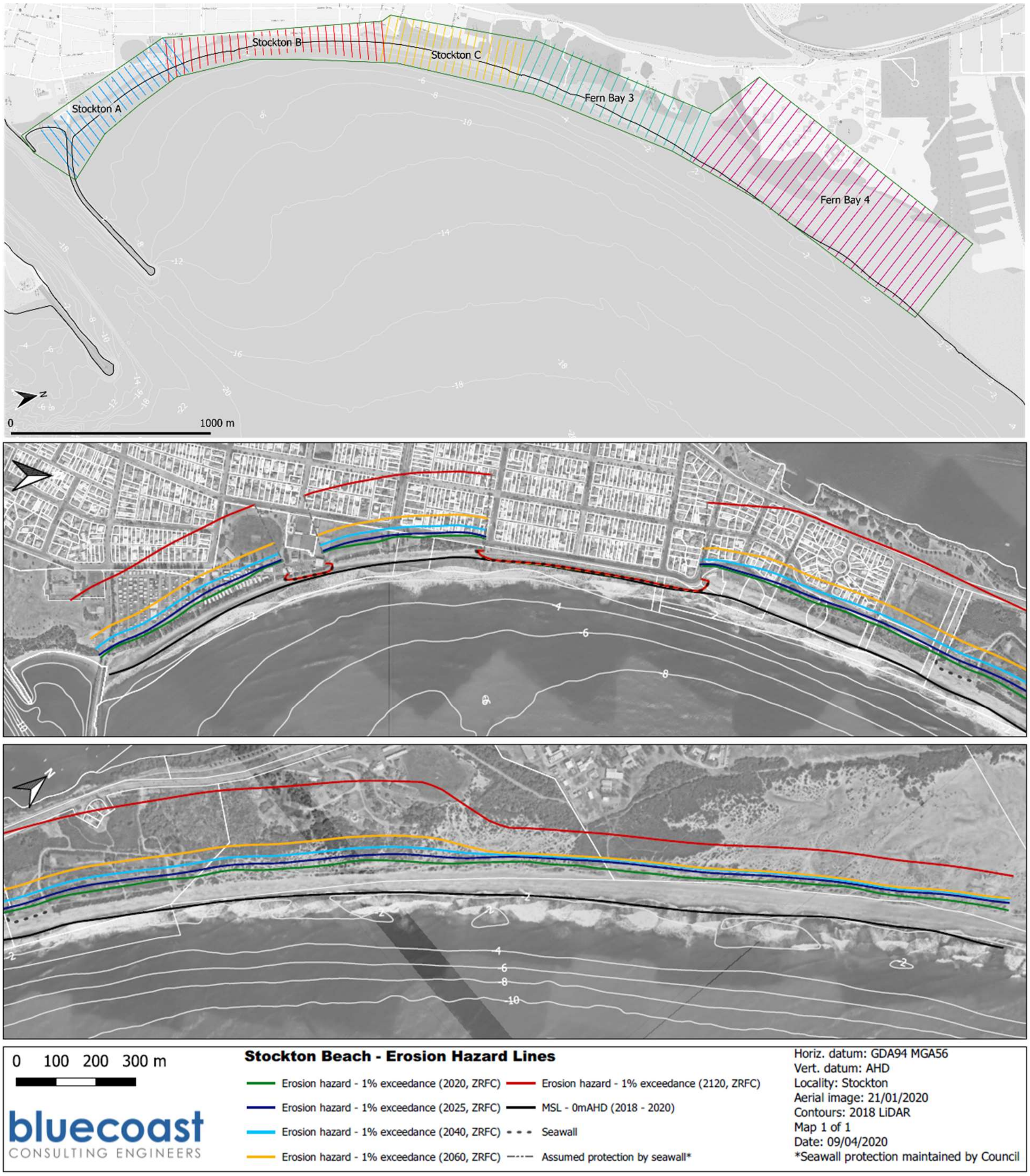

Figure 5: (top) NSW photogrammtery profile locations and (bottom) hazard lines for the 1% AEP erosion hazard for various years in the planning period.

Recession extents for four forecast years were evaluated for each of the options assessed. Within each forecast year, three PoE of erosion setback scenarios were assessed. The erosion setback was assumed to be the calculated ZRFC. The scenarios assessed are summarised in Table 8.

Table 8: Erosion scenarios assessed.

Year	ZRFC PoE Scenarios	Source
2020	50%	Hazard Mapping
	10%	Hazard Mapping
	1%	Hazard Mapping
	100%	*Linear extrapolation*
2040	50%	Hazard Mapping
	10%	Hazard Mapping
	1%	Hazard Mapping
	100%	*Linear extrapolation*
2060	50%	Hazard Mapping
	10%	Hazard Mapping
	1%	Hazard Mapping
	100%	*Linear extrapolation*
2120	50%	Hazard Mapping
	10%	Hazard Mapping
	1%	Hazard Mapping
	100%	*Linear extrapolation*

It is seen in Table 8 the 50% PoE represents the most likely occurring scenario assessed. In the absence of analysis of a more certain extent (e.g. a 100% PoE), linear extrapolation of the three PoE data points was adopted as a conservative (i.e. likely to underestimate the extent) method of estimating these more frequent events and allowing for a fuller probabilistic evaluation of potential impacts over time. Figure 6 provides an example of the estimated scenarios and associated linear extrapolation function adopted.

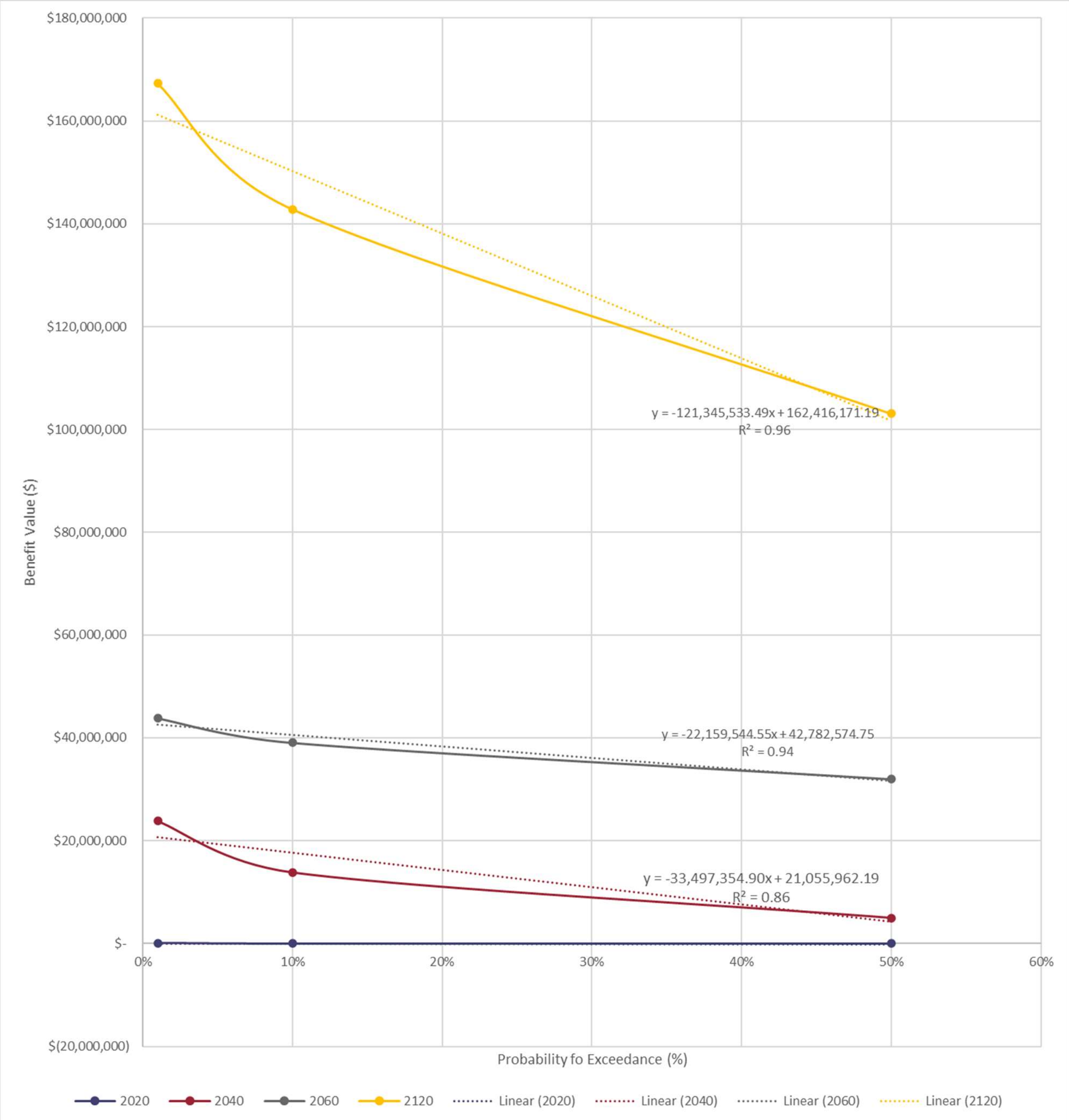

Figure 6: Value of properties affected by year and PoE.

Within each of the 16 scenarios, the following impact or erosion setback to a range of aspects were considered. Table 9 summarises the categories considered, and key units and assumptions utilised in quantifying the impacts. The GIS asset databases provided by CN and hazard mapping extents were utilised as the basis of identification and evaluation.

Table 9: Categories of assets affected by erosion setback.

Asset Category	Metric / Unit	Assumptions / Rules
Private Property (Buildings)	No. of Buildings Affected	Where the scenario ZRFC was seen to intersect with the known main structure on a property it was assumed the building would be lost. Secondary structures (e.g. shed) were not considered independently of the main building per lot.
Private Property (Land)	m^2	The proportion of affected land within individual lots was evaluated.
Council owned land and other non-private lands	m^2	The proportion of affected land within individual lots was evaluated.
Council owned assets (Buildings)	No. of buildings Affected	Where the scenario ZRFC was seen to intersect with the known main structure on a property it was assumed the building would be lost. For the Holiday Park, multiple structures were counted and evaluated independently although falling within a single lot.
Council owned assets (Roads and Paved Areas)	m^2	The proportion of affected land within individual lots was evaluated.
Council owned assets (Shelters)	No. of Buildings Shelters	Where the scenario ZRFC was seen to intersect with a shelter it was assumed the shelter would be lost.
Council owned assets (Stormwater Drainage Infrastructure)	m	The length of affected land within individual lots was evaluated
Council owned assets (Public Artworks)	No. of Artworks Affected	No artworks fell within any of the scenarios assessed.
Council owned assets (Public Furniture)	No. of Furniture Affected	No furniture fell within any of the scenarios assessed.
Council owned assets (Public Playgrounds)	No. of Playgrounds Affected	No furniture fell within any of the scenarios assessed.

Table 10 summarises the resulting assets at risk identified within each category, for each scenario under the base case. There is a marked increase in the extent of affected private assets between 2040 and 2060. In contrast, affected council assets are seen to increase significantly between 2020 and 2040.

Table 10: Base case assests affected.

Year	PoE	Private Property		Council and Non-Private Property				
		Buildings (no.)	Land (m^2)	Buildings (no.)	Land (m^2)	Pavement (m^2)	Shelter (no.)	Drainage (m)
2020	50%	-	-	-	-	132	-	-
	10%	-	-	16	15,279	1,622	-	-
	1%	1	2,694	18	28,023	4,866	-	-
2040	50%	4	2,213	24	70,588	6,004	3	-
	10%	12	4,427	28	76,635	8,592	4	-
	1%	24	6,640	31	83,028	11,131	4	4
2060	50%	26	389,141	33	87,227	12,218	4	13
	10%	37	445,684	34	94,520	14,579	5	29
	1%	44	496,447	34	100,990	16,293	5	43
2120	50%	114	687,003	36	129,710	28,381	6	371
	10%	167	797,980	37	139,250	35,254	6	505
	1%	202	879,902	37	145,530	47,189	7	840

Under each of the project case scenarios it was assumed that all these losses would be avoided through either the maintenance of the beach or the provision of seawall protection structures. However, under Option 2 and Option 3, while retaining some beach amenity, the beach will effectively still recede back to the proposed seawalls and be maintained at the location. As such the construction of the seawall will require both the demolition of assets along its alignment as well as the gradual recession and loss of council land as the beach moves to the seawalls. For the purposes of this assessment it is assumed that this will occur at the same rate as would occur under the base case scenario. However, it is recognised that studies indicated the presence of seawall structures may accelerate the rate of recession. For both Option 2 and Option 3, land areas affected under the 2040 50% PoE will be lost. Beyond 2040, no further loss would occur. In terms of assets, other than assets required for removal in construction of the seawall, no assets will be lost within the area landward of the seawall. Construction will require some Holiday Park assets to be relocated or demolished. For the purposes of this CBA it was assumed that all such losses would occur in 2027 (Table 11). None of the options resulted in the loss of private property.

Table 11: Project case assests affected for Options 2 and 3.

Year	PoE	Council	
		Buildings (no.)	**Land**
2027	-	23 Holiday Park structures and 2 shelters	2.8 ha
2040	50%	-	8.3 ha

4.1.3 Beach areas

The current and forecast beach areas were estimated into the future, considering the:

- Historic variation in beach widths (Figure 7) based on photogrammetry.
- Variation between sections in terms of landward infrastructure (e.g. seawalls), see Figure 8.
- Projected impacts of climate change to sea levels and storm erosion.

The current dry beach area was considered adopting RHDHV's definition (i.e. 1.5m AHD to scarp). Historic dry beach widths were calculated based on available survey data between June 1994 and February 2020 and average occurrence frequencies were determined for representative beach zones, see Figure 8. These zones follow the management zones defined in the 2018 Newcastle CZMP but also include the SLSC revetment as a separate zone. Applying the estimated combined underlying and sea level rise recession (Bluecoast, 2020) to the distribution of historic beach widths provided the projected future beach width for each representative zone.

This was based on assumptions in RHDHV (2020a) that any future beach recession would result in a reduction in available (dry) beach widths and associated amenity values where seawalls are in place while unprotected areas would recede without a change in the beach area. Recession of the unprotected areas without a change in beach area assumes that the landward area is composed of sand. This is considered a reasonable assumption given Stockton is a sand spit/coastal barrier. The geotechnical data required to confirm this assumption does not exist. Any storm erosion hazard is excluded from this part of the assessment because it is assumed that the beach naturally recovers from episodic storm-driven erosion. In general, it was assumed that as the shoreline recedes the beach width would not change. Estimated recession rates included both long term shoreline recession and recession due to sea level rise and varied between the 1.31 m/year for photogrammetry Block A and 1.62 m/year for Block B (see photogrammetry locations in Figure 5).

In addition, dry beach areas have been calculated based on the 1.5m AHD contour and scarp (or structure) position in the 2018 LiDAR topography data. The future beach areas over the planning period were estimated by applying the representative beach width reduction over the alongshore distance of each section. Based on five yearly increments from 2020 to 2120, probabilistic estimates of exceedance for beach area were estimated for the base case as well as for each of the project case scenarios. Based on the modelled probabilities of exceedance (100%, 99%, 98% 95%, 90%, 75%, 50%, 25%, 10%, 5%, 2%, 1%, 0.1% and 0.0001%) an expected average annual beach width was determined for each year. An example sub-set for the adopted beach areas is presented in Table 12.

The resultant areas for each project case are summarised in Table 13. The mass nourishment options, significantly expand the available average beach areas, whereas Option 2 provides a constant minor addition, and Option 3 leads to a gradual decay as the beach retreats to the seawalls.

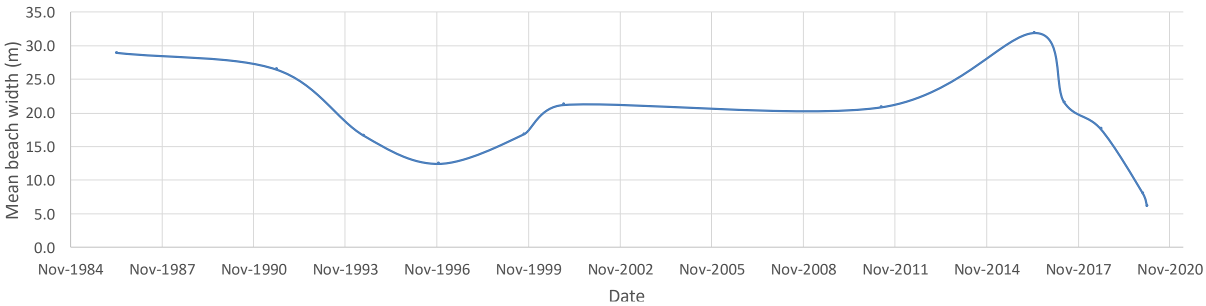

Figure 7: Historic photogrametry-based beach widths averaged over Block A.

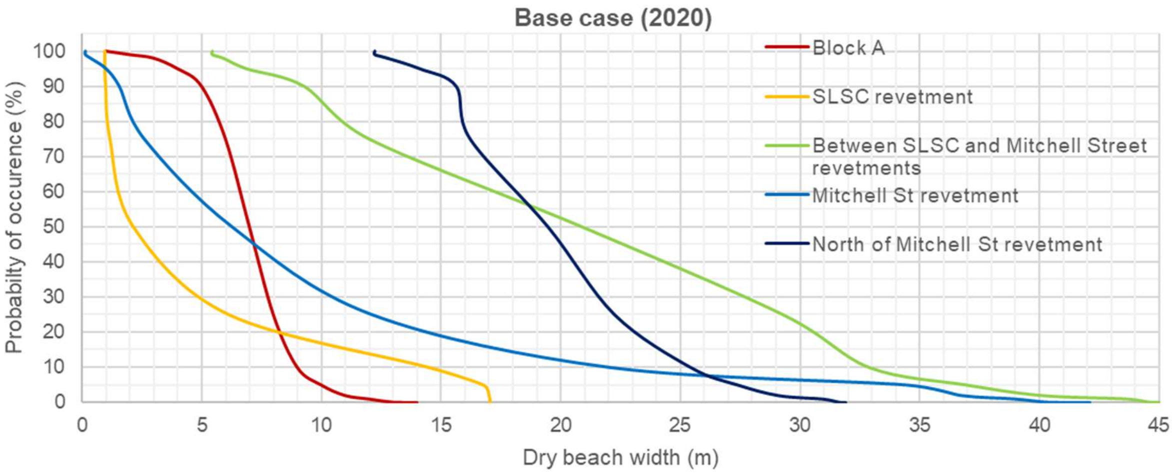

Figure 8: Distribution of beach width occurrences for representative sections along Stockton Beach comparing periods when a rock revetment was in place.

Note: the periods represented in this figure vary depending on the construction date of the rock revetments. For the Block A and SLSC revetment sections the period presented is from August 2018 to February 2020. For all other sections, the periods presented in from June 1994 to February 2020.

Table 12: Example summary of the distribution of adopted dry beach areas in square metres for the base case scenario for Block A.

	Probability of occurrence (%) of beach areas (m²)								
Year	**100**	**90**	**75**	**50**	**25**	**10**	**5**	**1**	**0.1**
2020	916	2,278	2,460	3,072	6,667	9,887	11,120	14,018	14,036
2025	916	2,278	2,460	3,072	6,667	9,887	11,120	14,018	14,036
2040	916	2,278	2,460	3,072	6,667	9,887	11,120	14,018	14,036
2060	916	2,278	2,460	3,072	6,667	9,887	11,120	14,018	14,036
2120	916	2,278	2,460	3,072	6,667	9,887	11,120	14,018	14,036

Table 13: Forecast average annual beach areas.

Year	Expected Beach Area (m²)					
	Base Case	Option 1a & 1c	Option 1b & 1d	Option 2	Option 3	Option 3b
2020	23,146	89,646	95,104 *(23,146 for 1b)*	29,844	28,988	28,988
2025	19,279	85,779	95,104	29,844	23,479	21,702
2040	19,279	85,779	95,104	29,844	21,279	14,127
2060	19,279	85,779	95,104	29,844	13,888	500
2120	19,279	85,779	95,104	29,844	0	0

4.2 Costs

4.2.1 Capital costs

The capital costs for each option were provided in RHDHV (2020) and are summarised in Table 14. It is seen that the forecast costs for Option 1 and 2 greatly exceed other components due to the high cost of terrestrial sand acquisition for nourishment.

Table 14: Project option capital costs.

Project case	Component				TOTAL COSTS
	Nourishment		Vertical structures (seawalls, rock toe etc.)		
	Volume (m³)	Costs ($M)	Length (m)	Costs ($M)	
Option 1a	4,500,000**	364.5	458	12.2	376.7
Option 1b	2,400,000	21.4	458	12.2	33.6
Option 1c	1,800,000	45.0	458	12.2	57.2
Option 1d*	2,400,000	25.4	225	5.8	31.2
Option 2a	525,000**	46.5	1,453	39.8	86.3
Option 2b	610,000	11.6	1,453	39.8	51.4
Option 2c	610,000	18.3	1,453	39.8	58.1
Option 3	200,000**	16.0	1,453	39.9	55.9
Option 3b	50,000**	4.0	1,411	36.0	40.0

*includes nourishment costs associated with Option 3b for the first year.

** These quantities are based on the quantities required from the source rather than the effective beach nourishment volume (as presented in Table 2). Due to grain size compatibility the quantity required from the source is 2.5 times the effective beach nourishment volume.

The expenditure profile for each of the option is shown in Table 15. Due to the logistics constraints associated with terrestrial transport of sand and volume of nourishment required under Option 1a, its costs have been extended over a five-year period. For options involving the development of one or more seawall components, this was assumed to be undertaken over a two-year period from 2025-2030.

Table 15: Capital cost expenditure profile.

Year	Expenditure ($M, 2020)								
	Option 1a	Option 1b	Option 1c	Option 1d	Option 2a	Option 2b	Option 2c	Option 3a	Option 3b
2020	-	-			-	-	-	-	
2021	376.7	27.2	50.8	9.8	609	26.0	32.6	28.2	9.8
2022	-	-	-	24.4	-	-	-	-	-
2023	-	-	-	-	-	-	-	-	-
2024	-	-	-	-	-	-	-	-	-
2025	-	-	-	-	-	-	-	-	15.1
2026	-	-	-	-	-	-	-	-	15.1
2027	-	-	-	-	12.7	-	-	13.9	-
2028	-	-	-	-	12.7	-	-	13.9	
2029						12.7	12.7		
2030	-	-	-	-		12.7	12.7		-
TOTAL	**376.7**	**27.2**	**50.8**	**31.2**	**86.3**	**51.4**	**58.1**	**55.9**	**40.0**
NPV (7% discount rate)	**352.0**	**25.4**	**47.5**	**27.8**	**72.2**	**37.6**	**43.9**	**43.0**	**30.0**

4.2.2 Operational and maintenance costs

The proposed beach nourishment works for each of the options will require on-going periodic maintenance nourishment in order to maintain the average estimated beach width under each option and protect assets from recession. In addition, the proposed vertical structures will require on-going periodic maintenance to ensure functionality and protection. The assumed maintenance works, frequencies and associated costs are summarised in Table 16 as well as the associated Net Present Value of future maintenance works under each option. Full details are provided in RHDHV (2020), including a figure showing the CZMP zones referred to in the table. All costs are additional over the base case scenario. As noted in Section 3, the base case includes $200,000 per annum of emergency works (present value - $2.6M) which will be avoided under each project scenario.

Table 16: Operational and maitenance cost expenditure profile.

Activity	Frequency	Cost	Stage
Option 1a			
Terrestrial Beach Nourishment	5	112,000,000	1
Corroba Oval Nourishment Storage	1	2,500,000	1
Diesel pump	1	1,200,000	1
Zone 1 Pile wall	5	56,000	1
Zone 1 Rock toe	5	14,000	1
Zone 1 Waste disposal	5	-	1
Zone 2 Pile wall	5	224,000	1
Zone 2 Rock toe	5	56,000	1
Zone 2 Waste disposal	5	25,000	1
Zone 4 Pile wall	5	178,000	1
Zone 4 Rock toe	5	44,500	1
Zone 4 Beach access	5	22,500	1
Zone 4 Road and Footpath	5	21,250	1
NPV (7% Discount Rate)	**$297.8M**		
Option 2a			
Beach Nourishment	1	22,400,000	1
Corroba Oval Nourishment	1	2,500,000	1
Diesel pump	1	1,200,000	1
Zone 1 Pile wall (s1)	5	56,000	1
Zone 1 Rock toe (s1)	5	14,000	1
Zone 2 Pile wall (s1)	5	224,000	1
Zone 2 Rock toe (s1)	5	56,000	1
Zone 4 Pile wall (s1)	5	178,000	1
Zone 4 Rock toe (s1)	5	44,500	1
Zone 4 Barrie Cres	5	21,250	1
Zone 4 Griffiths	5	225,000	1
Zone 4 Beach access	5	10,000	1
Zone 1 Pile wall (s2)	5	420,000	2
Zone 1 Rock toe (s2)	5	1,050,000	2
Zone 1 Waste disposal (s2)	5	-	2
Zone 1 Accessways (s2)	5	7,500	2

Activity	Frequency	Cost	Stage
Zone 1 SLSC (s2)	4	144,000	2
Zone 2 Pile wall (s2)	5	223,000	2
Zone 2 Rock toe (s2)	5	55,750	2
Zone 2 Waste disposal (s2)	5	7,500	2
Zone 2 Accessways (s2)	5	25,000	2
Zone 4 Stg 2 Griffiths	5	352,000	2
Zone 4 stg 2 Rock Toe	5	88,000	2
Zone 4 Accessways	5	7,500	2
NPV (7% Discount Rate)	**$339.2M**		
Option 2b			
As with Option 2a except:			
Beach Nourishment	5	10,640,000	1
NPV (7% Discount Rate)	**$26.0M**		
Option 2c			
As with Option 2a except:			
Beach Nourishment	5	16,800,000	1
NPV (7% Discount Rate)	**$39.8M**		
Option 3			
Beach Nourishment	1	16,000,000	1
Corroba Oval Nourishment	0	-	1
Diesel pump	0	-	1
Zone 1 Pile wall (s1)	5	56,000	1
Zone 1 Rock toe (s1)	5	14,000	1
Zone 2 Pile wall (s1)	5	224,000	1
Zone 2 Rock toe (s1)	5	56,000	1
Zone 4 Pile wall (s1)	5	44,500	1
Zone 4 Rock toe (s1)	5	25,000	1
Zone 4 Barrie Cres	5	21,250	1
Zone 4 Griffiths	5	178,000	1
Zone 4 Beach access	0	-	1
Zone 1 Pile wall (s2)	5	420,000	2
Zone 1 Rock toe (s2)	5	105,000	2

Activity	Frequency	Cost	Stage
Zone 1 Waste disposal (s2)	0	-	2
Zone 1 Accessways (s2)	5	7,500	2
Zone 1 SLSC (s2)	4	144,000	2
Zone 2 Pile wall (s2)	5	223,000	2
Zone 2 Rock toe (s2)	5	55,750	2
Zone 2 Waste disposal (s2)	5	25,000	2
Zone 2 Accessways (s2)	5	7,500	2
Zone 4 Stg 2 Griffiths	5	352,000	2
Zone 4 stg 2 Rock Toe	5	88,000	2
Zone 4 Accessways	5	7,500	2
NPV (7% Discount Rate)	**$207.6M**		
Option 1b			
Beach Nourishment	10	12,400,000	1
Corroba Oval Nourishment	1	-	1
Diesel pump	1	-	1
Zone 1 Pile wall	5	56,000	1
Zone 1 Rock toe	5	14,000	1
Zone 1 Waste disposal	5	-	1
Zone 2 Pile wall	5	224,000	1
Zone 2 Rock toe	5	56,000	1
Zone 2 Waste disposal	5	25,000	1
Zone 4 Pile wall	5	178,000	1
Zone 4 Rock toe	5	44,500	1
Zone 4 Bleachers	5	22,500	1
Zone 4 Road and Footpath	5	21,250	1
NPV (7% Discount Rate)	**$10.4M**		
Option 1c			
Beach Nourishment	5	16,800000	1
Corroba Oval Nourishment	1	-	1
Diesel pump	1	-	1
Zone 1 Pile wall	5	56,000	1
Zone 1 Rock toe	5	14,000	1

Activity	Frequency	Cost	Stage
Zone 1 Waste disposal	5	-	1
Zone 2 Pile wall	5	224,000	1
Zone 2 Rock toe	5	56,000	1
Zone 2 Waste disposal	5	25,000	1
Zone 4 Pile wall	5	178,000	1
Zone 4 Rock toe	5	44,500	1
Zone 4 Bleachers	5	22,500	1
Zone 4 Road and Footpath	5	21,250	1
NPV (7% Discount Rate)	**$14.5M**		
Option 1d			
Option 3b Costs for 1 year	-		-
Option 1b costs from year 2	-		-
NPV (7% Discount Rate)	**$13.9M**		
Option 3b			
Beach Nourishment	1	4,000,000	1
Zone 1 Pile wall	5	35,000	1
Zone 1 Rock toe	5	8,750	1
Zone 2 Pile wall	5	150,000	1
Zone 2 Rock toe	5	37,500	1
Zone 4 Pile wall (s1)	5	40,000	1
Zone 4 Rock toe (s1)	5	10,000	1
Zone 4 Barrie Cres	5	10,000	1
Zone 4 Accessways	5	2,500	1
Zone 1 Pile wall (s2)	5	441,000	2
Zone 1 Rock toe (s2)	5	110,250	2
Zone 1 Accessways (s2)	5	7,500	2
Zone 1 SLSC (s2)	4	144,000	2
Zone 2 Pile wall (s2)	5	295,000	2
Zone 2 Rock toe (s2)	5	73,750	2
Zone 2 Waste disposal (s2)	5	25,000	2
Zone 2 Accessways (s2)	5	7,500	2
Zone 4 Stg 2 Griffiths	5	450,000	2

Activity	Frequency	Cost	Stage
Zone 4 stg 2 Rock Toe	5	112,500	2
Zone 4 Accessways	5	7,500	2
NPV (7% Discount Rate)	**$52.7M**		

4.2.3 Other unquantified aspects

A summary of other non-quantified aspects not included in the CBA are:

- Approvals risks for obtaining the required sand volumes from any of the sources.
- There are existing approvals for relatively modest quantities of beach nourishment material to be placed at Stockton Beach. They do not allow for the larger quantities required for mass nourishment. The existing approvals are associated with maintenance dredging in an area referred to as Area E, located at the entrance to the navigation channel of the Port of Newcastle. This area has a high sand content. The existing approvals are described further in WorleyParsons, 2012.
- The results of the 2019 beach nourishment trial showed that sand delivered by terrestrial sources does not match the colour of native beach material at Stockton. This is often poorly received by the community and has been raised as a concern in the CLG. However, the effect of this negative perception has not been factored into the amenity value of the beach. It is noted that sand delivered to the inner surf zone would be expected to naturally mix with native sand and not show marked colour differences.
- The high cost of the terrestrial sand along with the overfill ratio means that this represents extremely poor value for money and is unlikely to be a widely acceptable expenditure of public money.
- Wave overtopping and coastal inundation from storm surge, large storm waves and sea level rise as they relate to Stage 1 and Stage 2 structures have not been included herein. While not expected to be significant in the short term, by 2040 and beyond, in the case nourishment is not maintained at the desired levels and when the structures start to serve their intended erosion protection function, wave overtopping and inundation risks is considered likely to become significant offsetting the erosion protection benefits.
- The completion of Stage 1 and Stage 2 coastal structures, when combined with the existing rock revetments, would see the armouring of a total of 2,200m of coastline that is known to be undergoing long term recession. Should nourishment not compensate for the long-term sand losses and losses due to sea level rise, downdrift (i.e. northern) areas will be at an increased risk of erosion and shoreline recession. It is recommended that the future Newcastle CMP consider a sediment compartment wide strategic approach when developing feasible options.
- Trucking of terrestrial sand and placement on the subaerial beach would require four works campaigns a year, each taking 7-weeks at three project sites spread across the CMP area (RHDHV, 2020). Heavy machinery occupying the beach for up to 28-weeks a year is a high level of disruption to amenity value of the beach but has not been factored into the CBA. The public safety risks, damage to public roads and/or the local traffic disruption associated with truck movements have not been factored into the CBA.

4.3 Benefits

For the purposes of the CBA and given the magnitude of the costs identified the analysis has focussed upon quantification of the major benefit streams. The following benefits were estimated:

- Beach amenity (i.e. use and non-use values)
- Avoided private property loss
- Avoided public land loss
- Avoided public infrastructure loss
- Avoided loss of producer surplus
- Residual value

The following sections details the derivation of the each of the benefits identified. Table 17 provides a summary of the contribution of each benefit to the economic performance of each project. It is seen that beach amenity represents the major benefit for several project cases. Avoided impacts to private land and property remains relatively constant across all options as all options provide a similar level of protection in this regard.

Table 17: Summary of estimated benefits ($2018/20 constant dollars).

	O1a		O2a-c		O3		O1b		O1c		O1d		O3b	
	$M	%	$M	%	$M	%	$M	%	$M	%	$M	%	$M	%
Beach amenity	40.5	76.5	15.0	63.2	8.1	48	42.7	77.3	40.5	76.4	40.6	76.6	2.3	20.5
Property loss	7.2	13.5	7.2	30.1	7.2	42.5	7.2	12.9	7.2	13.5	7.2	13.5	7.2	65.1
Council asset loss	2.5	4.8	0.4	1.7	0.4	2.4	2.5	4.6	2.5	4.8	2.5	4.8	0.4	3.5
Council land loss	1.3	2.4	0.4	1.7	0.4	2.4	1.3	2.3	1.3	2.4	1.2	2.8	0.4	3.7
Producer Surplus	1.5	2.8	0.4	1.5	0.4	2.4	1.5	2.7	1.5	2.8	1.5	2.3	0.2	2.0
Residual value	0.0	-	0.4	1.7	0.4	2.4	0.1	0.2	0.1	0.2	0.1	0.1	0.6	5.2
TOTAL	**52.9**	**100**	**23.8**	**100**	**16.8**	**100**	**55.2**	**100**	**53.0**	**100**	**53.0**	**100**	**11.0**	**100**

It is noted that there are number of additional benefits that have not been able to be captured within the CBA given its timing and scope. These are discussed in Section 4.3.7.

4.3.1 Beach amenity

Beach amenity is a broad term that can capture a wide range of beach values to both active and non-active beach users. For the purposes of this economic assessment, beach amenity is defined to be the collective use and non-use values ascribed to the presence and extent of Stockton Beach. In the absence of site specific information regarding usage of the beach and associated foreshore areas for the CBA and literature review was undertaken to identify potential benefit transfer values that could be taken to be representative of the Stockton Beach use and non-use value of the beach. Numerous studies have been undertaken regarding beach valuation, however in general many relate to high usage or high tourism value beaches (e.g. Gold Coast, Manly, Bondi) and rely upon travel-cost / willingness to pay valuations for users wanting to utilise the beach and broader impacts into surrounding economies. Given that Stockton Beach is not of a similar tourism scale to many such studies (although the Holiday Park does attract regional visitors), the economic analysis does not directly consider tourism values, but rather focuses on estimate recreational and non-use values for beach areas.

A number of studies have been completed recently which attempt to place high level order of magnitude values to both beach use values (i.e. the values humans derive from the beach through some form of interaction with it; this may be direct (e.g. visitation) or indirect (e.g. ecosystem services provide by the beach that support fisheries) or non-use values (the intrinsic value assigned by individuals to the beach that it should continue to exist, independent of personal use). Table 18 summarises a series of recent valuation estimates for use and non-use values for beaches within Sydney and across NSW. In particular, the Pascoe et al. (2017) study represents a state-wide (considering both Sydney and regional locations) to estimate use and non-use values per hectare of beach area. The methodology within combines a range of techniques (choice experiments and analytic hierarchy process), based on a single survey. While the resultant valuations are highly influenced by LGA populations, for the purposes of this CBA the valuations are potentially representative of a lower valuation range.

Table 18: Use and non-use valuations.

Source	Non-Use	Unit	Use	Unit
Pascoe et al 2017	$1.19	per household per quarter per hectare	$11.70	per person per visit
Deloitte 2016	$28.50	per person per year	$40.12	per person per visit
Sydney Coastal Councils 2013	$141.76	per person	$16.13	per person per visit

Based on the estimated current annual beach visitation rates, population and household size within the Stockton and surrounding suburbs and LGA, and the current beach area, these literature values were converted to $/m^2 of Stockton Beach and a conservative weighted[2] estimate derived:

- Use value: $57.31 per m^2 per year
- Non-use value: $19.0 per m^2 per year

It is recognised that the local community have strongly expressed their concern for protection of the beach and the preservation of connectivity, supporting an elevated level of beach value. However, a limitation of the utilisation of per square meter metrics is that it does not recognise the variation that may arise in valuation between circumstances in which there is little or a lot of additional beach area and how this may vary over time. In response to these elements the following assumptions were adopted:

- Diminishing marginal returns of sand provision - A diminishing rate of return per additional square meter of beach area (over the existing beach area) was applied to use values, reaching a floor of $1 per m^2 per year.

[2] For use values 80%:10%:10% was applied to Pascoe et al (2017), Deloitte (2016) and Sydney Coastal Council (2013). For non-use values 90%:10% was applied to Pascoe et al (2017), Deloitte (2016).

- Connectivity losses – Where recession and erosion led to segmentation of the beach through separation of lengths of sea wall (in either the base case or project case) a series of reduction in use and non-use rates was applied: 15% for the first division, 20% for the second and a floor of 50% for further segmentation.

Based on the forecast expected beach areas under each year (Table 13), an estimate of the change in beach amenity relative to the base case was derived. The resultant present values are summarised in Table 19. It is seen that Options 1a-d generate significant amenity benefit through the more than five-fold increase in average beach area sustained into the future.

Table 19: PV of beach amenity benefits.

	Base Case	Project Case	Difference
Option 1a	18.1	58.5	40.5
Option 2a-c	18.1	33.1	15.0
Option 3	18.1	26.1	8.0
Option 1b	18.1	60.7	42.7
Option 1c	18.1	58.5	40.4
Option 1d	18.1	58.7	40.6
Option 3b	18.1	20.3	2.3

As way as comparison, the current base case present value of Stockton Beach ($18M), consists of $13.5M in use value and $4.5M in non-use value. This non-use value is equivalent to approximately $1.6M (present value) per hectare of beach. This is at the lower end of estimate values for sandy beaches estimated by Pascoe et al 2017 for non-Sydney Beaches. Given the strongly expressed community values for protection of the beach (within the immediate community) this may be a conservative estimate of value. It also demonstrates the high dependency of the result upon forecast beach visitation. As noted previously, the lack of beach visitation and utilisation data is a constraint to this analysis and ratification of the assumptions therein should be undertaken.

4.3.2 Private property

City of Newcastle (CN) provided a database of current land values and sale prices for all private properties within the affect hazard extents. Where cadastral blocks land values and/or sale prices were unavailable, an estimated land value and sale price was based on the average multiplied between land values and sale prices and, where required, the cadastral lot size. To account for variation in land and sale prices with proximity to beach frontage, the estimated valuations were applied incrementally within each of the 16 probability of exceedance scenarios. The average land value per cadastral block was seen to be approximately $545,000 and the average sale price $800,000 (the average sale price for properties in closest proximity to the beach were seen to be $1.39M). Using the criteria outlined in Table 9, each affected building and land parcel under each scenario was estimated using the following assumptions:

- If the erosion extent intruded within a cadastral block but did not affect the main structure, the value of impact was the proportionate land value of area affected.

- If the erosion extent intruded within the footprint of the main structure, the value of impact was the sale price for the property.
- For strata properties, it was assumed all property values would be lost where the main structure was affected. To avoid duplication, strata properties with non-structural erosion, were only applied to one of the listed properties.

Based on the three PoE scenarios assessed (and linear extrapolation of 100% scenario) an average annual private property estimate was determined for the base case scenario (Table 20). There is a significant difference in the magnitude of properties affected between 2040 and 2060, and between 2060 and 2120. For the project case, none of the private properties identified were forecast to be affected under any of the options (i.e. all potential impacts are avoided). The resultant present value of each property loss benefit is shown in Table 21.

Table 20: Base case affected property values over time.

	2020	2040	2060	2120
100%	$ -	$ -	$ 20,623,030	$41,070,637
50%	$ -	$5,011,471	$ 31,981,724	$103,110,659
10%	$ -	$13,872,320	$ 39,048,047	$142,837,673
1%	$66,277	$23,850,707	$ 43,800,630	$167,279,405
Annual Value	**$2,982**	**$ 6,727,162**	**$ 31,085,333**	**$ 99,190,259**

Table 21: PV of avoided private property loss.

	Base Case	Project Case	Difference
Option 1a	7.15	0.00	7.15
Option 2a-c	7.15	0.00	7.15
Option 3	7.15	0.00	7.15
Option 1b	7.15	0.00	7.15
Option 1c	7.15	0.00	7.15
Option 1d	7.15	0.00	7.15
Option 3b	7.15	0.00	7.15

4.3.3 Council lands

Due to the range of assets potentially affected, the estimation of impact to Council property was calculated separately: Council owned land and associated land values, council owned assets and associated asset values. CN provided estimates of current land values associated with CN owned land parcels. Where a land parcel was not assigned a current land value, an estimate was derived based on the average per square metre value of land. Within some cadastral blocks, Council maintains sub-lots; it was not possible to confirm the extent of valuation boundaries (i.e. whether they applied to specific sub-lots or the parcel as a whole). Where this occurred, a conservative approach was adopted, and the cumulative total of estimate land value applied to the whole cadastral block area extent to derive a per square meter value. The value of council owned land was seen to vary from approximately $31 per square meter near the foreshore, to $23 per square meter at the 2120 erosion extent.

As with private property land valuation, the proportion affected within a cadastral block under each assess scenario was used to estimate the base case expected annual average cost of erosion within each year into the future (Table 22). This was linearly interpolated between years to estimate the growth rate per year. It is seen that, in contrast to private property, a lot of council land at risk is affected within the next 40 years and diminishes thereafter.

Table 22: Base Case affected council land values over time.

	2020	2040	2060	2120
100%	$-	$-	$3,594,536.59	$3,247,247.00
50%	$168,744.66	$3,496,601.13	$3,839,284.28	$4,641,428.00
10%	$932,018.14	$3,639,668.69	$3,976,710.84	$4,822,377.22
1%	$1,397,798.24	$3,760,159.90	$4,098,994.11	$4,947,497.38
Annual Value	$367,180.46	$2,634,396.53	$3,785,060.96	$4,304,574.15

*due to linear extrapolation of growth rates the 2120 100% PoE value is lower than that of the corresponding 2060 value

Under the project case scenario, Option 1a, 1b and 1c were assumed to effectively remove all potential impacts to Council Assets as the nourishment programs are of sufficient magnitude to retain the current average shoreline (NB. It is recognised that under 5- or ten-year maintenance nourishment regimes there may be small short-term local erosion impacts to Council land which would need to be addressed, however, this element has not been captured within the current CBA). In contrast, Options 2, 3 (and 1d as it performs as Option 3b for the first year) while retaining some beach amenity, will effectively recede back to the seawall and be maintained at this location. Therefore, the construction of the seawalls will require both the demolition of assets along its alignment (Section 4.3.4) as well as the gradual recession and loss of Council land as the beach moves to the seawall. For the purposes of this assessment it is assumed that this will occur at the same rate as would occur under the base case scenario. However, it is recognised that studies indicated that the presence of seawall structures may accelerate the rate of recession. For both Option 2 and Option 3, land areas affected under the 2040 50% PoE will be lost. Beyond 2040, no further loss would occur (Table 16). Option 3b, includes additional areas around Barrie Crescent and the Griffith Street car park that will be lost at a time that accords with the recession in the hazard lines (Bluecoast, 2020). Table 17 summarises the present value savings of each option in comparison to the base case.

Table 23: Project case affected Council land values over time Option 2 and 3.*

	2020	2040	2060	2120
100%	$-	$- ($ 30,431)	$ 3,496,601.13 ($ 3,527,033)	$ 3,496,601.13 ($ 3,527,033)
50%	$168,744 ($168,745)	$3,496,601 ($ 3,527,033)	$ -	$ -
10%	$932,018 ($ 942,765)	$ -	$ -	$ -
1%	$1,397,798 ($1,428,231)	$-	$ -	$ -
Annual Value	$367,180.46 ($ 371,183)	$1,573,470.51 ($ 1,594,773)	$ 3,496,601.13 ($ 3,527,033)	$ 3,496,601.13 ($ 3,527,033)

*figures in brackets represent corresponding 3b costs with additional impacts

Table 24: PV of avoided Council land loss ($M).

	Base Case	Project Case	Difference
Option 1a	1.3	0	1.3
Option 2a-c	1.3	0.85	0.4
Option 3	1.3	0.85	0.4
Option 1b	1.3	0	1.3
Option 1c	1.3	0	1.3
Option 1d	1.3	0.1	1.2
Option 3b	1.3	0.9	0.4

4.3.4 Council assets

For each of the Council Assets identified (Table 9), Council provided an estimate of current replacement value for the asset in question. For assets in which it was possible for partial replacement to be undertaken (e.g. road pavement areas, car parks areas, stormwater drainage lengths etc.) an estimate of the value of asset at risk under each PoE scenario was determined based on the proportionate extent of the area/length of impact relative to the overall asset and asset value. For structural or non-separable assets identified (e.g. buildings, shelters), whether the hazard modelling identified an impact to the structure it was assumed the whole asset value would be lost. Table 25 summarises the forecast value of each of the asset types at risk under each of the modelled scenarios. The buildings and structures represent the greatest magnitude of assets at risk. This is predominantly comprised of the facilities at the Holiday Park, Lynn Oval and tennis club, and the Surf Life Saving Club facilities. Road pavement areas and carparking represent a significant value by 2120 but are not significantly impacted within the next 40 years.

Table 25: Estimated value of Council assets at risk.

Council Buildings and Structures

Council Buildings and Structures	2020	2040	2060	2120
50%	$121,950	$5,145,694	$6,849,500	$7,777,971
10%	$2,881,800	$6,087,993	$7,534,851	$7,846,999
1%	$4,535,943	$ 6,889,041	$7,534,851	$9,326,999
Paved Areas	**2020**	**2040**	**2060**	**2120**
50%	$8,059	$277,356	$468,085	$1,194,056
10%	$90,323	$345,263	$536,784	$1,481,975
1%	$224,239	$435,907	$593,655	$2,038,054
Stormwater Pipe	**2020**	**2040**	**2060**	**2120**
50%	$-	$-	$7,922	$162,679
10%	$-	$-	$17,672	$209,297
1%	$-	$2,438	$26,204	$306,306
Public Shelter	**2020**	**2040**	**2060**	**2120**
50%	$-	$157,000	$164,500	$208,500
10%	$-	$164,500	$196,500	$208,500
1%	$-	$164,500.00	$196,500	$213,000

Under the project case scenario, the construction of the seawalls under Options 2 and 3 will necessitate the removal of a number of assets within the Stockton Beach Holiday Park. These assets are at risk from erosion by 2040. However, for the purposes of this CBA it is assumed that the loss of these assets will be incurred as part of the construction of the seawall in 2027 (approximately $3.4M). In addition, Option 3b (and subsequently Option 1d) will lose the car park area and associated road infrastructure at this location (approximately $100K to be lost by 2120). Table 26 summarises the associated present value savings of each option.

Table 26: PV of avoided Council asset loss ($M).

	Base Case	Project Case	Difference
Option 1a	2.51	0.0	2.51
Option 2a-c	2.51	2.1	0.4
Option 3	2.51	2.1	0.4
Option 1b	2.51	0.0	2.51
Option 1c	2.51	0.0	2.51
Option 1d	2.51	0.01	2.5
Option 3b	2.51	2.1	0.4

4.3.5 Producer surplus

While there are a number of businesses and economic activities that are undertaken within proximity to and are partially dependent upon Stockton Beach, for the purposes of this CBA the assessment of foregone producer focused on the Holiday Park operations. The Holiday Park would be most directly affected by both the base case shoreline recession as well as the proposed infrastructure. In absence of detailed operational information regarding the Holiday Park the potential impacts to the facility were assessed through the following assumptions:

- Assumed average direct expenditure within the LGA associated with the park is $4M per year. This was determined based on reported average annual operational revenue to the park ($3.25M) and a factor for additional expenditure (e.g. local food and beverage expenditure).
- In accordance with the OEH manual recommendations, in the absence of more specific data, a conversion factor of 0.3 was applied to the estimated direct expenditure to provide an estimated annual producer surplus of $1.2M.
- It is considered that with the forecast level of erosion, the Holiday Park is likely to become financial unviable in advance of physical impacts (i.e. loss of operational space and facilities). For the purposes of the assessment, it is assumed that 50% of producer surplus will be lost by 2027 under the base case and for those Options requiring construction of a seawall within park areas. It is assumed that under the base case 100% of the producer surplus would be lost by 2040 based on the forecast rate of recession. Project case option 1a – d will afford protection such that 100% of producer surplus will be maintained into the future. The proposed seawalls under Options 2 and 3 will permit 50% producer surplus generation onwards from 2027.
- Where a forecast loss in produced surplus is identified in the base case and project case it was assumed that:
    - 80% of this value would be redistributed within the LGA (e.g. to other accommodation venues) and is not considered and economic cost for inclusion within the CBA.

- 20% of this value is assumed to be lost from the economy and is considered a cost of recession.

Ground truthing and surveys would need to be undertaken to validate these desktop assumptions. Table 25 summarises the present value of producer surplus values able to be retained under each of the options.

Table 27: PV of Producer Surplus ($M).

	Base Case	Project Case	Difference
Option 1a	1.6	3.1	1.5
Option 2a-c	1.6	2.0	0.4
Option 3	1.6	2.0	0.4
Option 1b	1.6	3.1	1.5
Option 1c	1.6	3.1	1.5
Option 1d	1.6	3.1	1.5
Option 3b	1.6	1.8	0.2

4.3.6 Residual value

The maintenance requirements of beach nourishment are such that the works are considered to have a negligible service life beyond the 50-year evaluation period. However, the proposed seawalls are likely to have a design service life of in excess of 100 years. For the purposes of this CBA, it was assumed that at the end of the 50 year economic assessment period, the seawalls would have a further 50 years of service life and their residual value was estimated to be 50% of their capital cost (approximately $12M). Table 28 summarises the associated present value of option residual values.

Table 28: PV of avoided Council asset loss.

	Base Case	Project Case	Difference
Option 1a	0.00	0.00	0.00
Option 2a-c	0.00	0.4	0.4
Option 3	0.00	0.4	0.4
Option 1b	0.00	0.1	0.1
Option 1c	0.00	0.1	0.4
Option 1d	0.00	0.1	0.1
Option 3b	0.00	0.6	0.6

4.3.7 Unquantified benefits

There are a range of other intangible benefits and non-quantified benefits that were not assessed as part of the economic assessment. As such, the economic evaluation for this project should be a conservative appraisal. Other benefits arising from the project are likely to include:

- Benefits associated with reduced frequency of storm related inundation and associated damages.
- Avoided costs of periodic emergency response works following storm surge events.
- Impacts to areas beyond the northern extent of the study area.
- Usage values for Council parkland / reserve area adjacent to the beach.
- Avoided commercial and recreational fishing activity loses.
- Avoided loss of Holiday Park and local business revenue that is not captured elsewhere within the LGA.
- Loss of tourist and tourism expenditure due to Holiday Park impacts.
- Loss of recreational space associated with Lynn Oval, tennis club and bowls club.
- Environmental values.
- Any sand that moves from the CMP area in a northerly direction will have a benefit in slowing the erosion observed to the north.
- A shoreline control structure (e.g. a longer groyne or artificial headland) aimed at reducing the rate of sand loss in the CMP area has not been considered as an option. If successful, this would have the benefit of reducing maintenance nourishment costs while delivering equivalent beach amenity outcomes updrift of the control structure. DHI's (2009) study indicated that such a structure would serve this purpose but would create downdrift impacts. As the location is outside the defined CMP, such an option has not been considered as part of this CMP but may be considered as part of a future Newcastle CMP.
- Mass nourishment of the profile would be expected to achieve lasting surf amenity benefits at Stockton Beach. These benefits have been included within the use-value assigned to the beach amenity. If they had been separated a higher amenity benefit may have been found but would be unlikely to change the outcomes. Again, however, it highlights the conservative approach to valuing beach amenity adopted herein.

5. CBA RESULTS

5.1 Results

The relative costs and benefits of the Project Case for each option in comparison to a Base Case, as outlined above, were compared through a Cost Benefit Analysis (CBA). The results of the economic assessment for each of the project options are provided in Table 29 to Table 35. Of the seven options, only Options 1b and 1d are seen to have a BCR greater than one at a 7 per cent discount rate. For Option 1b, at 7 percent discount rate the BCR is 1.5, implying for every $1 spent on the project, $1.5 is expected to be returned in economic benefits. The net benefit under this option is $19.4M. For Option 1d at 7 percent discount rate the BCR is 1.3, implying for every $1 spent on the project, $1.30 is expected to be returned in economic benefits. The net benefit under this option is $11.3M. Option 1b is the economically preferred option. However, as noted previously, there may be a range of legislative and environmental issues associated with this option that would prevent its implementation at present. Both Options 1b and 1d depend upon access to a cheaper nourishment sand source to be available upon commencement of mass nourishment activities. Provided this is obtainable both options are likely to be viable.

It is noted that Options 1b and 1d are similar, with the exception for the first years of operation in which Option 1d includes the nourishment profile and protection works associated with Option 3b. None of the other options are feasible at a 7% discount rate, although Option 1c is seen to be viable at a 3% discount rate.

Option 2, 3 and 3b do not generate positive results as they provide little to no (even negative in the case of 3b for some years) amenity benefit in comparison to the base case, while incurring high upfront costs. While these options do provide protection of private assets, the risk of damage and loss of these assets is too far into the future to economically support investment in these options which rely upon physical infrastructure for asset protection. It is considered that seawall options are likely to improve in their economic feasibility over time (i.e. by 2040).

Table 29: Economic Appraisal Results for Option 1a.

	3%	***7%***	***10%***
PV COST	$983,184,531	$649,861,672	$540,331,071
PV BENEFIT	$109,563,722	$52,908,176	$35,581,032
NPV	-$873,620,809	-$596,953,496	-$504,750,039
BCR	**0.1**	**0.1**	**0.1**
NPVI	-2.4	-1.7	-1.5
FYRR	1%	1%	1%
IRR	-	-	-

Table 30: Economic Appraisal Results for Option 2a

	3%	***7%***	***10%***
PV COST	$738,680,424	$411,390,278	$304,277,300
PV BENEFIT	$56,411,570	$23,769,741	$14,811,643
NPV	-$682,268,854	-$387,620,536	-$289,465,657
BCR	**0.1**	**0.1**	**0.0**
NPVI	-8.6	-5.4	-4.3
FYRR	2%	2%	2%
IRR	-	-	-

Table 31: Economic Appraisal Results for Option 3a.

	3%	***7%***	***10%***
PV COST	$453,186,216	$250,641,117	$183,909,981
PV BENEFIT	$39,498,485	$16,836,521	$10,526,005
NPV	-$413,687,732	-$233,804,597	-$173,383,976
BCR	**0.1**	**0.1**	**0.1**
NPVI	-8.4	-5.4	-4.4
FYRR	2%	2%	3%
IRR	-	-	-

Table 32: Economic Appraisal Results for Option 1b.

	3%	7%	10%
PV COST	$51,424,817	$35,831,443	$30,861,447
PV BENEFIT	$114,771,668	$55,231,092	$37,104,439
NPV	$63,346,851	$19,399,649	$6,242,991
BCR	**2.2**	**1.5**	**1.2**
NPVI	2.4	0.8	0.3
FYRR	13%	12%	12%
IRR	13%	13%	13%

Table 33: Economic Appraisal Results for Option 1c.

	3%	7%	10%
PV COST	$83,925,253	$61,994,994	$54,804,428
PV BENEFIT	$110,203,197	$52,999,787	$35,603,393
NPV	$26,277,944	-$8,995,207	-$19,201,035
BCR	**1.3**	**0.9**	**0.6**
NPVI	0.5	-0.2	-0.4
FYRR	7%	6%	6%
IRR	5%	5%	5%

Table 34: Economic Appraisal Results for Option 3b.

	3%	7%	10%
PV COST	$138,504,145	$82,743,592	$63,378,309
PV BENEFIT	$24,149,701	$10,983,131	$7,312,100
NPV	-$114,354,445	-$71,760,461	-$56,066,209
BCR	**0.2**	**0.1**	**0.1**
NPVI	-3.3	-2.4	-2.1
FYRR	3%	3%	4%
IRR	-	-	-

Table 35: Economic Appraisal Results for Option 1d.

	3%	7%	10%
PV COST	$58,473,549	$41,755,105	$36,035,001
PV BENEFIT	$112,197,643	$53,060,612	$35,078,300
NPV	$53,724,094	$11,305,507	-$956,701
BCR	**1.9**	**1.3**	**1.0**
NPVI	1.8	0.4	0.0
FYRR	4%	4%	4%
IRR	10%	10%	10%

5.2 Sensitivity testing

It is recognised that the results of the assessment presented in Table 29 to Table 35 are dependent upon a range of assumptions made as part of the economic analysis. Both in terms of financial parameters (i.e. discount rates) as well as cost and benefit assessments (e.g. beach valuations, construction costs). Consequently, to assess the robustness of the observed results, detailed sensitivity analysis of the CBA was undertaken on the three best performing options: Options 1b, 1c and 1d. The results are shown in Table 36 and Table 38. **Appendix D** provides a summary of key sensitivity testing results for all options.

Table 36: Sensitiviy testing for Option 1b.

	BCR	NPV ($M)	IRR	NPVI
Original	1.5	$19,399,649	12.6%	0.8
Cost Estimate +40%	1.1	$5,067,072	8.1%	0.3
Cost Estimate +20%	1.3	$12,233,360	10.0%	0.6
Cost Estimate – 20%	1.9	$26,565,938	16.3%	0.8
PV Benefits +20%	1.8	$30,445,867	15.6%	1.2
PV Benefits – 20%	1.2	$8,353,431	9.5%	0.3
PV Benefits –40%	0.9	-$2,692,788	6.1%	-0.1
Delay by 1 Year	1.4	$15,150,049	11.1%	0.6
Delay by 3 years	1.3	$10,771,369	9.6%	0.4
50% increase in assumed beach use and non-use value per m^2	2.1	$40,757,087	18.5%	1.6
50% reduction in assumed beach use and non-use value per m^2	0.9	-$1,957,789	6.4%	-0.1

Table 37: Sensitivity testing for Option 1c.

	BCR	NPV ($M)	IRR	NPVI
Original	0.9	-$8,995,207	5.5%	-0.2
Cost Estimate +40%	0.6	-$33,793,205	2.4%	-1.0
Cost Estimate +20%	0.7	-$21,394,206	3.8%	-0.5
Cost Estimate – 20%	1.1	$3,403,792	7.7%	0.1
PV Benefits +20%	1.0	$1,604,751	7.3%	0.0
PV Benefits – 20%	0.7	-$19,595,164	3.4%	-0.4
PV Benefits – 40%	0.5	-$30,195,122	0.7%	-0.6
Delay by 1 Year	0.8	-$12,857,271	4.8%	-0.3
Delay by 3 years	0.7	-$16,415,609	4.4%	-0.3
50% increase in assumed beach	1.2	$11,246,578	8.8%	0.2

use and non-use value per m²				
50% reduction in assumed beach use and non-use value per m²	0.5	-$29,236,992	1.3%	-0.6

Table 38: Sensitiviy Testing for Option 1d.

	BCR	*NPV ($M)*	*IRR*	*NPVI*
Original	1.3	$11,305,507	9.7%	1.3
Cost Estimate +40%	0.9	-$5,396,534	6.0%	0.9
Cost Estimate +20%	1.1	$2,954,487	7.6%	1.1
Cost Estimate – 20%	1.6	$19,656,528	12.6%	1.6
PV Benefits +20%	1.5	$21,917,630	12.0%	1.5
PV Benefits – 20%	1.0	$693,385	7.2%	1.0
PV Benefits –40%	0.8	-$9,918,737	4.3%	0.8
Delay by 1 Year	1.3	$10,575,324	9.6%	1.3
Delay by 3 years	1.2	$6,131,432	8.4%	1.2
50% increase in assumed beach use and non-use value per m²	1.8	$31,624,594	14.2%	1.1
50% reduction in assumed beach use and non-use value per m²	0.8	-$9,013,579	4.7%	-0.3

For those options which enhance beach amenity the key challenge to feasibility is the relative benefit per square meter of **additional** sand in comparison to the per square meter cost of maintenance nourishment requirement. For most scenarios tested the quantity and cost of nourishment activities outweighs the benefit generated. Given the dependency of the CBA results upon the capital and maintenance costs of nourishment, a series of further cost sensitivity scenarios were undertaken on Option 1d, as described in the following paragraphs.

Based on the assumed use of terrestrial sourced sand delivered by trucks and the like, the high capital and maintenance costs were considered to have already been assessed and the sensitivity tests focused on the low to moderate costs sources and methods, as:

- **Low capital cost:** adopted a combined sand placement rate of $1.83/m³ assuming that the sand would be sourced from material that is excess to the needs of another large infrastructure project and delivered to Stockton free of charge. The unit rate is the additional rate for rainbowing the sand to the surf zone.

- **Moderate capital cost:** adopted a combined sand placement rate of $21.50/m^3 assuming that the sand would be sourced from the North Arm of the Hunter River (between Welsh Point and Stockton Bridge). The rate is based on the value presented in RHDHV (2020) (for an 850mm CSD with one booster discharging sand to the upper beach).
- **Low maintenance cost:** adopted a combined sand placement rate assuming that the sand would be sourced from the entrance area of the Hunter River and could be delivered on an annual basis using a dredger based at the Port of Newcastle (i.e. a local vessel). This arrangement and any commercial rate would be subject to capability, willingness, capacity, and negotiations.
- **Moderate maintenance cost:** adopted a combined sand placement rate of $6.42/m^3 assuming a dredging contractor would use a small TSHD to rainbow and bottom dump up to 1.2M m^3 sand in a campaign every 10-years under a long-term contract. The rate was based on budgetary pricing provided by potential contractors.

The sensitivity tests then included a range of capital and maintenance cases including:

- Low capital cost, low maintenance costs.
- Low capital cost, moderate maintenance costs.
- Moderate capital cost, moderate maintenance costs.
- Moderate capital cost, low maintenance costs.

Table 39 to Table 42 demonstrate that there are a number of scenarios in which the economic performance of Option 1d will significantly improve through the identification and use of cost-effective nourishment sources.

Table 39: Economic Appraisal Results for Option 1d – Low : Low.

	3%	*7%*	*10%*
PV COST	$23,331,079	$19,283,798	$17,663,847
PV BENEFIT	$112,197,643	$53,060,612	$35,078,300
NPV	$88,866,564	$33,776,815	$17,414,453
BCR	**4.8**	**2.8**	**2.0**
NPVI	6.5	2.6	1.4
FYRR	8%	8%	8%
IRR	20%	20%	20%

Table 40: Economic Appraisal Results for Option 1d – Low : Moderate.

	3%	*7%*	*10%*
PV COST	$31,100,932	$22,044,888	$19,040,011
PV BENEFIT	$112,197,643	$53,060,612	$35,078,300
NPV	$81,096,711	$31,015,724	$16,038,289
BCR	**3.6**	**2.4**	**1.8**
NPVI	5.9	2.4	1.3
FYRR	8%	8%	8%
IRR	20%	20%	20%

Table 41: Economic Appraisal Results for Option 1d – Moderate : Moderate.

	3%	*7%*	*10%*
PV COST	$75,591,459	$63,271,196	$58,048,276
PV BENEFIT	$112,197,643	$53,060,612	$35,078,300
NPV	$36,606,184	-$10,210,584	-$22,969,975
BCR	**1.5**	**0.8**	**0.6**
NPVI	0.6	-0.2	-0.4
FYRR	2%	2%	2%
IRR	6%	6%	6%

Table 42: Economic Appraisal Results for Option 1d – Moderate : Low.

	3%	*7%*	*10%*
PV COST	$39,355,209	$34,132,256	$31,713,434
PV BENEFIT	$112,197,643	$53,060,612	$35,078,300
NPV	$72,842,434	$18,928,356	$3,364,867
BCR	**2.9**	**1.6**	**1.1**
NPVI	2.5	0.7	0.1
FYRR	4%	4%	4%
IRR	11%	11%	11%

The CBA results show that, in the absence of sand sourced from another large infrastructure project, offshore marine sand is the most viable source of sand for beach nourishment. There are several cost sensitivities associated with access and delivery of nourishment material. One of the assumptions underlying cost estimates for Option 1b and Option 1d is that suitable sand can be sourced within 5NM of the sand placement areas. Based on budgetary estimates provided by experienced dredging contractors an additional sailing distance of 2.5NM would incur an additional $0.60/m^3, which equates to an extra $1.44M or a 6.7% increase in capital costs of initial mass nourishment works. For the preferred option (Option 1d), the 6.7% increase in capital costs for nourishment would equate to a PV cost of approximately $43.2M, reducing the BCR to 1.2. It follows that the Option 1d would remain economically viable, if sand could be sourced from within a radius of 22.5NM.

Table 43 to Table 46 provide the results of further sensitivities tests carried out for Option 2a, 2b and 2c (see Table 2 and **Appendix A** for more detail on these cases). The results demonstrate the issue with both these options is that they are still too expensive and generate small beach amenity benefits in comparison to the cost of maintenance. The offset factor applied to terrestrial sand sources is seen to be a significant cost factor. However, even when reduced to 1, the costs of terrestrial access still outweigh the benefits and do not make the option viable in comparison to marine sources. The reduced cost per m^3 for Options 2b and 2c in comparison to 2a, while generating a notable improvement in costs, do not generate a real change on the benefit side. The figure below demonstrates this issue in regard to Option 2b: the discounted sum of the red bars above the line would need to exceed those below the line to be economically feasible, the five year maintenance costs clearly show this is not achievable at 5 yearly maintenance increments with a nourishment cost of $11M. Running 2b at 10-yearly maintenance increments is a big improvement, saving some $14M in cost (see Figure 9 below) but the capital cost is still $49M for the Stage 1 and Stage 2 works, plus initial nourishment. These costs alone outweigh the total estimated present value benefit of $24M.

Table 43: Economic Appraisal Results for Option 2a – Overfill Ratio of 1.

	3%	7%	10%
PV COST	$378,478,455	$214,491,184	$160,227,203
PV BENEFIT	$56,411,570	$23,769,741	$14,811,643
NPV	-$322,066,885	-$190,721,443	-$145,415,560
BCR	**0.1**	**0.1**	**0.1**
NPVI	-5.9	-3.9	-3.2
FYRR	2%	2%	3%

Table 44: Economic Appraisal Results for Option 2a – Overfill Ratio of 1 and cost of $50 per m^3

	3%	7%	10%
PV COST	$288,427,962	$165,266,411	$124,214,679
PV BENEFIT	$56,411,570	$23,769,741	$14,811,643
NPV	-$232,016,393	-$141,496,669	-$109,403,036
BCR	**0.2**	**0.1**	**0.1**
NPVI	-4.7	-3.3	-2.8
FYRR	3%	3%	3%

Table 45: Economic Appraisal Results for Option 2b.

	3%	7%	10%
PV COST	$101,215,438	$63,639,289	$50,520,600
PV BENEFIT	$56,411,570	$23,769,741	$14,811,643
NPV	-$44,803,868	-$39,869,548	-$35,708,958
BCR	**0.6**	**0.4**	**0.3**
NPVI	-1.0	-1.1	-1.1

Table 46: Economic Appraisal Results for Option 2b adjust to have a 10-year renousihment period for discussion purposes.

	3%	7%	10%
PV COST	$74,337,575	$49,708,269	$40,829,372
PV BENEFIT	$56,411,570	$23,769,741	$14,811,643
NPV	-$17,926,006	-$25,938,528	-$26,017,730
BCR	**0.8**	**0.5**	**0.4**
NPVI	-0.4	-0.7	-0.8
FYRR	3%	3%	3%

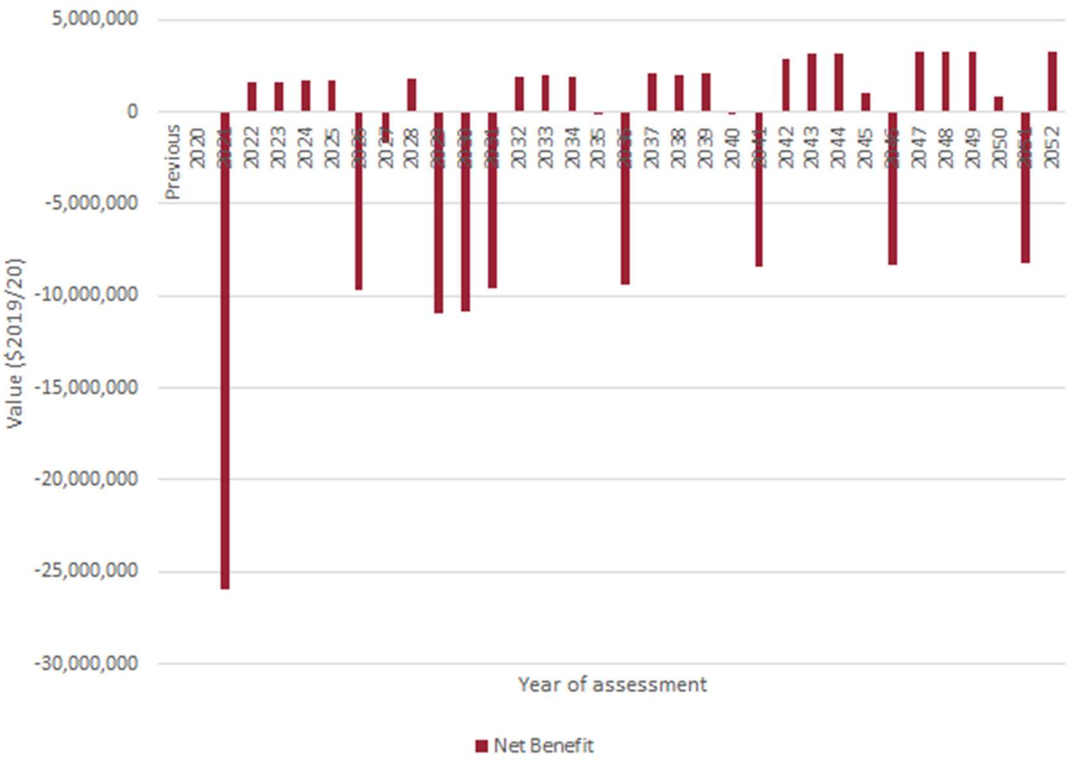

Figure 9: Annual net benefits for Option 2b.

5.3 Transfer of amenity benefits

The calculated amenity benefit provided by each of the options varies between 20% and 77% of total option benefit. Of this, the use values associated estimated with the amenity benefit represents approximately 65% - 75% of the overall amenity benefit for each of the options. Based on the per square meter benefit transfer approach as detailed above, the current beach is seen to have a use value of approximately $13.5M (present value), with the mass beach nourishment options generating an additional $23M (present value), while Options 2 and 3, generate smaller additional use values ($11M and $6M present value, respectively).

However, it is recognised that beach use values may be transferable to other beaches within the LGA, and the use values are thus maintained rather than lost. In the case of Stockton Beach, the estimated approximate 100,000 beach visits per year (in 2020) are unlikely to be readily transferred as:

- Most trips are understood to be undertaken either by residents within Stockton or from visitors associated with the Caravan Park. Stockton is relatively isolated from other town centres with one main access road (Fullerton Street) providing access to the community (Newcastle CBD is approximately a 20-minute drive). The proximity to an isolated beach is a strong residential location choice factor for many residents for both passive and active use of the beach.
- Stockton Beach provides a unique combination of relatively low-density patronage, commercial facilities, surf lifesaving club facilities (and patrols), as well as coastal conditions that make it attractive. There are few other beaches in proximity which provide the same combination of amenity factors. Nobby’s Beach and Mereweather Beach in Newcastle are similar (although larger) and approximately 25 min travel time distance. To the north, One

Mile Beach, Port Stephens, provides a similar amenity range, although approximately 43km distant (35 minutes) away from Stockton.

It is recognised that some specific beach uses (e.g. surfing) may be able to be undertaken at suitable alternate locations within closer or further proximity to the few beaches identified that provide a similar overall amenity environment. Further details regarding beach use, purpose, demand and willingness to pay would enable a more detailed analysis of the likelihood of potential transfer of amenity.

However, while any such transfer may prevent the loss of use values, the change in beach use represents a reduction in consumer surplus (i.e. an existing beach user currently prefers to use Stockton Beach given the availability of alternate options). Alternate sites either provide a lower benefit (e.g. lesser surfing experience) or additional access costs (e.g. costs of travel), or a combination therein. As such, an alternate beach use valuation method is consideration of transport cost associated with accessing alternate locations to undertake the preferred use. Utilising Nobby's beach as representative of the nearest next best beach location (for all users), a preliminary travel cost analysis (considering travel time, vehicle operation cost, but not crash risk or externalities) was undertaken in accordance with the Transport for NSW Guidelines for Economic Appraisal (2019)[3]. Based on the estimate 100,000 trips (2 ways) an annual travel time value of $1.4M per year and vehicle operating costs of $1M per year were derived. Were the beach to be maintained in its current extent into the future, the use value of the beach, measured by avoided travel cost is approximately $35M. While it is recognised that not all current beach users would be willing (or need) to pay the associated cost, were the beach to be lost, the magnitude of use-value estimate is consistent with the order of magnitude estimates assessed within the benefit transfer methodology adopted within this assessment. For example, even if under the base case, loss of beach amenity through recession leads to only 50% of current beach users switch to an alternate beach, the associated additional travel cost would be in the order of $17.5M PV. This cost would be avoided under any option which preserves current beach usage at Stockton Beach (i.e. Options 1 and 2). In comparison the CBA estimates a use value of $23M for Option 1 and $11M for Option 2.

A more detailed understanding of beach use drivers and behaviour would be required to assess the potential more rigorously for beach usage to be transferred to alternate locations. However, the preliminary analysis undertaken indicates that the transport cost of access to alternate sites is relatively high, such that the extent of transfer is likely to be relatively low and that the order of magnitude valuations for beach usage adopted within the CBA are consistent with values determined through an next best alternative travel cost estimation approach.

It is also noted that the provision of additional beach area at Stockton Beach, has the potential to increase switching of beach usage currently undertaken at other beaches within the LGA to Stockton Beach (e.g. trips to a crowded beach (e.g. Merewether Beach) may be made to Stockton Beach instead due to enhanced amenity, although potentially incurring a greater travel cost to do so.

5.4 Preliminary distribution analysis

From a distributional perspective the affected and benefit parties varies over time. Under the base case scenario, it is Council and the users of the Stockton Beach Holiday Park that are likely to incur the greatest costs associated with the business as usual approach. The expected value of land and assets at risk to Council exceeds $8M dollars within the next 20 years. Other community members

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[3] Assumptions included: All trips undertaken by car. Assumed persons per car = 1.7, Average travel time of 25 minutes, within a distance of 20km and travel speed of 48km/h (Google Maps). Value of average light vehicle with 1.7 occupancy – $29.21/h. Vehicle operating cost of light vehicle at 48 km/hr (43.2 c/km)

will not be directly affected through impacts to property in the short term, but are likely to experience the loss of Beach Amenity (although the beach width will likely remain relatively constant) as well as reduced associated foreshore amenity, loss of recreational spaces and sporting grounds. The short-term impacts to the Holiday Park are likely to be large and could ultimately lead to the closure of the Holiday Park. Tourists from outside the LGA will be required to choose alternate destinations for beach side camping (of which there are many within the areas to the north and south of Newcastle). Beyond 2040 it is likely that some landowners near the beach will experience property damage and Council will start to lose rate income.

Under all the options proposed private property damages are avoided into the future. However, the options differ in the broader impacts to the communities. The mass beach nourishment options retain and even enhance the value of the asset to the beach and are likely to add additional value to properties and the attractiveness of the Stockton Beach Holiday Park. This may also support increased economic activity through beach related commerce. In contrast, Options 2 and 3 will ultimately loose public space adjacent to the beach as recessions shifts back to the proposed seawalls. While a beach area will be retained, the reduced area will alter the utilisation and desirability of the beach. Moreover, the construction of the seawall will require the removal of a significant portion of facilities at the Stockton Beach Holiday Park. A financial analysis would need to be undertaken to assess whether the park would remain viable within the reduced land area and whether the reduced beach and foreshore area is considered suitable to continue to attract tourists to the community.

The benefit estimation methodology adopted within the economic assessment is based on a benefit transfer approach and does not readily allow for a detailed distributional analysis of costs and benefits to specific stakeholders. A preliminary analysis of the major stakeholder groups and their applicable costs and benefits is provided in Table 48 in relation to Option 1d. The benefit distribution is quantified over two time periods (2030 and 2060), to show the incremental shift towards private property owners over time. It is also noted that a financial and commercial analysis of beach front businesses (as well as sporting ground operatons) would need to be undertaken to better benefits to local economic activity

Table 48: Preliminary Distribution Analysis of Costs and Benefits

Stakeholder	Benefits	Net Present Value	Value – 2030	Value - 2060
COSTS				
Local Government	Capital investment costs for initial nourishment and physical protection	$28M	-	-
	Ongoing Beach Nourishment and Maintenance	$14M	$0.2M	$0.2M
Local Community – Residents in proximity to the beach	Construction noise and visual amenity impacts. This is likely to be associated predominantly with terrestrial protection works, rather than offshore nourishment and are likely to be temporary and minor	n/a	n/a	n/a
Tourists	Disruption and temporary closure of the Caravan park during construction of physical protection works. Impacts are likely to be temporary	n/a	n/a	n/a
BENEFITS				
Local Government	Avoided damage and loss of assets and property	$2.5M	$0.2M	$0.2M
	Avoided loss of Council owned lands	$1.2M	$0.1M	$0.05
	Revenues associated with the Caravan Park preserved and potentially enhanced	$1.5M	$0.1M	$0.2M
	Rate revenues preserved through mitigated hazard and loss of private land	n/a	n/a	n/a
State Government	Protection of beach environment values and coastal ecosystems	n/a	n/a	n/a

Stakeholder	Benefits	Net Present Value	Value – 2030	Value - 2060
Local Community – Beach Users	Protection and enhancement of beach amenity to support passive and active uses. While a detailed study has not been undertaken it is understood that most beach visitors are residents of Stockton and surrounding suburbs.	$22M	$1.7M	$2.1M
Local Community – Residents	Protection of property owner land values and assets, including associated repair through mitigated hazard.	$7.1M	$0.3M	$1.2M
	Protection and enhancement of beach amenity and associated non-use values	$19M	$1.5M	$1.7M
Local Community – Clubs and Sports	Community groups associated with the beach of recreations sports facilities immediately behind the foreshore (e.g. tennis and bowls club, swimming pool, oval) will not be disrupted by long term beach recession	n/a	n/a	n/a
Tourists	The Caravan park will remain viable for regional tourists	n/a	n/a	n/a
	Local tourists may take advantage of enhanced beach amenity	n/a	n/a	n/a
Businesses	Viability of businesses based upon the presence of the beach as a recreational and social gathering space will not be threatened by reduced beach amenity (e.g. Lexies on the Beach)	n/a	n/a	n/a

Most of the capital and maintenance costs are incurred by Council (indirectly ratepayers). Approximately 1/3 of all assets and land values at risk to coastal hazard, that are protected by Option 1d, are seen to belong to Council. However, the costs of development and maintenance to Council, significantly outweigh the avoided asset and property protection generated. Most of the benefit (approximately 70%) is received in terms of beach amenity, either to beach users directly or more broadly to the surrounding suburbs considered likely to place a non-use value upon Stockton Beach. As all beneficiaries are located within the LGA and not limited to a highly limited number of properties (see Table 10), there is reasonable justification for Council to seek funding. However, it is noted that Stockton Beach is a proportionately smaller beach within Newcastle (in terms of visitation), utilised predominantly by the Stockton local community and not all households within the LGA are likely to receive the use or non-use benefits generated through the project. Stockton represents approximately 2.6% of households within the City of Newcastle LGA. As the broader LGA population will contribute to the significant CAPEX and OPEX associated with the project, consideration of the magnitude of investment relative to Council rate revenues per household and other investment priorities should be recognised in project decision making.

6. SUMMARY

A cost benefit analysis (CBA) has been completed in support of the coastal management program (CMP) being prepared by the City of Newcastle (CN) for the area north of the Stockton Breakwater (northern training wall of the Hunter River) to Meredith Street, Stockton. The CBA has been prepared in accordance with the Coastal Management Act 2016 and the NSW Coastal Management Manual (the Manual) with consideration of the *Guidelines for using cost-benefit analysis to assess coastal management options* (OEH, 2018).

Three main coastal management options have been developed as part of the CMP. In addition to the three main options a total of nine project cases and an additional four cost sensitivities were assessed by the CBA. The options developed provide a comprehensive array of solutions to two key issues associated with forecast erosion and recession:

- Loss of beach area and amenity.
- Need for protection of Council assets, services and private property.

The CBA was undertaken over a 50-year period, utilising a 7% discount rate. The options assessed represent combinations of the two major management measures to address these issues: beach nourishment and physical coastal protection infrastructure. As both options achieve protection of property, due to the high values ascribed to the presence of a continuous beach, nourishment options were seen to generate higher benefits than options that focused on physical infrastructure. The benefits considered included: beach amenity, avoid losses to private property, Council lands and Council assets, producer surplus and residual value.

However, the nourishment options were also observed to be significantly more expensive than infrastructure options. Of the currently environmentally and legally permissible options, none of the options identified were seen to be economically feasible. It is likely that, overtime, the cheaper physical infrastructure options will become more viable as the value of property at risk increases (e.g. by 2040, Option 3b may become viable). However, the change to character of the Stockton Beach foreshore, the wave overtopping and coastal inundation risk and the high level of impacts on downdrift (northern) coastline require further consideration.

Option 1b was identified as the economically preferred option, with a benefit to cost ratio (BCR) of 1.5 and producing over $19M in net present value to society. However, the permits and approvals required for this option requires further investigation and resolution. Option 1d would give time for these issues to be resolved while still addressing the immediate issues associated with beach erosion and returning a positive BCR. As such it is recommended that further investigation of Option 1d be considered as a practical viable option. It is noted that all the nourishment options identified are highly sensitive to the cost assumptions associated with access and delivery of nourishment material. The sensitivity analysis undertaken indicates that should lower costs be realised, the economic performance of Option 1d will significantly improve. It is recommended that nearby any geophysical survey and geotechnical field investigation to identify suitable sand for nourishment be focused on areas as close to Stockton Beach as possible.

The lowest capital cost of mass nourishment would be realised if suitable nourishment material that is in excess to the needs of another large infrastructure project is delivered to Stockton free of charge. At present there are no existing approvals that would allow the placement of significant quantities of suitable nourishment material at Stockton Beach. It is therefore recommended that a concept level approval for additional sand placements be investigated as a priority action under the CMP. The next lowest capital cost is for sand sourced from offshore marine sources. This is an economically viable options that could be undertaken independent of other projects. It is recommended that investigations into obtaining approvals for sand extraction from the nearby seabed for the purposes of beneficial beach nourishment also be investigated as a priority action under the CMP.

Regarding maintenance nourishment, it is recommended that CN consult with the Port of Newcastle and relevant government agencies regarding the maintenance dredging sea dumping permit that is due for renewal in March 2022. This permit is issued by the Federal government and requires assessment under the National Assessment Guidelines for Dredging 2009 (Commonwealth of Australia, 2009). This includes assessing opportunities for beneficial reuse of dredged material in preference to sea disposal as well as the assessment of the impacts of the maintenance dredging activity (both loading and unloading) that lead to the “alternation of wave and current conditions affecting sediment regimes and leading to erosion of areas”.

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Sydney Coastal Councils (2012*). Sydney Beaches Valuation Project.*

APPENDIX A – RHDHV’S CBA INPUTS

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Classification:	Open		

Technical Note: RHDHV input information for a Cost Benefit Analysis for Stockton Beach

1 Background

In line with the Coastal Management Act 2016 and the NSW Coastal Management Manual Part A (the Manual), a Cost Benefit Analysis (CBA) for Stockton Beach will be undertaken for the City of Newcastle (CN). The CBA is being undertaken by Bluecoast Pty Ltd (Bluecoast). The location under consideration is limited to the area north of the northern training wall of the Hunter River (Breakwater) as far as the northern boundary of Meredith Street. This technical note describes input parameters for potential coastal management actions to be considered within the CBA.

This revision has been undertaken in response to queries from the Department of Planning, Infrastructure and Environment (DPIE), to provide clarity regarding technical assumptions and detailing methods applied. This involves a further breakdown of calculations applied in estimating nourishment volumes and represents the final values applied in the CBA after what has been an iterative process involving management option development, coastal process/hazard investigations, CBA, and consultation with CN and DPIE.

A CN long-term sand nourishment plan is being developed and assessed in regard to its ability to meet the amenity desire of the community, considering:

- the results of beach monitoring;
- completion of a sediment transport study; and
- as sand sources for nourishment are identified, CN proposes to proceed with the investigation of three options for the CBA for comparison against a base case.

It is noted that whilst nourishment volumes have been estimated by RHDHV in this technical note, nourishment volumes should be refined by Bluecoast for input into the CBA, using models and outcomes of the Stage 2 Sediment Transport Study (also being undertaken by Bluecoast).

While acknowledging that marine sand sources are currently either; restricted by legislation, or not available, there may be potential future opportunities to access these sources. CN have requested RHDHV provide estimates of costs and recommendations as to potential methodology required to undertake provision of marine sands as a coastal management action. Accordingly, marine sand sources have been included for Options 1 and 2 outlined below to allow the CBA to undertake sensitivity analysis of benefit cost ratios for potential future use of offshore marine sand and/or Hunter River marine sand. Cost estimates of coastal management options are provided in **Appendix A, B, C** and **D**. Details of potential terrestrial sources, methodology and costs are provided in **Appendix E.** Details of potential marine sources, methodology and costs are provided in **Appendix F.**

Base Case – Business as Usual

General Description – The Base Case involves continued delivery of the actions within the Newcastle Coastal Zone Management Plan (CZMP) 2018 Part A. This certified CZMP provides a planning and approvals pathway to undertake a range of management actions and investigations, which are eligible to receive grant funding.

Option 1 - Mass sand nourishment for protection + amenity, limited terminal coastal protection works

General Description - Option 1 involves sand nourishment to a level that provides coastal protection to existing assets, and the construction of buried terminal coastal protection structures to protect assets at risk within the next 5 years (in accordance with established 2025 hazard lines[1]).

Option 2 - Sand nourishment for improved beach amenity + staged terminal coastal protection works

General Description - Option 2 involves beach nourishment to provide improved recreational access amenity. The beach amenity objective is a minimum annual average beach width of 5m at the narrowest point including volume to accommodate a 1 year Average Recurrence Interval (ARI) storm every year. This option also includes construction of buried terminal coastal protection structures, constructed in two stages, to address the current and future risk of potentially high consequence, low probability events that may affect the area (mandatory requirement 13, Coastal Management Manual Part A).

Option 3 – Nominal sand nourishment to reduce ongoing beach amenity loss + staged terminal coastal protection works

General Description - Option 3 involves beach nourishment of a logistically and economically feasible volume using available terrestrial sources of sand (i.e. less volume than considered in Option 2). This nourishment volume would reduce (but not prevent) future loss of beach width and amenity. As in Option 2, this option also includes construction of buried terminal coastal protection structures, constructed in two stages, to address the current and future risk of potentially high consequence, low probability events that may affect the area (mandatory requirement 13, Coastal Management Manual Part A). In Option 3,

[1] This approach allows a 5 years' time period for sufficient nourishment to be in place to provide ongoing protection to coastal assets further landward.

Stage 1 terminal coastal protection structures have been optimised (relative to Option 2) to reduce capital costs with comparatively more works delayed to Stage 2.

Sand Sources (all options)

Noting that terrestrial sand is currently the only readily available source, all Options have been developed using this supply source, with relevant methodology and cost estimates.

Recognising that various alternative marine sand sources may become available, RHDHV have developed a range of cost estimates based on vessel sizes, methodology, and volumes required for use in sensitivity analysis of some of the Options. A Technical Note regarding marine sources of sand is provided as **Appendix F.**

Sand Nourishment Volume Calculations

Initial nourishment volumes are calculated, assuming a re-nourishment every 'x' years, though the addition of the following three volumetric components:

1. volume requirement to *establish the amenity outcome objective or asset protection outcome objective*, based on current beach state (a critical section of beach may control this volume, e.g. 'pinch point' or specific asset, given the nourishment volume will be distributed along the coast); plus

2. 'x' years times projected underlying loss (based on historical record and any future adjustment of the historical value from a processes perspective); plus

3. 'x' years times projected sea level rise loss.

Underlying loss comes about due to the occurrence of storms over time of varying ARI and the absence of full beach recovery, so this is 'built in' to the calculation. At times, post storms, there may not be the minimum beach width for amenity or minimum beach volume for asset protection, but subsequent beach recovery occurs.

The last two components (2 and 3) of the above, typically comprise the ***maintenance re-nourishment volume*** component which will be required every 'x' years following the initial establishment of the desired coastal management outcome. This is equivalent to the what is referred to as the "Dutch Method" described in Section 2.6 of the Guidelines for Sand Nourishment (WRL, 2017), referred to by DPIE in their technical review queries.

For all calculations herein, the:

- projected underlying loss (based on historical record and any future adjustment of the historical value from a processes perspective) has been taken as **1m/yr** (Bluecoast, 2020); and

- projected sea level rise loss (based on an average future SLR allowance of 0.36m by 2070 (interpolated from 2050 and 2100 SLR data in Bluecoast, 2020), or 0.0072m years, and adopting a Bruun factor of 50 (average presented in (Bluecoast, 2020)) equates to **0.36m/yr** recession

Shape and Depth of the Active Profile

For first pass consideration, it is assumed that the borrow material is similar to the native material (or an overfill ratio will be applied, where it is not), and that therefore the shape of the active profile after nourishment would be similar to the natural profile. Further consideration of the shape of the active profile is not required at this time. It is necessary, however, to establish the likely depth to which the active profile will develop as this will govern the quantity of sand required for specific widening of the beach (i.e. to establish and maintain the desired coastal management outcome as discussed above).

Several approaches are commonly adopted (in combination) for estimating the depth of the active profile:

- wave climate based zonation approach (based on annual wave climate and statistics and local sand characteristics) developed at the US Army Corps of Engineering Research Centre (Hallermeier, 1981)
- examination of shore-normal seabed profiles (identification of a break in the bed slope);
- examination of variations in surface sediment characteristics along shore normal profiles (not considered here due to insufficient spatial data across the profile); and
- adoption of proven depth limits established for similar situations (commonly -8 to -12 m AHD for exposed NSW beaches).

The approach by Hallermeier is recommended in the Coastal Engineering Manual (CEM) (US Army Corp of Engineers) and is also the method advised in the Manual on Artificial Beach Nourishment produced in the Netherlands jointly by the Centre for Civil Engineering Research, Codes and Specification, the Netherlands Department of Public Works or Rijkswaterstaat, and the Delft Hydraulics Laboratory (Rijkswaterstaat, 1987).

Hallermeier (1981) divides the coastal profile into three zones as noted and shown in ***Figure 1*** below:

1. a littoral zone out to a water depth d_L (commonly referred to as the "depth of closure"). This depth is the seaward limit to extreme surf related effects, so that significant alongshore transport and intense onshore-offshore transport are restricted to depths less than d_L;

2. a shoal zone between d_L and a depth d_i. This latter depth defines the seaward limit of all onshore-offshore transport; and

3. an offshore zone seaward of d_i where the effects of surface waves on the bed are usually negligible.

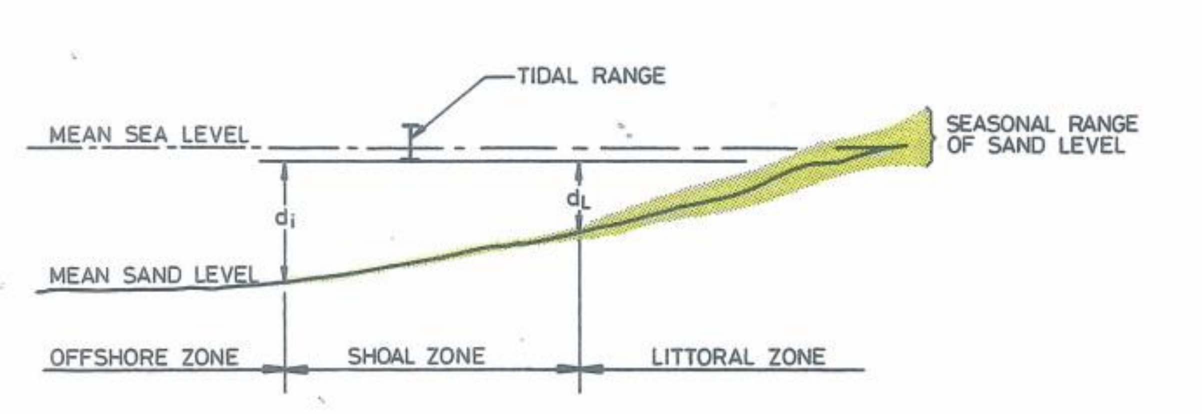

Figure 1 - Beach Zonation and Terminology (Source: Hallermeier, 1981)

RHDHV initially estimated d_L and d_i (closure depths), as 8m and 16m, respectively. These initial values are consistent with the statistical range developed in analysis of depth of closure subsequently undertaken in the Stockton Beach coastal erosion hazard study (Bluecoast, 2020). Accordingly, for the purposes of this revised memo, closure depths have not been adjusted from the initial values and the "full" profile is considered to develop to -16m AHD.

After Rijkswaterstaat (1987) see ***Figure* 2**, the sub-aqueous nourishment volume should consider a transition zone below the depth of closure out to a depth of twice the depth of closure where the thickness of the nourishment volume decrease linearly to zero (assuming the borrow sand is similar to the native sand).

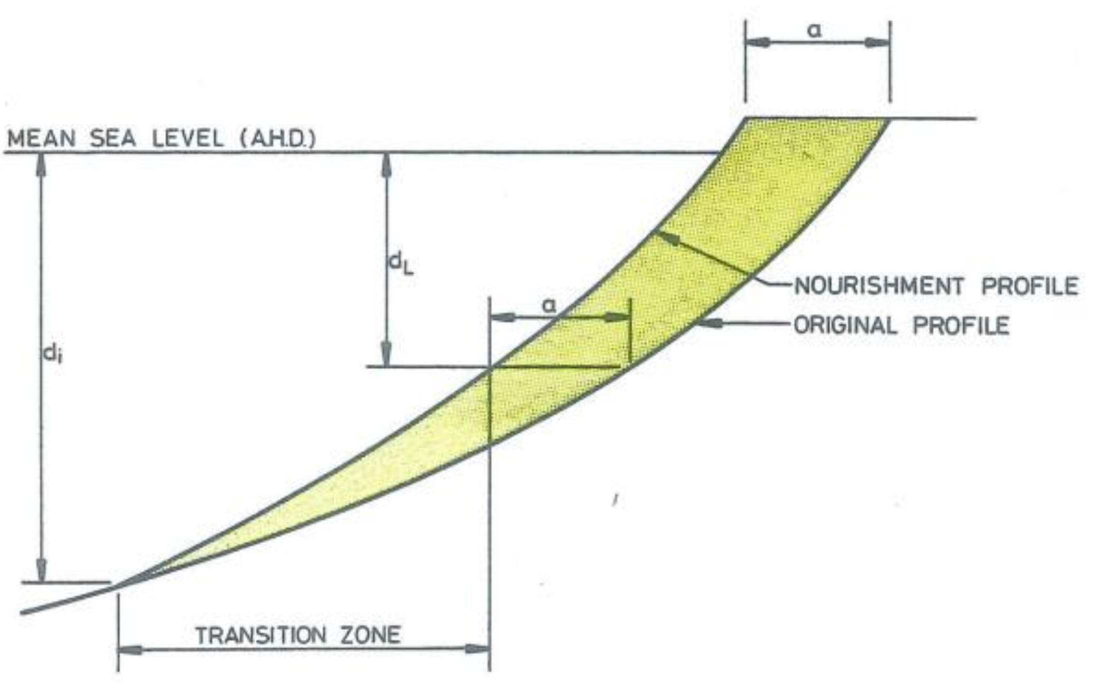

Figure 2 - Profile of Nourishment, Borrow Sand similar to Native Sand (Source: Rijkswaterstaat, 1987)

Accordingly, adopting a d_L value of the depth of closure of -8 m AHD and using the approach of Rijkswaterstaat (1987) gives a subaqueous nourishment requirement for a seaward advancement of the beach system of "a" m, of approximately 12 x a m^3/m i.e.:

Sub aqueous volume (m^3/m) = a x 8 + 0.5 x a x (16 - 8)

= **12 x a m^3/m**

Height of the Dune System

The existing dune heights along the beach are variable and have been modified by the presence of the numerous seawall constructions. It is considered likely that the nourishment exercise for Stockton Beach would only be able to practically achieve a dune height of 3m AHD. For the purposes of calculation of nourishment volumes, it is assumed that the average dune crest level would form (or be placed) at the design "profile" of 3.0 m AHD along the length of beach at threat.

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Length of Beach to be Nourished

Whilst the method adopted for any "massive" nourishment exercise would involve the majority of the sand being placed in a particular area of the stretch of beach at threat, the sand will redistribute over the beach length (primarily to the north) naturally over time as a result of alongshore transport rates.

For the purposes of calculation of nourishment volumes, it is assumed that it would be necessary in effect to provide sufficient sand to nourish the approximately 2200m between the Breakwater and the northern management area extent (a length of 200m north of the CMP area has been included as this area would realistically also need to be nourished to achieve the nourished profile at Meredith St), to achieve the desired management objectives.

Estimate of Sand Nourishment Volumes

Based on the above discussion, estimates have been prepared of the total sand nourishment to achieve the desired objective of each management option (which equates to a particular seaward advancement of the beach system "a"). This generic estimate is set out below. The total nourishment volume requirement is estimated to be approximately **33,000 x "a" m^3** and assumes the borrow sand is similar to the native sand.

Volume to achieve management objective:

(i)	sub-aerial volume (i.e. above AHD)	
	3.0 m (dune height) x "a" m (width) x 2200 m (length)	6,600 x "a" m^3
(ii)	sub-aqueous volume (i.e. below AHD)	
	(to 8 m depth)	
	8 m x "a" m x 2200 m	17,600 x "a" m^3
	(8 m to 16 m depth)	
	0.5 x 8 m x "a" m x 2200 m	8,800 x "a" m^3
	Total	**33,000 x "a" m^3**

The estimated volume above can be seen to be a factor of the desired objective of each management option. In this assessment the sub-aqueous volume has been estimated based on closure depths of d_L (adopted as -8 m AHD) and inclusion of a "wedge' of material below this limit to a depth d_i at which the effects of surface waves are negligible (adopted as -16 m) in line with recommendations set out in the Manual on Artificial Beach Nourishment (Rijkswaterstaat, 1987).

The approach by Rijkswaterstaat provides an estimate of the "full" nourishment volume and follows from a comprehensive overview of available literature, design practices and performance of nourishment projects worldwide. Accordingly, it is considered a conservative estimate.

For NSW beaches historical surveys indicate that very limited movement of sediment occurs beyond d_L (adopted in this case as -8m AHD). Furthermore, for the local application, longshore movement dominates the sediment transport processes. Accordingly, the temporal scale associated with cross shore movement beyond the depth of closure is significantly greater than the processes occurring within the active profile. This would effectively limit any significant development of the "full" nourishment profile as described by Rijkswaterstaat.

It is therefore appropriate to consider estimate of the volumes which would be required based on the less conservative approach of Hallermeier (adopted by CEM) for which the total nourishment volume requirement to advance the average profile “a” m would be <u>at least</u> **24,200 x “a” m^3**. This estimate is set out below.

Volume to achieve management objective:

(i) sub-aerial volume (i.e. above AHD)

3.0 m (dune height) x “a” m (width) x 2200 m (length)	6,600 x “a” m^3

(ii) sub-aqueous volume (i.e. below AHD)

(to -8 m depth)

8 m x “a” m x 2200 m		17,600 x “a” m^3
	Total	**(at least) 24,200 x “a” m^3**

The qualification “at least” is believed to be recognition of a somewhat indeterminate volume of material below d_L in the area between the nourished profile and the natural profile. As discussed above, for development of a nourished profile at Stockton Beach this is not considered to be a significant volume.

However, in recognition of the uncertainty and variability in estimates of closure depths (Bluecoast, 2020), and to account for this uncertainty, it is considered prudent for this comparative, feasibility level investigation to adopt the more conservative values of the <u>Rijkswaterstaat approach</u>. This is the approach that has consistently been followed for all subsequent calculations herein, described for each management option in the following sections.

2 Base Case

In 2018, CN adopted the Newcastle CZMP 2018, which outlines a range of coastal management actions for the local government area. Part A – Stockton, is limited to the coastal zone north of the Hunter River while the remainder of the coastal zone within the Newcastle Local Government Area (LGA) is addressed in, Part B - Coastline South of the Harbour. The Base Case discussed herein, involves continued delivery of the actions within the Newcastle CZMP 2018 Part A (refer ***Figure 3***).

DRAWING No. PA2395-RHD-00-DR-MA-1011

DO NOT SCALE

FIGURE 3

BASE CASE (SOUTH)

1:2000 (A1)

BASE CASE (NORTH)

1:2000 (A1)

LEGEND

- APPROX. CREST OF EROSION SCARP FROM 17 FEB 2020 UAV SURVEY (PROVIDED BY NEWCASTLE CITY COUNCIL)
- MAINTAIN EXISTING ROCK REVETMENT
- 2018-2020 MSL (0m AHD)
- 2020 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2025 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2040 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2060 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2120 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)

DIAL BEFORE YOU DIG www.1100.com.au

AUSTRALIAN HEIGHT DATUM

40 0 40 80 120 160 200m

1:4000 (A3) 1:2000 (A1)

REV	DATE	DESCRIPTION	BY	CHK	APP
B	14.04.2020	RE- ISSUED FOR REVIEW	BR	NP	AT
A	07.04.2020	ISSUED FOR REVIEW	BR	NP	AT

REVISIONS

CLIENT: City of Newcastle

PROJECT: STOCKTON CMP

TITLE: COASTAL MANAGEMENT BASE CASE

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DRAWN	COORD. SYSTEM	DATUM	DATE
-	MGA ZONE 56	AHD	09.04.2020
SCALE AT A1 AS SHOWN	REF. PA2395-RHD-00-M3-MA-1001		

DRAWING No. PA2395-RHD-00-DR-MA-1011 REVISION B

C:\USERS\220068\BOX\PA2395 STOCKTON CMP\PA2395 STOCKTON CMP TEAM\PA2395 TECHNICAL DATA\E11 WORKING DRAWINGS\PA2395-RHD-00-M3-MA-1001

The Stockton study area has been divided into seven management action zones to enable identification of the location of management actions within the study area. The seven zones are located from south to north along the Stockton coastline as shown in ***Figure 4*** and comprise:

- Zone 1 - Little Beach, including Stockton Breakwater and the foreshore area north to the seawall east of the Stockton Surf Life Saving Club (SLSC);
- Zone 2 - Seawall east of Stockton SLSC and the foreshore area north to the Mitchell Street seawall;
- Zone 3 - Mitchell Street seawall extent;
- Zone 4 – Foreshore from the northern end of Mitchell Street seawall north to Meredith Street;
- Zone 5 – Foreshore from Meredith Street to the northern boundary of Corroba Oval;
- Zone 6 – Foreshore from the northern boundary of Corroba Oval north to the southern boundary of Fort Wallace (main land ownership by Hunter Water Corporation); and
- Zone 7 – Foreshore from the southern boundary of Fort Wallace to CN LGA boundary (main land ownership by Defence Housing Australia and Family and Community Services).

Figure 4: Management action zones for Stockton study area.

Beach erosion and shoreline recession are identified as coastal hazards in the Stockton study area. Replenishment of sand to the Stockton study area was identified as a high priority by the community. Port of Newcastle (PoN) currently places suitable sand, from maintenance dredging activities undertaken for navigational safety at the harbour entrance, off Stockton Beach. This sand is bottom dumped in the nearshore zone at a designated location offshore of Mitchell St revetment.

Implementation of CZMP actions includes:

- maintenance to Mitchell Street seawall (as identified in the condition assessment report (RHDHV, 2019));
- beach management works such as beach scraping and beach grooming to increase dune volume in a number of locations;
- dune maintenance; and
- ongoing temporary emergency works, as required.

The CZMP authorised repairs to the northern end of the Mitchell Street seawall. The CZMP authorised temporary coastal protection works for the former landfill site at 310 Fullerton Street (Lot 202 DP 1150470) which are now complete.

The CZMP outlines the requirement for detailed investigations and other required studies, including a scoping study and assessment of sand replenishment sources, to be undertaken to facilitate certification of a Coastal Management Program (CMP) under the *Coastal Management Act 2016*. Costs for the full range of management actions are included within the Newcastle Coastal Zone Management Plan 2018.

3 Option 1 - Mass sand nourishment for protection + amenity, limited terminal coastal protection works

General Description

Option 1 involves sand nourishment to a level that provides coastal protection to existing assets and the construction of terminal coastal protection structures to protect those particular assets at risk within the next 5 years (in accordance with established 2025 hazard lines (Bluecoast, 2020)).

Option 1 comprises the following components:

- ongoing maintenance of existing rock revetment structures at the Surf Lifesaving Club (SLSC) and Mitchell St;
- buried terminal coastal protection structures to protect the following assets at risk within the next 5 years (refer established 2025 hazard line shown in ***Figure 5***):
    - the flanks of all of the existing rock structures;
    - roadways; and
    - residential assets,
- an initial mass sand nourishment for the full extent of the CMP area (northern breakwater to Meredith St) to provide coastal protection to existing foreshore alignment and all assets from a 50 year ARI storm event, with maintenance nourishment every 5 years (nourishment to provide coastal protection would by default also provide significant improvements in beach amenity).

Refer to; ***Figure 5*** for layout of Option 1, and **Appendix A** for breakdown of estimated costs and timing. The rationale behind this option and further detail of each component is provided below.

Rationale

The community of Stockton have indicated a desire to limit hard terminal structures, as much as possible in the provision of coastal protection, in preference for beach nourishment. This option aims to provide coastal protection from storm erosion and long term beach recession (including allowance for sea level rise (SLR)) through beach nourishment. Due to the immediate threat to some assets, it is proposed that the minimum extent of buried terminal coastal protection structures be built to protect these assets whilst beach nourishment works are in planning and progress. Timing of proposed works is provided in cost estimates in **Appendix A**.

Nourishment

In order to provide coastal protection from long term recession and a potential succession of storm events, the nourishment volume to achieve this objective has been derived for the most critical part of the beach. The combination of the most vulnerable, or most seaward, asset with the most exposed part of the beach occurs at Barrie Cres., and more specifically at the convergence with Griffiths Ave. The sand nourishment volume and frequency has been designed to protect this location, and by default other less exposed parts of the CMP coastline.

A permissible risk of ‘failure’ of the nourishment volume of 10% has been adopted for the 50 year ARI design storm event, implying a re-nourishment (maintenance) period of **5 years** (in accordance with the binomial distribution of event occurrence outlined in **Table 1).**

DESIGN RETURN PERIOD T IN YEARS

PERMISSIBLE RISK OF FAILURE (R)	EXPECTED PROJECT LIFE IN YEARS (N)							
	1	2	5	10	20	25	50	100
0.99	1.01	1.11	1.66	2.71	4.86	5.95	11.40	22.20
0.95	1.05	1.29	2.22	3.86	7.18	8.85	17.20	33.90
0.90	1.11	1.46	2.71	4.86	9.19	11.40	22.29	43.90
0.75	1.33	2.00	4.13	7.73	14.90	18.60	36.60	72.60
0.50	2.00	3.41	7.73	14.90	29.40	36.60	72.60	145.00
0.33	3.00	5.45	12.90	25.20	49.90	62.10	124.00	247.00
0.25	4.00	7.46	17.90	35.30	70.00	87.30	174.00	348.00
0.20	5.00	9.47	22.90	45.30	90.10	113.00	225.00	449.00
0.10	10.00	19.50	48.00	95.40	190.00	238.00	475.00	950.00
0.05	20.00	39.50	98.00	195.00	390.00	488.00	975.00	1,950.00
0.02	50.00	99.00	248.00	495.00	990.00	1,238.00	2,476.00	4,951.00
0.01	100.00	199.50	498.00	995.00	1,990.00	2,488.00	4,977.00	9,953.00

Table 1: Binomial distribution of event occurrence

The following has also been considered when applying the adopted Rijkswaterstaat approach in developing the nourishment scheme design:

Initial nourishment volumes

- Allowing for a 50 year ARI storm at Barrie Cres., a 220m^3/m storm erosion demand has been adopted (interpolating between the 80m^3/m at the breakwater and 220m^3/m at the LGA boundary (Bluecoast, 2020) and allowing for end effects adjacent to the Mitchell St revetment[2]).

- For the current beach state, there is approximately 14m between the critical asset and the foreshore. Given the dune height in this location of approximately 5.5.m AHD, this equates to 77m^3/m of existing sediment in the subaerial profile to partially meet the 220m^3/m storm demand. The deficit is therefore 143m^3/m. Based on a 3m design nourishment profile this is approximately **47.5m** of beach width that needs to be provided.

[2] According to DECCW (2010b) additional erosion close to the ends of a seawall can be estimated in its cross-shore and alongshore extents. In assessing the additional erosion that may result from a seawall, the estimated design erosion volume should be increased by 80% near the wall and increased above the design value for a distance of up to 70% of the length of the seawall along the shore or 500 m, whichever is the lesser.

After Rijkswaterstaat (1987)

1. Volume to *establish the amenity outcome objective or asset protection outcome objective*, based on current beach state (47.5m increased width):

(i)	sub-aerial volume (i.e. above AHD)	
	3.0 m (dune height) x 47.5 m (width) x 2200 m (length)	313,500 m^3
(ii)	sub-aqueous volume (i.e. below AHD)	
	(to 8 m depth)	
	8 m x 47.5 m x 2200 m	836,000 m^3
	(8 m to 16 m depth)	
	0.5 x 8 m x 46 m x 2200 m	418,000m^3
	(sub)Total	**1,567,500 m^3**

2. Volume for five years times projected underlying loss (1m/yr). i.e. 5m beach width

(i)	sub-aerial volume (i.e. above AHD)	
	3.0 m (dune height) x 5 m (width) x 2200 m (length)	33,000 m^3
(ii)	sub-aqueous volume (i.e. below AHD)	
	(to 8 m depth)	
	8 m x 5 m x 2200 m	88,000 m^3
	(8 m to 16 m depth)	
	0.5 x 8 m x 5 m x 2200 m	44,000m^3
	(sub) Total	**165,000 m^3**

3. Volume for five years times projected sea level rise loss (0.36m/yr) i.e. 1.8m beach width

(i)	sub-aerial volume (i.e. above AHD)	
	3.0 m (dune height) x 1.8 m (width) x 2200 m (length)	11,880 m^3
(ii)	sub-aqueous volume (i.e. below AHD)	
	(to 8 m depth)	
	8 m x 1.8 m x 2200 m	31,680 m^3
	(8 m to 16 m depth)	
	0.5 x 8 m x 1.8 m x 2200 m	15,840m^3
	(sub) Total	**59,400 m^3**
Totalling 1, 2 and 3	**Total**	**1.8 million m^3**

Previous assessments of terrestrial sand sources found that the median grain size available in large quantities was generally finer than the native sand, requiring 1.8 to 5 times as much sand to retain 1m^3 on the beach (known as the overfill ratio, as outlined in Supporting Document E – Potential Sand Sources). An overfill ratio of approximately 2.5 has therefore been included for terrestrial sand sources. The total nourishment volume required would therefore be approximately **4.5 million m^3 for the initial nourishment campaign (for the terrestrial source). It is recommended that a sensitivity analysis be undertaken to assess an overfill ratio of 1, should a perfectly compatible sand source become available.**

Maintenance nourishment volumes

As discussed in Section 1, the last two components (2 and 3) of the above calculation, typically comprise the maintenance re-nourishment volume. i.e. approximately 225,000 m^3 every 5 years.

However, the findings of the Stage 2 investigation (Bluecoast, 2020a) note that the combined rate of long-term sand loss from the Stockton CMP area is 112,000m^3/yr, which is based on the historical observations of:

- 100,000m^3/yr of sand loss from the sub-aqueous part of the coastal profile in the southern Stockton embayment between the northern breakwater and Fort Wallace (inshore of 20m depth contour) between 1988 and 2018.
- 12,000m^3/yr of sand loss from sub-aerial part of the coastal profile in Block A, Block B and Block C between 1985 and 2020.

On this basis it is proposed that the maintenance nourishment volume be **560,000 m^3 every 5 years**. This recognises the uncertainty in the coastal processes understanding and an acknowledgment of the indication from data that the beach profile at the site is not only receding but changing in shape (deepening).

Applying the overfill ratio factor, the **maintenance nourishment becomes 1.4 million m^3 every 5 years (for the terrestrial source).** For the placement of sand from a terrestrial source the following is noted:

- Due to logistical constraints and the subsequent limited rate of placement of sand from terrestrial sources, the sand would need to be placed constantly rather than at 5 yearly intervals. To achieve the initial nourishment campaign of 4.5 million m^3 would require 234,375 truck and dog loads (32t or 19.2m^3 per truck and dog). As outlined below sand would need to be transported and placed on the subaerial beach constantly throughout the year.

- The recent sand placement Pilot Study undertaken in front of the Holiday Park involved placement of 5564t (approximately 3340m^3) of sand transported in 173 truck-and-dog loads (32t) over 4 days i.e. 44 loads/day. This rate of trucking was generally considered acceptable in the community for a short time frame. At this rate it would take approximately 21 years to place the initial amount of sand transported by truck. To place this amount within the first 5 years would require more than 4 times the rate of trucking as previously experienced during the Pilot Study sand placement campaign. Community willingness to accept this rate of truck movements has not been assessed.

- To reduce truck movements through residential streets, an alternative sand placement methodology could be undertaken simultaneously. In addition to having trucks transporting sand directly onto the beach via the King St access (as per the Pilot Study methodology) it is also proposed that trucks transport sand to a sand pumping station established near Corroba Oval (on western side of Fullerton Rd). The sand would be pumped as a slurry via a buried pipeline to outlets at Dalby Oval frontage and Barrie Cres frontage. A trial diesel pumping station and pipeline with a 100,000m^3/year capacity could be established with a 5 year operational contract. However, this is only a small proportion of the 4.5 million m^3 and would provide negligible reduction in truck movements/costs overall for Option 1.

- Protection of assets for the design storm would not be established until the beach nourishment volume equalled the storm erosion demand (220m^3/m). This would require in the order of 484,000 m^3, or 1.2 million m^3 considering the overfill ratio. This would take around 6 years at the same trucking rate as the recent pilot study and including the establishment of the sand pumping station and pipeline.

- **It is noted that based on existing demand for quarry sand locally, it is currently considered unlikely that the required nourishment volume could be sourced from local quarries within the existing licensing arrangements. This issue would need to be addressed to make this option feasible, otherwise alternative sources would be required. It is also noted that the quantity of sand could not logistically be placed on the current sub aerial beach width.**

Option 1 - Sensitivity Analysis

While acknowledging that marine sand sources are currently either; restricted by legislation, or not available, there are potential future opportunities to access these sources. Accordingly, it is recommended that a sensitivity analysis be undertaken in the CBA to examine the benefit cost ratio (BCR) for Option 1 – mass sand nourishment for coastal protection, using marine sourced sand from offshore sources (Option 1b), or Hunter River sources (Option 1c). The nourishment volumes would be:

- **1.8 million m^3 initial**, and **560,000 m^3** maintenance for a 5 year re-nourishment period; or
- 2.1 million m^3 initial (or **2.4 million m^3** after Bluecoast (2020a)) with **1.12 million m^3** maintenance for a 10 year re-nourishment period.

It should be noted that values adopted have been updated following Bluecoast's further refinement with modelling and data from the Stage 2 Sediment Transport Study. A detailed outline of the development of refined volumes and the residual risks is requested in the CBA. Stage 1 terminal coastal protection works would still be required in Option 1b and Option 1c.

Risks

It is important to note that Option 1 – Mass sand nourishment for coastal protection, is a relatively high risk option in terms of protection of assets. When beach nourishment is intended for asset protection, a different risk approach needs to be taken compared to use of sand nourishment for amenity purposes.

This approach needs to include the following considerations:

- What safety factor should be applied (or risk level is deemed acceptable) to the sand volume on the beach? E.g. In the case of amenity considerations, a succession of more severe storms than average may be acceptable because the outcome is a level of inconvenience. Whereas, if it means the loss of an asset, the consequences may not be acceptable. The need to design for a lower risk profile becomes apparent.
- Will a dredger be available when you want it at a future time? What will mobilisation/ demobilisation costs be if you need it in a hurry?

- Will funds be available at a future time?

Under any variant of Option 1 – mass sand nourishment for coastal protection strategy, assets would potentially be at risk if any of the following occurred:

- more than one design storm occurs within the re-nourishment period, or a series of storms with a cumulative impact exceeding the design storm;
- a storm larger than the design storm occurs;
- beach recession exceeds estimated values;
- SLR exceeds estimated values;
- sufficient sand supply cannot be sourced; or
- the placement rate cannot be achieved, e.g. inclement weather.

It is noted that this risk can be significantly reduced through more frequent, smaller re-nourishment campaigns to avoid the beach becoming depleted at the end of a long re-nourishment period. Smaller scale more frequent re-nourishment campaigns from marine sources are generally not economically viable due to mobilisation/demobilisation costs. However, if a strategic alliance with other existing dredging operations can be created these costs can potentially be offset.

Option 1 poses minimal risk of negatively impacting downdrift beaches (to the north), as the proposed nourishment volume exceeds the estimated long term losses determined in the Stage 2 Sediment Transport Study (Bluecoast, 2020a). Downdrift beach are likely to benefit from additional sediment.

DRAWING No.
PA2395-RHD-00-DR-MA-1012

DO NOT SCALE

FIGURE 5

OPTION 1 (SOUTH)
1:2000 (A1)

OPTION 1 (NORTH)
1:2000 (A1)

LEGEND

- STAGE 1 - BURIED TERMINAL PROTECTION STRUCTURE
- APPROX. CREST OF EROSION SCARP FROM 17 FEB 2020 UAV SURVEY (PROVIDED BY NEWCASTLE CITY COUNCIL)
- POTENTIAL WASTE THAT NEEDS TO BE MANAGED
- MAINTAIN EXISTING ROCK REVETMENT
- BEACH NOURISHMENT FOR COASTAL PROTECTION
- POSSIBLE VEHICLE BEACH ACCESS RAMP
- 2018-2020 MSL (0m AHD)
- 2020 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2025 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2040 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2060 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2120 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)

REV	DATE	DESCRIPTION	BY	CHK	APP
C	14.04.2020	RE-ISSUED FOR REVIEW	BR	NP	AT
B	07.04.2020	RE-ISSUED FOR REVIEW	BR	NP	AT
A	03.04.2020	ISSUED FOR REVIEW	BR	NP	AT

REVISIONS

CLIENT
City of Newcastle

PROJECT
STOCKTON CMP

TITLE
COASTAL MANAGEMENT OPTION 1

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DRAWN	COORD. SYSTEM	DATUM	DATE
-	MGA ZONE 56	AHD	14.04.2020
SCALE AT A1 AS SHOWN	REF. PA2395-RHD-00-M3-MA-1001		

DRAWING No. PA2395-RHD-00-DR-MA-1012
REVISION C

40 0 40 80 120 160 200m
1:4000 (A3) 1:2000 (A1)

AUSTRALIAN HEIGHT DATUM

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4 Option 2 - Sand nourishment for improved beach amenity + coastal terminal protection works

General Description

Option 2 involves beach nourishment to provide improved recreational beach access amenity and construction of buried terminal coastal protection structures, in two stages, to address the current and future risk of potentially high consequence, low probability events that may affect the area (mandatory requirement 13 of the Coastal Management Manual Part A).

Option 2 comprises the following components:

- ongoing maintenance of existing rock revetment structures at the Stockton SLSC and Mitchell St;
- Stage 1 buried terminal coastal protection structures are to be built in the short term to protect the following assets at risk within the next 5 years (in accordance with established 2025 hazard lines):
  - the flanks of all of the existing rock structures,
  - roadways; and
  - residential assets,
- Stage 2 buried terminal coastal protection structures set back at the established hazard lines to be constructed if/when minimum foreshore width triggers are reached;
- Stage 2 small rock headland at the end of Griffiths Ave to protect the road head and create a stable embayment within the Barrie Cres frontage to be constructed if/when minimum foreshore width triggers are reached;
- sand nourishment for the full extent of the CMP area (Breakwater to Meredith St) to provide ongoing beach amenity, with the specific objective of a minimum annual average beach width of 5m at the narrowest point along the CMP area (revetment structures) measured at 1.5m AHD (approximately 1m above MHW to account for wave runup) accommodating a volume for a 1 year ARI storm each year; and
- aspirational goals of sand nourishment include:
  - a wide beach width at popular locations to enable the continuation of established recreational uses of the beach (such as nippers);
  - minimum dry beach width provides reasonable space at the narrowest point for two people walking along the beach in opposite directions to comfortably pass one another; and
  - minimum dry beach width provides adequate operational space to undertake nourishment.

Refer to; ***Figure 6*** for layout of Option 2, and **Appendix B** for breakdown of estimated costs and timing. The rationale behind this option and further detail of each component is provided below.

Rationale

The objective of Option 2 is to improve beach amenity through sand nourishment whilst ensuring assets at immediate risk are protected by buried terminal coastal protection structures (refer immediate hazard lines). The rationale behind Option 2 is to improve the beach's resilience and capacity to accommodate coastal processes and avoid loss of beach amenity.

This resilience is achieved by creating a foreshore zone for adaptive land use that effectively creates a buffer for the natural coastal processes of short term erosion and recovery to occur. If/when the beach recedes back such that the erosion scarp is within the minimum threshold distance of the Stage 2 alignment, this would trigger the need for Stage 2 buried terminal coastal protection to be constructed, connecting the two Stage 1 seawalls (refer ***Figure 6***).

Having the Stage 2 structures set back at this alignment and a sand buffer in front of it, reduces the likelihood of the interaction between the structure and wave action. Accordingly, the potential for; reflective wave energy, toe scour and exacerbated beach erosion, ultimately causing a loss of the sandy beach, are also reduced. The buffer width (to the point of the trigger) provides a minimum volume equivalent to the storm erosion demand of a 10 year ARI event.

Assuming it would take a maximum of 5 years from triggering the need for the terminal coastal protection works to completing them, there would be about a 40% chance of the 10 year ARI event occurring in that period. During this time, assets would be at risk, prior to completion of the terminal coastal protection structures. If the structures can be completed within a shorter timeframe, the probability of the storm event occurring and assets being at risk reduces. E.g. there is a 20% chance of the 10 year ARI event occurring in a 2 year period. For this reason, it is recommended that preparations be made to allow this protection to be implemented with expediency once triggers are reached. CN has acknowledged and accepted this level of risk.

In Stage 1, buried terminal coastal protection structures would be constructed to protect assets seaward of the 2025 Zone of Reduced Foundation Capacity (ZRFC) 1% Annual Exceedance Probability (AEP) hazard line (Bluecoast, 2020), i.e. there is a 1% risk that the ZRFC will reach this shoreline position in the next 5 years. This is typically at the flanks of the existing revetment structures and the Barrie Cres roadway including the end of Griffiths Ave as shown in ***Figure 6***.

The timing of the trigger for the Stage 2 buried terminal protection structures will be dependent on a number of factors including:

- the performance of the beach nourishment;
- the rate of beach recession;
- ambient conditions (whether it has been a stormy period or not); and
- sea level rise.

If some or all of these factors are favourable, the construction of the buried terminal coastal protection structures could be delayed, or may not be triggered, offsetting the capital cost of this Option. For the purpose of undertaking the CBA it assumed that **the buried terminal coastal protection structures would be triggered in year 7 with the full economic cost realised in year 9**.

The Stage 2 buried structures would provide terminal coastal protection to the foreshore areas including:

- a portion of the Holiday Park;
- Dalby Oval; and
- the roadway and residential assets behind these areas.

In each zone, the alignment of the proposed Stage 2 structures allows for terminal coastal protection of a portion of the existing foreshore land. Any built assets should be behind this alignment. The land seaward of this alignment can still be utilized for adaptive environmental and recreational activities. However, as it is within the proposed buffer zone it will be subject to coastal processes over time. Appropriate and adaptive land use in these areas might include grassed areas for casual recreation, or camp sites etc.

In Zone 1, the alignment of the proposed Stage 2 buried terminal coastal protection structures allows for protection of the majority of the Holiday Park. Accordingly, the area landward of the structures could be used for the built assets such as amenities and cabins. The area seaward of the proposed buried structures could still be utilized for Holiday Park functions such as caravans and camping, allowing flexibility to adapt these sites as required. A Holiday Park upgrade would be required to rebuild amenities blocks etc. and rearrange the layout, but current revenue could be maintained in the future.

In Zone 2, the alignment of the proposed Stage 2 buried terminal coastal protection structure allows for protection of the majority of Dalby Oval. Accordingly, the land seaward of this alignment can still be utilized for environmental and recreational activities. However, as it is within the proposed buffer zone it will be subject to coastal processes over time. Appropriate and adaptive land use in these areas might include grassed areas for casual recreation.

In Zone 4, most of Barrie Cres and the seaward end of Griffiths Ave are within the 2025 ZRFC. Accordingly, terminal coastal protection structures are proposed as shown in ***Figure 6*****.**

The proposed buried terminal coastal protection structure is a vertical seawall with rock scour protection at the toe, as demonstrated in **Attachment A**. A vertical seawall is more costly than a rock revetment (typically in the order of 1.5 times the cost/lineal m). However, the reasons for selecting this style of structure over a rock revetment (like existing protective structures at Stockton) are as follows:

- increasing difficulty in sourcing local rock of a suitable size and integrity for rock armour is a factor (as evidenced by the issues with the rock armour splitting and fracturing in the existing Stockton SLSC revetment);
- narrower footprint of the vertical seawall option is of benefit in reducing the encroachment on the sandy beach amenity area; and
- the vertical seawall can be constructed using secant piles which can be installed without the need for complete excavation which has the following advantages:
    - avoids excavation which is difficult, costly (due to groundwater) and high risk due to the exposure to wave action; and
    - can incorporate a concrete capping beam and upstand at the top of the wall which provides a visually appealing wall as it becomes exposed when beach levels lower (e.g. towards the end of a beach nourishment period).

Timing of works is provided in cost estimates in **Appendix B.**

<u>Nourishment</u>

The objective of the beach nourishment in this option is to provide improved beach amenity. The design of the nourishment has been based on a minimum beach width of 5m measured at 1.5m AHD[3], approximately 1m above mean high water (MHW) (including the effects of typical wave runup, which approximately delineates the “permanently dry” portion of the sandy beach). This width would be monitored at the existing rock revetment structures as they are the most prominent areas on the beach. This will equate to significantly wider beaches in the adjacent areas. The premise is that a 5m beach width is considered to provide reasonable space for two people walking along the beach in opposite directions to comfortably pass one another.

[3] The MHW level is located at approximately RL 0.5. A 1 m allowance for typical wave runup has been included, which was calculated based on methods described in Hanslow and Nielsen (1995). Therefore, the amenity objective is measured at RL 1.5 for the purposes of this study.

When the annual average beach width adjacent to the either the Stockton SLSC or Mitchell St revetment reduces to 8m, this serves as a trigger for Council to commence investigations for a nourishment project which is implemented within a period of two years. Based on February 2020 UAV data, the existing nominal beach width in the CBA Study Area is assessed to range approximately between 0 m (at the existing revetments) to 20 m (near Meredith St).

The sand placements would be designed to accommodate recession such that the minimum beach width is in place at the commencement of successive nourishment campaigns. In practice, the exact timing of nourishment campaigns would vary according to beach conditions, available sand sources and the like.

For the purposes of the CBA, it has been assumed that an improved amenity sand nourishment exercise would conceptually involve adding **5 m beach width** to the length of the CBA Study Area and maintenance nourishment would effectively occur **annually**.

Depending on the quantities required, nourishment material could be supplied by truck and dog haulage from Port Stephens quarries and/or through back passing (trucked or pumped via land-based pipeline) from the northern end of the beach, or a combination of these options. An alternative to reduce truck movements in residential streets would be to truck sand to the Corroba Oval foreshore where it is mixed into a slurry and pumped via a land-based pipeline to the southern end of the beach.

The following has also been considered when applying the adopted Rijkswaterstaat approach in developing the nourishment scheme design:

Initial nourishment volumes

After Rijkswaterstaat (1987)

1. Volume to *establish the amenity outcome objective or asset protection outcome objective*, based on current beach state (5m increased width):

(i) sub-aerial volume (i.e. above AHD) + (ii) sub-aqueous volume (i.e. below AHD)

33,000 x 5 m (from Section 1 and detailed in Option 1 above)		165,000m^3
	(sub)Total	**165,000 m^3**

2. Volume for one year times projected underlying loss (1m/yr). i.e. 1m beach width

(i) sub-aerial volume (i.e. above AHD) + (ii) sub-aqueous volume (i.e. below AHD)

33,000 x 1 m		33,000m^3
	(sub) Total	**33,000 m^3**

3. Volume for one year times projected sea level rise loss (0.36m/yr) i.e. 0.36m beach width

(i) sub-aerial volume (i.e. above AHD) + (ii) sub-aqueous volume (i.e. below AHD)

33,000 x 0.36 m		12,000m^3
	(sub) Total	**12,000 m^3**
Totalling 1, 2 and 3	**Total**	**210,000 m^3**

Maintenance nourishment volumes
As discussed in Section 1, the last two components (2 and 3) of the above calculation, typically comprise the maintenance re-nourishment volume. i.e. approximately 45,000 m^3 annually.

However, as previously discussed, the findings of the Stage 2 investigation note that the sediment deficit, over the full active profile between the 1980's and 2018 has been in the order of 112,000m^3/year (Bluecoast, 2020a). On this basis it is proposed that the maintenance nourishment volume be **112,000 m^3 as an annual maintenance regime**.

Previous assessments of terrestrial sand sources found that the median grain size available in large quantities was generally finer than the native sand, requiring 1.8 to 5 times as much sand to retain 1m^3 on the beach (known as the overfill ratio, as outlined in Supporting Document E – Potential Sand Sources). An overfill ratio of approximately 2.5 has therefore been included for terrestrial sand sources. The total nourishment volume required would therefore be approximately **525,000m^3 in the first year and 280,000m^3 placed annually thereafter (for the terrestrial source).** For the placement of sand from a terrestrial source the following is noted:

- Due to logistics constraints and the subsequent limitations on the rate of placement of sand from terrestrial sources, the sand would need to be placed continually at a rate of 14,300m^3/day or 75 truck and dog loads/day. This is almost twice the truck movements involved in the recent 4 day Sand Placement Pilot Study undertaken in front of the Holiday Park where 5564t was placed in 173 truck and dog loads over 4 days. This is likely to cause an unacceptable level of traffic/environmental/social impacts on the local community and it is therefore proposed that the nourishment be approached in two ways.

    - trucks transporting sand directly onto the beach via the King St access (as per the Pilot Study methodology); and
    - trucks transporting sand to a sand pumping station established near Corroba Oval (on western side of Fullerton Rd) which would then be pumped as a slurry via a buried pipeline to the outlets at Dalby Oval frontage and Barrie Cres. frontage. This would reduce truck movements within residential streets. A trial diesel pumping station and pipeline could be established with a 5 year operational contract.

- **It is noted that based on existing demand for quarry sand locally, it is currently considered unlikely that the required nourishment could be sourced from local quarries within the existing licensing arrangements. This issue would need to be addressed to make this option feasible, otherwise alternative sources would be required.**

<u>Option 2 - Sensitivity Analysis</u>

As for Option 1, while acknowledging that marine sand sources are currently either; restricted by legislation, or not available, there are potential future opportunities to access these sources. Accordingly, it is recommended that a sensitivity analysis be undertaken in the CBA to examine the benefit cost ratio (BCR) for Option 2 – sand nourishment for improved amenity coastal protection. The management option object is therefore, accommodate a 1 year ARI storm event with demand of 20m^3/m, (i.e. provide a buffer of 6.7m considering a 3m design dune height) and achieve the minimum annual average beach width of 5m at the narrowest point, using marine sourced sand from offshore sources (Option 2b), or Hunter River sources (Option 2c). The nourishment volumes for a **5 year** re-nourishment frequency would be:

Initial nourishment volumes

After Rijkswaterstaat (1987)

1. Volume to *establish the amenity outcome objective or asset protection outcome objective*, based on current beach state (6.7m + 5m = 11.7m increased width):

(i) sub-aerial volume (i.e. above AHD) + (ii) sub-aqueous volume (i.e. below AHD)

33,000 x 11.7 m		386,100m^3
	(sub)Total	**386,100 m^3**

2. Volume for five years times projected underlying loss (1m/yr). i.e. 5m beach width

(i) sub-aerial volume (i.e. above AHD) + (ii) sub-aqueous volume (i.e. below AHD)

33,000 x 5 m		165,000m^3
	(sub) Total	**165,000 m^3**

3. Volume for five years times projected sea level rise loss (0.36m/yr) i.e. 1.8m beach width

(i) sub-aerial volume (i.e. above AHD) + (ii) sub-aqueous volume (i.e. below AHD)

33,000 x 1.8 m		59,400m^3
	(sub) Total	**59,400 m^3**
Totalling 1, 2 and 3	**Total**	**610,000 m^3**

Maintenance nourishment volumes

As discussed in Section 1, the last two components (2 and 3) of the above calculation, typically comprise the maintenance re-nourishment volume. i.e. approximately 225,000 m^3 every five years.

However, as previously discussed, the findings of the Stage 2 investigation note that the sediment deficit, over the full active profile between the 1980's and 2018 has been in the order of 112,000m^3/year (Bluecoast, 2020a). On this basis it is proposed that the maintenance nourishment volume be **560,000 m^3 every five years**. For the placement of sand from a marine source the following is noted:

- It is assumed a marine source would typically be compatible with the native sand and as such an overfill ratio has not been included. The total nourishment volume required would therefore be approximately **610,000 m^3 initially and 560,000 m^3 every 5 years thereafter (for the marine source).**

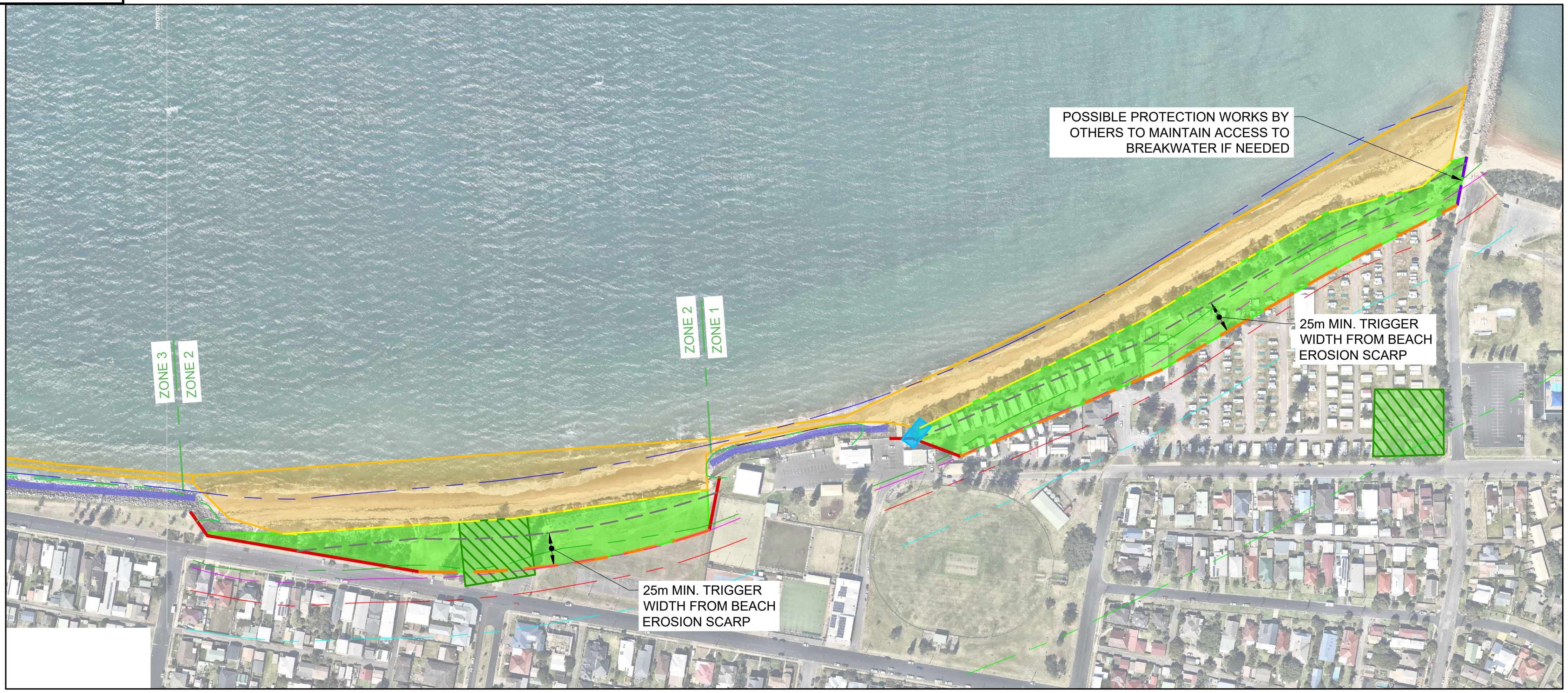
<u>Risks</u>

Option 2 - Sand nourishment for improved beach amenity + coastal terminal protection works, presents a lower risk than Option 1. The risks associated with this option include:

- If more than one design storm occurs within the re-nourishment period, or a storm larger than the design storm occurs, the Stage 2 buried terminal structure would need to be constructed sooner than predicted.
- If sufficient sand supply cannot be sourced when required, beach amenity would not be maintained.
- If the placement rate cannot be achieved, e.g. inclement weather, beach erosion limits access for trucks and plant on beach, etc then beach amenity would not be maintained.
- This option poses minimal risk of impacting downdrift beaches as the proposed nourishment volume approximate the long term losses determined in the Stage 2 Sediment Transport Study (Bluecoast, 2020a).
- Potential Acid Sulphate Soils being exposed through erosion. The Department of Land and Water Conservation Acid Sulfate Soil Risk Map for Newcastle (DLWC, 1997) indicates that the Holiday Park Site is located an area of low probability of occurrence of ASS, 1 to 3 m below ground surface (GHD, 2017). Further soil investigations are required to assess these areas. The Newcastle Local Environmental Plan (LEP) 2012 identifies the site as a Class 3 Acid Sulfate Soil region. The plan stipulates that a development consent is required for the carrying out of works more than 1 meter below the natural ground surface and/or works by which the water table is likely to be lowered more than 1 meter below the natural ground surface.
- Potential contamination seaward of the proposed alignment of the proposed terminal coastal protection structures requiring removal and disposal with associated costs and environmental/social impacts. There is thought to be waste material beneath the carpark at the Monument, directly east of Hereford St in Zone 2. There is also building waste in the form of brickwork and concrete in other parts of Zone 2, which has been exposed in the erosion scarp and on the beach after erosion events. Based on the findings of investigations undertaken to date this risk is considered low in Zone 1 as the only waste material identified was well behind the proposed alignment of the buried terminal structures.

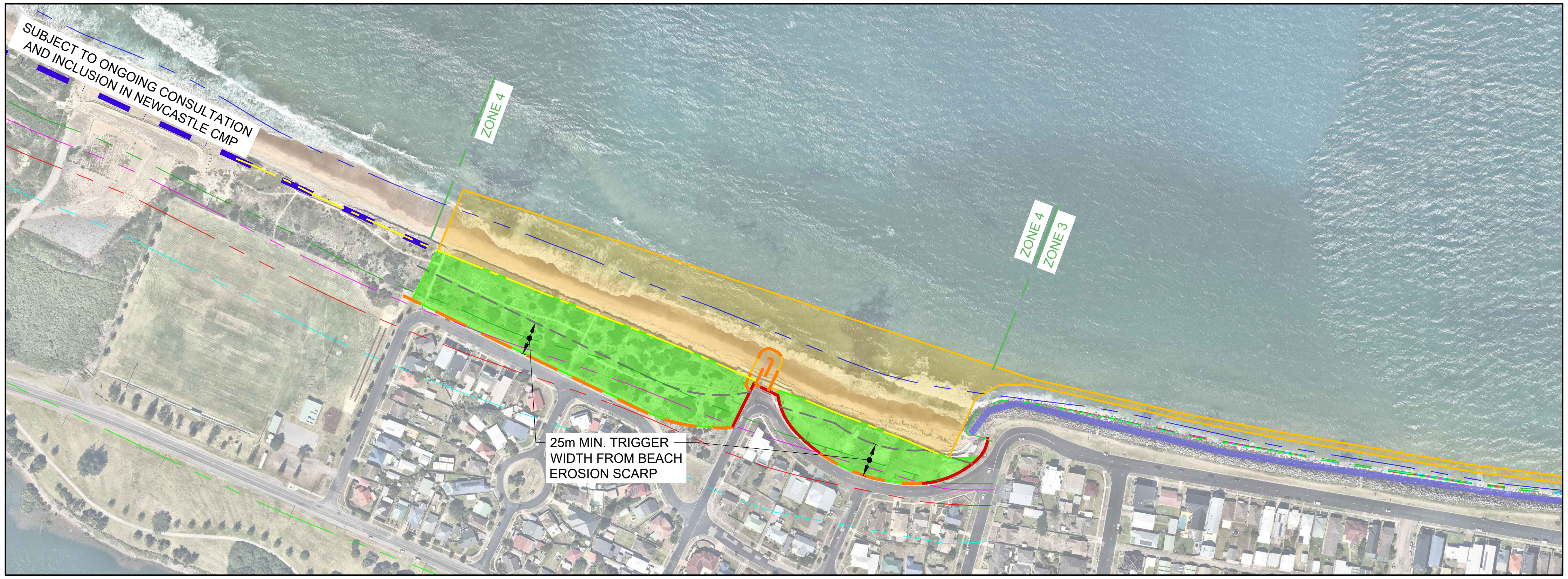
DRAWING No. PA2395-RHD-00-DR-MA-1013 | DO NOT SCALE

FIGURE 6



OPTION 2 (SOUTH)

1:2000 (A1)



OPTION 2 (NORTH)

1:2000 (A1)

LEGEND

- STAGE 1 - BURIED TERMINAL PROTECTION STRUCTURE
- STAGE 2 - BURIED TERMINAL PROTECTION STRUCTURE AND HEADLAND
- APPROX. CREST OF EROSION SCARP FROM 17 FEB 2020 UAV SURVEY (PROVIDED BY NEWCASTLE CITY COUNCIL)
- POTENTIAL WASTE THAT NEEDS TO BE MANAGED
- MAINTAIN EXISTING ROCK REVETMENT
- BEACH NOURISHMENT FOR AMENITY
- POSSIBLE VEHICLE BEACH ACCESS RAMP
- ADAPTIVE ENVIRONMENTAL AND RECREATIONAL LAND USE AREA
- 2018-2020 MSL (0m AHD)
- 2020 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2025 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020))
- 2040 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2060 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2120 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)

REV	DATE	DESCRIPTION	BY	CHK	APP
C	14.04.2020	RE-ISSUED FOR REVIEW	BR	NP	AT
B	07.04.2020	RE-ISSUED FOR REVIEW	BR	NP	AT
A	03.04.2020	ISSUED FOR REVIEW	BR	NP	AT

REVISIONS

CLIENT: City of Newcastle

PROJECT: STOCKTON CMP

TITLE: COASTAL MANAGEMENT OPTION 2

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DRAWN	COORD. SYSTEM	DATUM	DATE
-	MGA ZONE 56	AHD	14.04.2020

SCALE AT A1: AS SHOWN | REF.: PA2395-RHD-00-M3-MA-1001

DRAWING No.: PA2395-RHD-00-DR-MA-1013 | REVISION: C

40 0 40 80 120 160 200m

1:4000 (A3) 1:2000 (A1)

AUSTRALIAN HEIGHT DATUM

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5 Option 3 – Sand nourishment to maintain beach amenity + terminal coastal protection works

General Description

Option 3a involves beach nourishment of a volume limited to what is logistically feasible using terrestrial sources of sand (i.e. less volume than considered in Option 2 using terrestrial sources), to reduce (but not prevent) future loss of beach amenity. As in Option 2, this option also includes construction of buried terminal protection structures, constructed in two stages, to address the current and future risk of potentially high consequence, low probability events that may affect the area (mandatory requirement 13, Coastal Management Manual Part A).

Option 3a comprises the following components:

- ongoing maintenance of existing rock revetment structures at the Stockton SLSC and Mitchell St;
- Stage 1 buried terminal coastal protection structures are to be built in the short term to protect the following assets at risk within the next 5 years (in accordance with established 2025 hazard lines):
    - the flanks of all of the existing rock structures,
    - roadways; and
    - residential assets,
- Stage 2 buried terminal coastal protection structures set back at the established hazard lines to be constructed if/when minimum foreshore width triggers are reached;
- Stage 2 small rock headland at the end of Griffiths Ave to protect the road head and create a stable embayment within the Barrie Cres. frontage to be constructed if/when minimum foreshore width triggers are reached; and
- sand nourishment for the full extent of the CMP area (Breakwater to Meredith St) to reduce future loss of beach amenity which, rather than target a specific beach width objective (as in Option 2), is an annual volume that has been calculated to be the realistic, logistically feasible quantity of sand that can be placed on the beach from terrestrial sources using trucks and dozers.

Refer to ***Figure 7*** for layout of Option 3a, and **Appendix C** for breakdown of estimated costs and timing. The rationale behind this option and further detail of each component is provided below.

Rationale

The objective of Option 3a is to provide as much beach nourishment as physically and logistically possible from terrestrial sources (as the only currently permissible source) whilst ensuring assets at risk by 2025 are protected by buried terminal coastal protection structures (refer 2025 hazard lines). The amount of sand nourishment in Option 3a is less than that in Option 2 (or 1) as it aims to eliminate constraints for terrestrial sand sources identified in the previous options, such as:

- availability of sand from local quarry sources;
- community acceptance of social/environmental/noise/traffic impacts of trucking movements and disruption of beach use during placement operations;
- cost; and
- physical and logistical constraints on the amount of additional sand that can be placed on the beach at any one time without creating public safety issues.

The rationale behind the combination of buried terminal coastal protection and beach nourishment in Option 3a is to maintain the beach's current levels of resilience and capacity to accommodate coastal processes and avoid loss of beach amenity whilst ensuring assets are protected.

The total sand volume that could be physically accommodated on the beach each year is approximately 200,000 m^3. However, based on the adopted overfill ratio of 2.5, the quantity of terrestrial sand effectively retained for nourishment on Stockton Beach is around 80,000 m^3 per year. This volume has been derived on the basis of the following key assumptions:

- CN could secure 20% of the licensed extraction limits from each of the local quarries;
- quarry material from each site is 'compatible', with an average overfill factor of 2.5;
- shoreline length that could accommodate truck movements = 1,500 m (i.e. revetment shorelines excluded due to insufficient beach width for safe plant access);
- max. depth of placement in a single campaign = 1 m to avoid excessively high vertical scarps forming in newly placed sand and ensuring public safety;
- average beach width = 30 to 35 m, therefore, max. volume that could be physically accommodated on the beach in a single campaign = 50,000 m^3;
- three project sites would operate alternately to distribute trucking movements and manage amenity impacts, as follow:
    - Holiday Park frontage with access via existing King St ramp,
    - Dalby Oval via newly constructed beach access from Dalby oval, and
    - Stone St to Meredith St frontage via newly constructed beach access from Meredith St,
- each of the three project sites would have four campaigns per year of 50,000 m^3 per campaign, which is (on average) ~17,000 m^3 per project site per campaign;
- each 17,000 m^3 'sub-campaign' could be completed in 4 weeks, working at the same trucking rate as per December 2019 Pilot Study; and
- works could be scheduled to avoid school holidays.

It is noted that these values are consistent with the sand quantities available from local quarries.

Further background information and detail regarding the development of the feasible terrestrial based nourishment can be found in **Appendix E.**

For the CBA Option 3 involves placement of **200,000m^3 on the subaerial beach each year.** Timing of works is provided in cost estimates in **Appendix C.**

Case 3b – Nominal sand nourishment to reduce ongoing loss of beach amenity + terminal protection

General Description

Option 3b involves beach nourishment of a volume limited to what is logistically and economically feasible using terrestrial sources of sand (i.e. less volume than considered in Option 2 using terrestrial sources), to reduce (but not prevent) future loss of beach amenity. As in Option 2, this option also includes construction of buried terminal coastal protection structures, constructed in two stages, to address the current and future risk of potentially high consequence, low probability events that may affect the area (mandatory requirement 13, Coastal Management Manual Part A).

Relative to Option 3a, the extent of the Stage 1 coastal protection works has been reduced with more works delayed until Stage 2 to reduce initial capital costs. This also has the benefit of providing time for alternative coastal management strategies to potentially become feasible, such as larger nourishment campaigns using marine sand sources, which could eliminate the need for the Stage 2 terminal protection works.

Option 3b comprises the following components:

- ongoing maintenance of existing rock revetment structures at the Stockton SLSC and Mitchell St;
- reduced Stage 1 buried terminal coastal protection structures are to be built in the short term to provide a degree of protection to assets including (refer ***Figure 8*** for extent of protected assets):
    - the flanks of all of the existing rock structures;
    - roadways; and
    - residential assets.
- Stage 2 buried terminal coastal protection structures set back at the established hazard lines to be constructed if/when minimum foreshore width triggers are reached, with trigger widths optimised relative to Option 3a to further delay Stage 2 works;
- sand nourishment for the full extent of the CMP area (northern breakwater to Meredith St) to reduce future loss of beach amenity, which, rather than a specific beach width objective (as in Option 2), is an annual volume that has been calculated to be the logistically and economically feasible quantity of sand that can be placed on the beach from terrestrial sources using trucks and dozers.

Refer to ***Figure 8*** for layout of Option 3b, and **Appendix D** for breakdown of estimated costs and timing. The rationale behind this option and further detail of each component is provided below.

Rationale

The objective of Option 3b is to provide as much beach nourishment as logistically and economically possible from terrestrial sources (as the only currently permissible source) whilst providing terminal coastal protection to assets seaward of the Zone of Slope Adjustment (ZSA) for a 5% Annual Exceedance Probability (AEP) within the next 5 years (in accordance with established 2025 hazard lines (Bluecoast, 2020)):

However, the cost of terrestrial sourced sand would require a $16 million p.a. commitment to implement and sustain the 200,000m^3 p.a. volume proposed in Option 3a. This is understood to be beyond CN funding capacity. Accordingly, the nourishment volume considered for the **CBA Option 3b involves an initial placement of 50,000m^3** on the subaerial beach in year 1 at a cost of **$4 million**. Based on the adopted overfill ratio for terrestrial sand sources of 2.5, the 50,000m^3 p.a. would effectively provide the equivalent of 20,000m^3 of native sand on the beach.

The extent of the Stage 1 terminal coastal protection works in Option 3b has been reduced relative to Option 3a. The rationale behind this reduction is to reduce (or delay) capital cost to make this option more economically feasible and to broaden the window of opportunity for an alternative coastal management option to become feasible, such as, marine sourced sand nourishment, that would eliminate the need for the Stage 2 terminal protection works to be constructed.

The reduced Stage 1 works provide coastal protection to assets seaward of the Zone of Slope Adjustment (ZSA) for a 5% Annual Exceedance Probability (AEP) within the next 5 years (rather than assets seaward of the Zone of Reduced Foundation Capacity for the 1% AEP in the next 5 years (in accordance with the 2025 hazard lines in (Bluecoast, 2020)).

CN have advised that under Option 3b they would not provide protection to the Barrie Cres./Griffiths Ave intersection road head, but rather create cul-de-sacs at the northern end of Barrie Cres and the eastern end of Griffiths Ave to maintain access to all residences. Stage 2 works would include a terminal coastal protection structure protecting a 4m wide pedestrian pathway adjacent to the residential property boundary in this location (refer ***Figure 8***).

CN have advised acceptance of a reduction in the trigger widths for implementation of the Stage 2 terminal coastal protection works in Option 3b from 25m (in Option 3a) to 20m, and the subsequent increase in risk. Accordingly, the trigger width for the Stage 2 works has been reduced to 20m and provides a minimum sand volume seaward of assets, approximately equivalent to the storm erosion demand of an 8 year ARI event. Assuming it would take a maximum of 3 years from triggering the need for the terminal protection works to completing them, there would be about a 33% chance of an 8 year ARI event occurring in the 3 year construction period putting assets at risk prior to completion of the coastal protection structures.

If the structures can be completed within a shorter timeframe, the probability of the storm event occurring and assets being at risk reduces, e.g. there is a 24% chance of the 8 year ARI event occurring in a 2 year period. For this reason, it is recommended that preparations be undertaken to allow this protection to be implemented with expediency once triggers are reached. CN has acknowledged and accepted this level of risk.

The estimated annual long-term sand deficit (for the full sub aerial and sub aqueous profile) noted in the Stage 2 Sediment Transport Study (Bluecoast, 2020) for this portion of the Stockton embayment was approx. 112,000m^3/year in the three decades. The effective volume of 20,000m^3 placed annually on the aerial beach does not match these losses and may therefore only produce short term maintenance of beach width but would not be sufficient nourishment to counter the ongoing losses. Option 3b would therefore result in loss of amenity and potentially lead to impacts on the downdrift coastline in the long term . Accordingly, it is recommended that this option be considered a short-term option only, with a view to **upgrading to Option 2 (or Option 1 if sufficient sand and funding are available)** when a more cost-effective marine source of sand becomes available. This is explored further in the sensitivity analysis outlined below.

Option 3 - Sensitivity Analysis

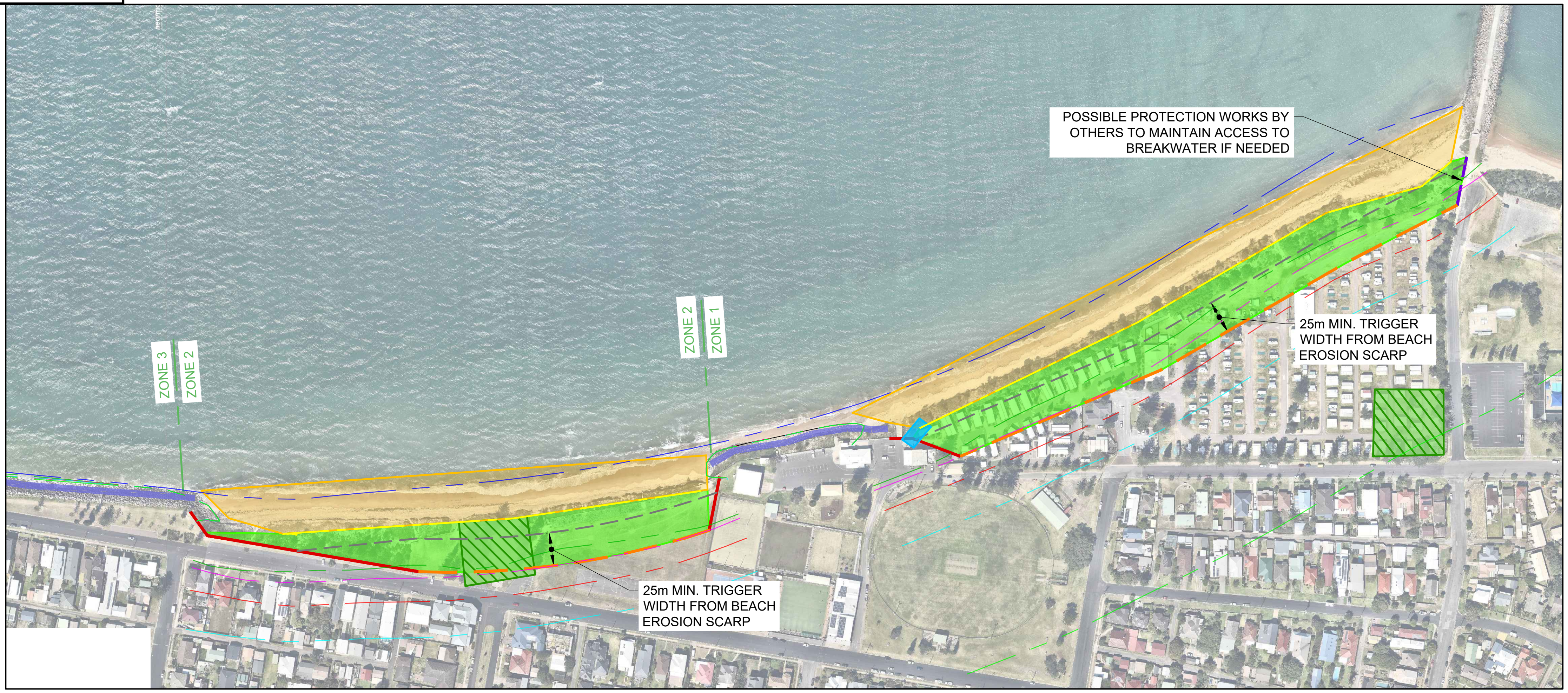
As noted previously, the amount of nourishment that is economically viable from terrestrial sources is not sufficient to offset ongoing losses of sand. As a result, there is likely to be continued loss of beach amenity and eventual impacts on the adjacent coastline to the north if Option 3 were implemented beyond the short term. Accordingly, it is recommended that the CBA assess a combined approach comprising Option 3b for the first year followed by a mass nourishment strategy from marine sources (Option 1b) in year 2 and for the remaining 49 years of the project life. In this scenario only the reduced Stage 1 terminal coastal protection works would be implemented and the Stage 2 terminal coastal protection works are assumed to be eliminated. This may identify a potential strategy that is technically and economically feasible in the short and longer term that would also be acceptable to the local community.

This option is termed **Option 1d.**

DRAWING No. PA2395-RHD-00-DR-MA-1014

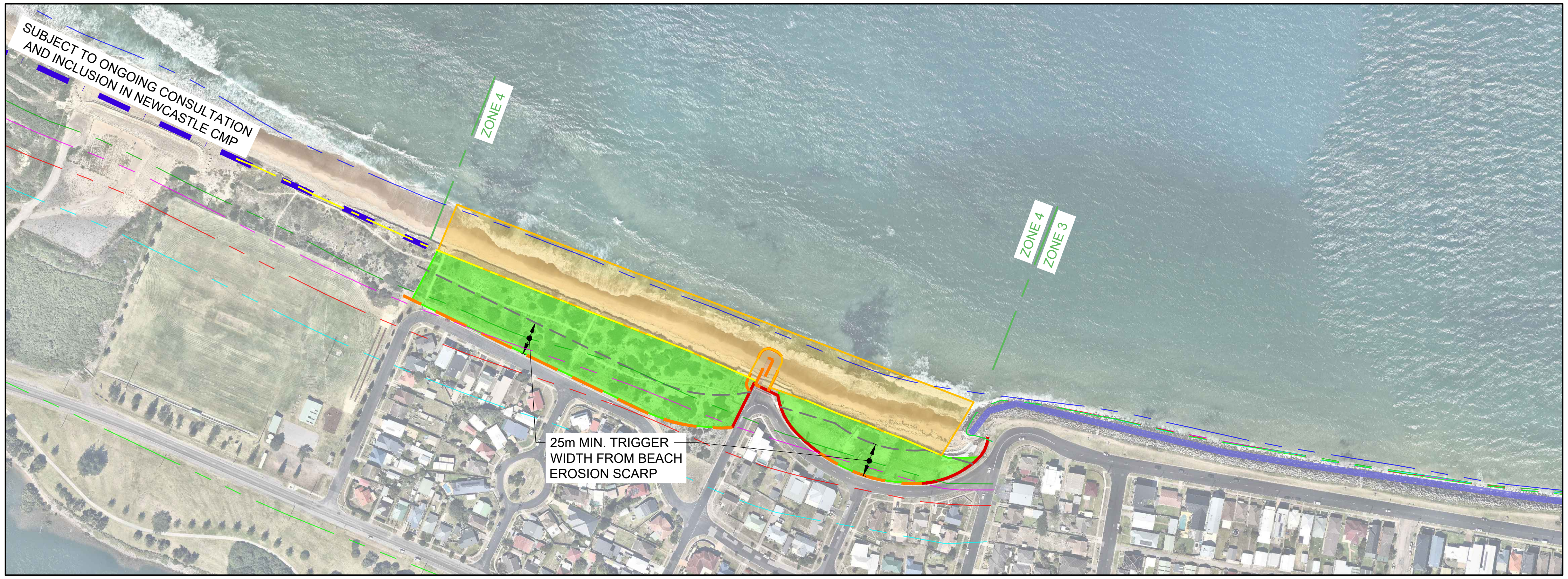
DO NOT SCALE

FIGURE 7



OPTION 3 (SOUTH)

1:2000 (A1)



OPTION 3 (NORTH)

1:2000 (A1)

LEGEND

- STAGE 1 - BURIED TERMINAL PROTECTION STRUCTURE
- STAGE 2 - BURIED TERMINAL PROTECTION STRUCTURE AND HEADLAND
- APPROX. CREST OF EROSION SCARP FROM 17 FEB 2020 UAV SURVEY (PROVIDED BY NEWCASTLE CITY COUNCIL)
- POTENTIAL WASTE THAT NEEDS TO BE MANAGED
- MAINTAIN EXISTING ROCK REVETMENT
- BEACH NOURISHMENT FOR AMENITY
- POSSIBLE VEHICLE BEACH ACCESS RAMP
- ADAPTIVE ENVIRONMENTAL AND RECREATIONAL LAND USE AREA
- 2018-2020 MSL (0m AHD)
- 2020 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2025 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2040 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2060 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2120 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)

DIAL BEFORE YOU DIG www.1100.com.au

AUSTRALIAN HEIGHT DATUM

40 0 40 80 120 160 200m

1:4000 (A3) 1:2000 (A1)

REV	DATE	DESCRIPTION	BY	CHK	APP
B	14.04.2020	RE- ISSUED FOR REVIEW	BR	NP	AT
A	08.04.2020	ISSUED FOR REVIEW	BR	NP	AT

REVISIONS

CLIENT: City of Newcastle

PROJECT: STOCKTON CMP

TITLE: COASTAL MANAGEMENT OPTION 3 a

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DRAWN	COORD. SYSTEM	DATUM	DATE
-	MGA ZONE 56	AHD	14.04.2020

SCALE AT A1: AS SHOWN | REF.: PA2395-RHD-00-M3-MA-1001

DRAWING No. PA2395-RHD-00-DR-MA-1014 | REVISION B

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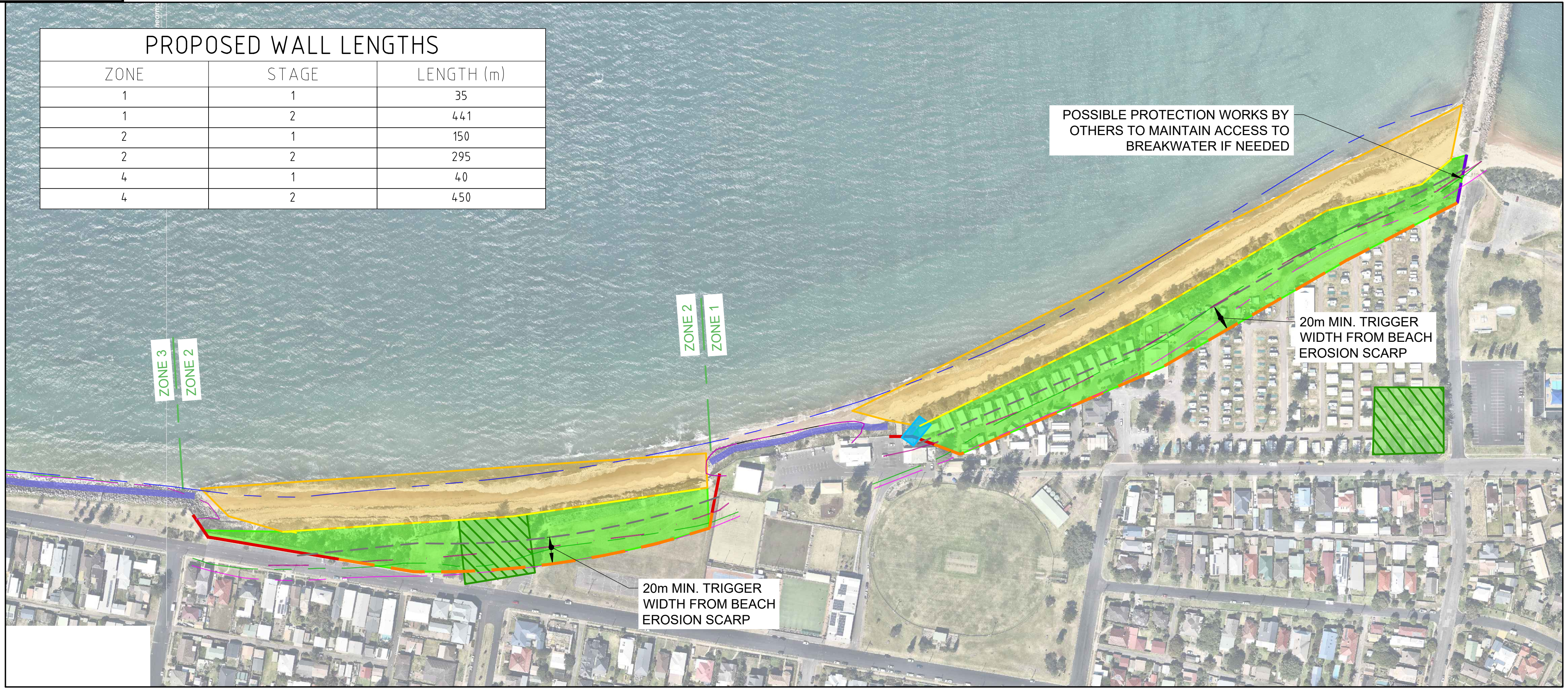
DRAWING No. PA2395-RHD-00-DR-MA-1014

DO NOT SCALE

FIGURE 8

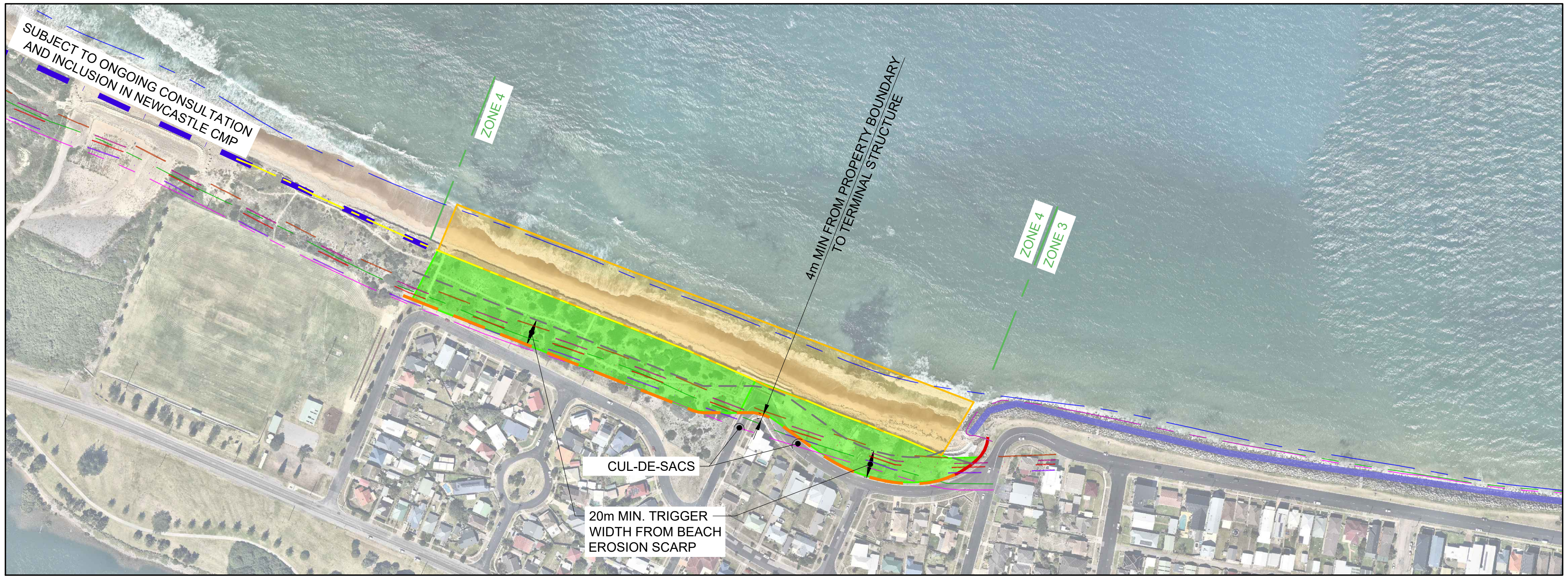
PROPOSED WALL LENGTHS

ZONE	STAGE	LENGTH (m)
1	1	35
1	2	441
2	1	150
2	2	295
4	1	40
4	2	450



OPTION 3 (SOUTH)

1:2000 (A1)



OPTION 3 (NORTH)

1:2000 (A1)

LEGEND

- STAGE 1 - BURIED TERMINAL PROTECTION STRUCTURE
- STAGE 2 - BURIED TERMINAL PROTECTION STRUCTURE AND HEADLAND
- APPROX. CREST OF EROSION SCARP FROM 17 FEB 2020 UAV SURVEY (PROVIDED BY NEWCASTLE CITY COUNCIL)
- POTENTIAL WASTE THAT NEEDS TO BE MANAGED
- MAINTAIN EXISTING ROCK REVETMENT
- BEACH NOURISHMENT FOR AMENITY
- POSSIBLE VEHICLE BEACH ACCESS RAMP
- ADAPTIVE ENVIRONMENTAL AND RECREATIONAL LAND USE AREA
- 2018-2020 MSL (0m AHD)
- 2020 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2025 ZONE OF REDUCED FOUNDATION CAPACITY HAZARD LINE (BLUECOAST 2020)
- 2025 ZONE OF SLOPE ADJUSTMENT HAZARD LINE 5% (AEP)

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AUSTRALIAN HEIGHT DATUM

40 0 40 80 120 160 200m

1:4000 (A3) 1:2000 (A1)

REV	DATE	DESCRIPTION	BY	CHK	APP
C	21.04.2020	RE- ISSUED FOR REVIEW	BR	NP	AT
B	14.04.2020	RE- ISSUED FOR REVIEW	BR	NP	AT
A	08.04.2020	ISSUED FOR REVIEW	BR	NP	AT

REVISIONS

CLIENT: City of Newcastle

PROJECT: STOCKTON CMP

TITLE: COASTAL MANAGEMENT OPTION 3b

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DRAWN	COORD. SYSTEM	DATUM	DATE
-	MGA ZONE 56	AHD	21.04.2020

SCALE AT A1: AS SHOWN

REF. PA2395-RHD-00-M3-MA-1001

DRAWING No. PA2395-RHD-00-DR-MA-1014

REVISION C

C:\USERS\220068\BOX\PA2395 STOCKTON CMP\PA2395 STOCKTON CMP TEAM\PA2395 TECHNICAL DATA\E11 WORKING DRAWINGS\PA2395-RHD-00-M3-MA-1001

Summary

A summary of the Options and nourishment quantities is provided below.

Option	Sub-option	Description	Sand Source	Initial nourishment vol (m^3)	Maintenance nourishment vol (m^3)	Maintenance nourishment frequency (years)
1	1a	Mass nourishment for protection + amenity, limited coastal protection works	Terrestrial**	4.5 million*	1.4 million*	5 years
	1b		Marine offshore	2.4 million	1.12 million	10 years
	1c		Hunter River	1.8 million	560,000	5 years
	1d	Option 3b for year 1 followed by Option 1b in year 2	Terrestrial** and marine	50,000 2.4 million	1.12 million	10 years
2	2a	Sand nourishment for improved beach amenity (5m width) + staged terminal protection	Terrestrial**	525,000*	280,000*	annual
	2b	Sand nourishment for improved beach amenity (5m width +1 yr ARI storm) + staged terminal protection	Marine offshore	610,000	560,000	5 years
	2c		Hunter River	610,000	560,000	5 years
3	3a	Sand nourishment to maintain beach amenity (feasible terrestrial volume) + staged terminal protection	Terrestrial**	200,000	200,000	annual
	3b	Sand nourishment to maintain beach amenity (affordable terrestrial volume) + staged terminal protection	Terrestrial**	50,000	50,000	annual

* exceeds volume from terrestrial sources that can feasibly be placed on the subaerial beach by trucking.

** an overfill factor of 2.5 has been adopted based on quarry investigations and a sensitivity analysis is recommended to assess an overfill factor of 1.

Sensitivity Analysis

The supply and place cost rate for terrestrial quarry sourced sand for the small (5,664 m^3) Pilot Study beach nourishment campaign at the Holiday Park in December 2019 was $100/$m^3$. This rate has been adopted with a 20% discount for the CBA cost estimates to account for economies of scale i.e. $80/$m^3$. A sensitivity analysis is recommended to assess the impact on CBA outcomes of the following:

- a further reduction of the sand cost rate to $50/$m^3$; and
- elimination of the overfill factor (i.e. overfill factor of 1).

References

Bluecoast, 2020, Stockton Beach coastal erosion hazard assessment, Report #: P19028_R02, 7 May 2020

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GHD, 2017, Stage 1 Preliminary Site Investigation for Stockton Beach Holiday Park, Stockton NSW prepared for Newcastle City Council

Hallermeier, 1981, Seaward Limit of Significant Sand Transport by Waves: An annual Zonation for Seasonal profiles, US Army Corp of Engineers, Coastal Engineering Technical Aid No 81-2, January 1981.

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WRL, 2017, Guidelines for Sand Nourishment. WRL Research Report 263. J T Carley and R J Cox.

ATTACHMENT A

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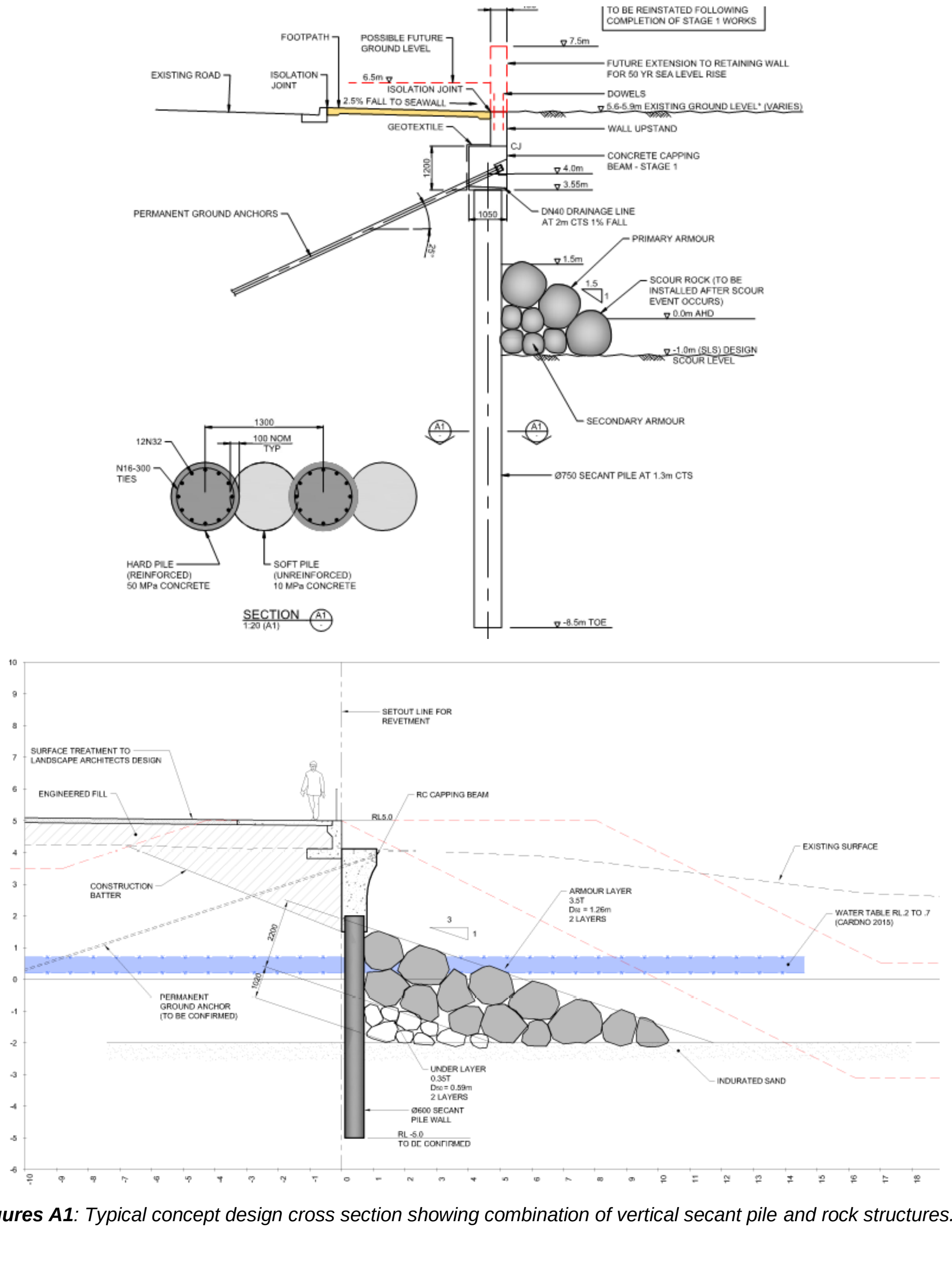

Figures A1*: Typical concept design cross section showing combination of vertical secant pile and rock structures.*

Appendix A – Cost Estimates for Option 1

Royal HaskoningDHV
Enhancing Society Together

Stockton CMP

Prepared By: N Patterson
Checked By: G Blumberg

Cost Estimate for CBA
Option 1 - Beach Nourishment for coastal protection

Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE SAND VOLUME (m3)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment (based on terrestrial source)**						**356,500,000**				
1.1a	Beach nourishment with sand from terrestrial sources placed constantly throughout year on subaerial beach	Based on costs from sand placement pilot study (Dec 2019) undertaken by SCS, as provided by Council, reduced by 20% for economies of scale	m3	4,400,000	80	352,000,000		1	1,400,000	112,000,000	every 5 years
	Beach nourishment with sand from commercial terrestrial sources transported to pumping station near Corroba Oval (20 x 30m area) and pumped via buried pipeline onto subaerial beach to Dalby Oval beach frontage constantly throughout year	Trial diesel system set up for 5 year contract with 100,000m3/year capacity (RH, 2018). Ongoing cost reduced as sand shifter not required.	capital cost item	1	2,000,000	2,000,000		1		1,200,000	yearly
		Sand from commercial terrestrial source delivered to Corroba Oval (based on pilot study)	m3	100,000	25	2,500,000		1	100,000	2,500,000	yearly
1.1b	**Alternative (b) for sensitivity testing**						**30,600,000**				
	Beach nourishment with sand sourced from offshore dredging within 7.5 nautical miles over 5 year period (with initial campaign then 5 year frequency)	1.8 million m3 initial campign and 1 million m3 maintenance nourishment every 5 years. Based on Trailing Suction Hopper Dredge (TSHD) . Rate of $19/m3 used for maintenance campaign (conservatively estimated between rates for 500,000m3 and 2,000,000m3 rates).	m3	1,800,000	17	30,600,000		1	560,000	19,000,000	every 5 years
1.1c	**Alternative (c) for sensitvity testing**						**45,000,000**				
	Beach nourishment with sand sourced from dredging within Hunter River eg. potential Gasdock project (with initial campaign then 5 year frequency)	1.8 million m3 initial campign and 1 million m3 maintenance nourishment every 5 years. Based on cutter suction dredge. Rate of $30/m3 used for maintenance campaign (conservatively estimated between rates for 500,000m3 and 2,000,000m3 rates).	m3	1,800,000	25	45,000,000		1	560,000	30,000,000	every 5 years

Disclaimer

The reader should note that cost estimate presented here is based on Royal HaskoningDHV's experience and judgement as a firm of practising professional engineers familiar with the coastal and maritime construction industry. It includes construction costs only and no allowance is made for contingencies. It would be reasonable to apply an average contingency of up to 40% for design development uncertainty and unforseen and uncontrollable items, such as those relating to ground and weather conditions.

The quantities used to develop the cost estimate have been gauged from typical concept arrangements and planform measurements made using available mapping and high level aerial photography.

The construction cost estimate can NOT be guaranteed as RHDHV have no control over Contractor's prices, market forces and competitive bids from tenderers. The cost estimate is for CONSTRUCTION ONLY and excludes items which should be considered in a cost plan such as site investigation fees, environmental assessment fees, design and tendering fees, project management fees, authority approval and permitting fees, and construction site supervision, works certification and administration fees.

Stockton CMP

Cost Estimate for CBA
Option 1 - Zone 1

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT ($)	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Vertical Structures**						**1,400,000**			
2.1	Secant pile wall (including capping beam and ground anchors)	Based on construction cost for Kingscliff Project and Rawlinsons	m	56	20,000	1,120,000		1	56,000	every 5 years
2.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for limited profile)	m	56	5,000	280,000		1	14,000	every 5 years
3	**Maintenance of SLSC revetment**	Current proposed repair works are included in Base Case and therefore not included here.	m	140	2,000	0	**0**		170,000	every 4 years

Stockton CMP

Cost Estimate for CBA
Option 1 - Zone 2

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Vertical Structures**						**5,600,000**			
2.1	Secant pile wall (including capping beam and ground anchors)	Based on construction cost for Kingscliff Project and Rawlinsons	**m**	224	20,000	4,480,000		1	224,000	every 5 years
2.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for dry construction)	m	224	5,000	1,120,000		3	56,000	every 5 years
3	**Removal and Disposal of Waste**	Provisional sum in case of discovery of General Solid Waste. No information available on quantities. Progressive removal would be required as it is exposed.	t	100	250	25,000	**25,000**	1	25,000	every 5 years
4	**Removal and disposal of carpark at the Monument**	Rawlinsons	m2	200	90	18,000	**18,000**	3	NA	

Royal HaskoningDHV
Enhancing Society Together

Stockton CMP

Cost Estimate for CBA
Option 1 - Zone 3

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Maintenance of Mitchell St revetment**									
	Current planned maintenance works	Current proposed repair works are included in Base Case and therefore not included here.	item	1	5,000,000		**0**		480,000	every 2 years

Stockton CMP

Cost Estimate for CBA
Option 1 - Zone 4

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Footpaths and roadworks**						**212,500**			
1.1	Close roadway lane and create one way road on Barrie Cres with new kerb		m	200	500	100,000		1	10,000	every 5 years
1.2	New footpath Barrie Cres		m3	150	750	112,500		1	11,250	every 5 years
2	**Vertical Structures**									
							4,900,000			
2.1	Barrie Crescent/Stone/Griffiths Ave secant pile wall and and rock wedge at Mitchell St flank	Based on construction cost for Kingscliff Project/Rawlinsons	**m**	178	20,000	3,560,000		1	178,000	every 5 years
2.2.	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	178	5,000	890,000		3	44,500	every 5 years
2.3	Beach access - Concrete bleachers on piles	Based on construction cost for Kingscliff Project	m	10	45,000	450,000		5	22,500	every 5 years
3	**Remove temporary emergency geocontainer structures**						**75,000**			
3.1	Stone St structure	Sand from geocontainers to be placed on the beach	m	30	1,000	30,000		1	NA	
3.2	Griffiths Ave structure	Sand from geocontainers to be placed on the beach	m	45	1,000	45,000		1	NA	

Appendix B – Cost Estimates for Option 2

Stockton CMP

Cost Estimate for CBA
Option 2 - Beach Nourishment for coastal amenity

Prepared By: N Patterson
Checked By: G Blumberg

Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE SAND VOLUME (m3)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment for amenity (based on terrestrial source)**						**38,500,000**			**18,100,000**	yearly
1.1a	Beach nourishment with sand from commercial terrestrial sources placed by trucks/dozers on subaerial beach at Holiday Park frontage via King St, constantly throughout year.	Based on costs from sand placement pilot study (Dec 2019) undertaken by SCS, as provided by Council, reduced by 20% for economies of scale	m3	425,000	80	34,000,000		1	180,000	14,400,000	yearly
	Beach nourishment with sand from commercial terrestrial sources transported to pumping station near Corroba Oval (20 x 30m area) and pumped via buried pipeline onto subaerial beach to Dalby Oval beach frontage constantly throughout year	Trial diesel system set up for 5 year contract with 100,000m3/year capacity (RH, 2018). Ongoing cost reduced as sand shifter not required.	capital cost item	1	2,000,000	2,000,000		1		1,200,000	yearly
		Sand from commercial terrestrial source delivered to Corroba Oval (based on pilot study)	m3	100,000	25	2,500,000		1	100,000	2,500,000	yearly
1.1b	**Alternative (c) for sensitivity testing (incl. 1 yr ARI storm)**						**11,590,000**				
	Beach nourishment with sand sourced from offshore dredging of sand lobe off Nobbys over 5 year period (with initial campaign then 5 year frequency)	750,000 m3 initial campaign and 1 million m3 maintenance nourishment every 5 years. Based on Trailing Suction Hopper Dredge (TSHD) . Rate of $19/m3 used (conservatively estimated between rates for 500,000m3 and 2,000,000m3 rates).	m3	610,000	19	11,590,000		1	560,000	19,000,000	every 5 years
1.1c	**Alternative (d) for sensitivity testing (incl. 1 yr ARI storm)**						**18,300,000**				
	Beach nourishment with sand sourced from dredging of shipping channel in the south-arm of the Hunter River as part of the potential Gasdock project (with initial campaign then 5 year frequency)	750,000 m3 initial campaign and 1 million m3 maintenance nourishment every 5 years. Based on cutter suction dredge. Rate of $30/m3 used for maintenance campaign (conservatively estimated between rates for 500,000m3 and 2,000,000m3 rates).	m3	610,000	30	18,300,000		1	560,000	30,000,000	every 5 years

Disclaimer

The reader should note that cost estimate presented here is based on Royal HaskoningDHV's experience and judgement as a firm of practising professional engineers familiar with the coastal and maritime construction industry. It includes construction costs only and no allowance is made for contingencies. It would be reasonable to apply an average contingency of up to 40% for design development uncertainty and unforseen and uncontrollable items, such as those relating to ground and weather conditions.

The quantities used to develop the cost estimate have been gauged from typical concept arrangements and planform measurements made using available mapping and high level aerial photography.

The construction cost estimate can NOT be guaranteed as RHDHV have no control over Contractor's prices, market forces and competitive bids from tenderers. The cost estimate is for CONSTRUCTION ONLY and excludes items which should be considered in a cost plan such as site investigation fees, environmental assessment fees, design and tendering fees, project management fees, authority approval and permitting fees, and construction site supervision, works certification and administration fees.

Stockton CMP

Cost Estimate for CBA
Option 2 - Zone 1

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT ($)	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Vertical Structures**									
2.1	**Stage 1**						**1,400,000**			
3.1.1	Secant pile wall (including capping beam and ground anchors)	Based on construction cost for Kingscliff Project and Rawlinsons	**m**	56	20,000	1,120,000		1	56,000	every 5 years
3.1.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for dry construction)	m	56	5,000	280,000		1	14,000	every 5 years
3.2	**Stage 2**						**10,650,000**			
3.2.1	Secant pile wall	Based on construction cost for Kingscliff Project and Rawlinsons	m	420	20,000	8,400,000		9	420,000	every 5 years
3.2.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	420	5,000	2,100,000		10	105,000	every 5 years
3.2.3	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		10	7,500	every 5 years
4	**Relocation of Holiday Park Assets behind seawall**	New amenities block timing will depend on conditions and nourishment behaviour	item	1	500,000	500,000	**500,000**	3	NA	NA
5	**Maintenance of SLSC revetment**	Based on current estimates for maintenance works	m	140	2,000		**0**	1	144,000	every 4 years

Royal HaskoningDHV
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Stockton CMP

Cost Estimate for CBA
Option 2 - Zone 2

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Vertical Structures**									
2.1	**Stage 1**						**5,600,000**			
3.1.1	Secant pile wall (including capping beam and ground anchors)	Based on construction cost for Kingscliff Project and Rawlinsons	**m**	224	20,000	4,480,000		1	224,000	every 5 years
3.1.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for dry construction)	m	224	5,000	1,120,000		1	56,000	every 5 years
3.2	**Stage 2**						**5,725,000**			
3.2.1	Secant pile wall	Based on construction cost for Kingscliff Project and Rawlinsons	m	223	20,000	4,460,000		9	223,000	every 5 years
3.2.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	223	5,000	1,115,000		10	55,750	every 5 years
3.2.3	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		10	7,500	every 5 years
4	**Removal and Disposal of Waste**	Provisional sum in case of discovery of General Solid Waste. No information available on quantities. Progressive removal would be required as it is exposed.	t	100	250	25,000	**25,000**	1	25,000	every 5 years
5	**Removal and disposal of carpark at the Monument**	Rawlinsons	m2	200	90	18,000	**18,000**	3	NA	

Stockton CMP

Cost Estimate for CBA
Option 2 - Zone 3

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING (YEARS)
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Maintenance of SLSC revetment**									
	Current planned maintenance works	Current planned works. Based on current estimates for maintenance works	item					1	$500,000	every 2 years

Stockton CMP

Cost Estimate for CBA
Option 2 - Zone 4

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Footpaths and roadworks**						**212,500**			
1.1	Close roadway lane and create one way road on Barrie Cres with new kerb		m	200	500	100,000		1	**10,000**	every 5 years
1.2	New footpath Barrie Cres		m3	150	750	112,500		1	**11,250**	every 5 years
2	**Stage 2- Headland Structure**						**2,250,000**			
2.1	**Griffiths Avenue**	Based on Contructed cost of Stockton SLSC seawall (factored for wet construction)	**m**	75	30,000	2,250,000		5	**225,000**	every 5 years
3	**Vertical Structures**									
	Stage 1						**4,900,000**			
3.1	Barrie Crescent/Stone St/Griffiths Ave secant pile wall and and rock wedge at Mitchell St flank	Based on construction cost for Kingscliff Project/Rawlinsons	**m**	178	20,000	3,560,000		1	**178,000**	every 5 years
3.1.1	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	178	5,000	890,000		3	**44,500**	every 5 years
3.1.2	Beach access - Concrete bleachers on piles	Based on construction cost for Kingscliff Project	m	10	45,000	450,000		5	**22,500**	every 5 years
	Stage 2						**8,950,000**			
3.2	Griffiths Ave/Eames Avenue secant pile wall	Based on construction cost for Kingscliff Project	**m**	352	20,000	7,040,000		5	**352,000**	every 5 years
3.2.1	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	352	5,000	1,760,000		8	**88,000**	every 5 years
3.1.2	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		10	**7,500**	every 5 years
4	**Remove temporary emergency geocontainer structures**						**75,000**			
4.1	Stone St structure	Sand from geocontainers to be placed on the beach	m	30	1,000	30,000				
4.2	Griffiths Ave structure	Sand from geocontainers to be placed on the beach	m	45	1,000	45,000				

Appendix C – Option 3a Cost Estimate

Royal HaskoningDHV
Enhancing Society Together

Stockton CMP

Cost Estimate for CBA
Option 3a - Beach Nourishment for coastal amenity

Prepared By: N Patterson
Checked By: G Blumberg

Date Issued: 01/05/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment (based on terrestrial source)**						**16,000,000**			
1.1a	Beach nourishment with sand from commercial terrestrial sources placed by trucks/dozers on subaerial beach at Holiday Park frontage via King St, constantly throughout year.	Based on costs from sand placement pilot study (Dec 2019) undertaken by SCS, as provided by Council, reduced by 20% for economies of scale	m3	200,000	80	16,000,000		1	16,000,000	yearly
	Disclaimer									

The reader should note that cost estimate presented here is based on Royal HaskoningDHV's experience and judgement as a firm of practising professional engineers familiar with the coastal and maritime construction industry. It includes construction costs only and no allowance is made for contingencies. It would be reasonable to apply an average contingency of up to 40% for design development uncertainty and unforseen and uncontrollable items, such as those relating to ground and weather conditions.
The quantities used to develop the cost estimate have been gauged from typical concept arrangements and planform measurements made using available mapping and high level aerial photography.
The construction cost estimate can NOT be guaranteed as RHDHV have no control over Contractor's prices, market forces and competitive bids from tenderers. The cost estimate is for CONSTRUCTION ONLY and excludes items which should be considered in a cost plan such as site investigation fees, environmental assessment fees, design and tendering fees, project management fees, authority approval and permitting fees, and construction site supervision, works certification and administration fees.

Stockton CMP

Cost Estimate for CBA
Option 3a - Zone 1

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 01/05/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT ($)	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Vertical Structures**									
2.1	**Stage 1**						**1,400,000**			
3.1.1	Secant pile wall (including capping beam and ground anchors)	Based on construction cost for Kingscliff Project and Rawlinsons	**m**	56	20,000	1,120,000		1	56,000	every 5 years
3.1.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for dry construction)	m	56	5,000	280,000		1	14,000	every 5 years
3.2	**Stage 2**						**10,650,000**			
3.2.1	Secant pile wall	Based on construction cost for Kingscliff Project and Rawlinsons	m	420	20,000	8,400,000		7	420,000	every 5 years
3.2.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	420	5,000	2,100,000		9	105,000	every 5 years
3.2.3	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		9	7,500	every 5 years
4	**Relocation of Holiday Park Assets behind seawall**	New amenities block timing will depend on conditions and nourishment behaviour	item	1	500,000	500,000	**500,000**	3	NA	NA
5	**Maintenance of SLSC revetment**	Based on current estimates for maintenance works	m				**0**	1	144,000	every 4 years

Royal HaskoningDHV
Enhancing Society Together

Stockton CMP

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 01/05/2020

Cost Estimate for CBA
Option 3a - Zone 2

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Vertical Structures**									
2.1	**Stage 1**						**5,600,000**			
3.1.1	Secant pile wall (including capping beam and ground anchors)	Based on construction cost for Kingscliff Project and Rawlinsons	**m**	224	20,000	4,480,000		1	224,000	every 5 years
3.1.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for dry construction)	m	224	5,000	1,120,000		1	56,000	every 5 years
3.2	**Stage 2**						**5,725,000**			
3.2.1	Secant pile wall	Based on construction cost for Kingscliff Project and Rawlinsons	m	223	20,000	4,460,000		7	223,000	every 5 years
3.2.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	223	5,000	1,115,000		9	55,750	every 5 years
3.2.3	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		9	7,500	every 5 years
4	**Removal and Disposal of Waste**	Provisional sum in case of discovery of General Solid Waste. No information available on quantities. Progressive removal would be required as it is exposed.	t	100	250	25,000		1	25,000	every 5 years
5	**Removal and disposal of carpark at the Monument**	Rawlinsons	m2	200	90	18,000		3	NA	

Stockton CMP

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 01/05/2020

Cost Estimate for CBA
Option 3a - Zone 3

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST AND TIMING	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Maintenance of SLSC revetment**									
	Current planned maintenance works	Current planned works. Based on current estimates for maintenance works	item					1	$500,000	every 2 years

Royal HaskoningDHV
Enhancing Society Together

Stockton CMP

Cost Estimate for CBA
Option 3a - Zone 4

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 01/05/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Footpaths and roadworks**						**212,500**			
1.1	Close roadway lane and create one way road on Barrie Cres with new kerb		m	200	500	100,000		1	**10,000**	every 5 years
1.2	New footpath Barrie Cres		m3	150	750	112,500		1	**11,250**	every 5 years
2	**Stage 2 - Headland Structure**						**2,250,000**			
2.1	**Griffiths Avenue**	Based on Contructed cost of Stockton SLSC seawall (factored for wet construction)	**m**	75	30,000	2,250,000		4	**225,000**	every 5 years
3	**Vertical Structures**									
	Stage 1						**4,950,000**			
3.1	Barrie Crescent/Stone St/Griffiths Ave secant pile wall and and rock wedge at Mitchell St flank	Based on construction cost for Kingscliff Project/Rawlinsons	**m**	178	20,000	3,560,000		1	**178,000**	every 5 years
3.1.1	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	178	5,000	890,000		3	**44,500**	every 5 years
3.1.2	Beach access - Concrete bleachers on piles	Based on construction cost for Kingscliff Project	m	10	50,000	500,000		5	**25,000**	every 5 years
	Stage 2						**8,950,000**			
3.2	Barrie Cres/Griffiths Ave/Eames Avenue secant pile wall	Based on construction cost for Kingscliff Project	**m**	352	20,000	7,040,000		4	**352,000**	every 5 years
3.2.1	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	352	5,000	1,760,000		6	**88,000**	every 5 years
3.1.2	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		6	**7,500**	every 5 years
4	**Remove temporary emergency geocontainer structures**						**75,000**			
4.1	Stone St structure	Sand from geocontainers to be placed on the beach	m	30	1,000	30,000				
4.2	Griffiths Ave structure	Sand from geocontainers to be placed on the beach	m	45	1,000	45,000				

Appendix D – Option 3b Cost Estimate

Royal HaskoningDHV
Enhancing Society Together

Stockton CMP

Cost Estimate for CBA
Option 3b - Beach Nourishment

Prepared By: N Patterson
Checked By: G Blumberg

Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment (based on terrestrial source)**						**4,000,000**			
1.1a	Beach nourishment with sand from commercial terrestrial sources placed by trucks/dozers on subaerial beach at Holiday Park frontage via King St, constantly throughout year.	Based on costs from sand placement pilot study (Dec 2019) undertaken by SCS, as provided by Council, reduced by 20% for economies of scale	m3	50,000	80	4,000,000		1	4,000,000	yearly
	Disclaimer									

The reader should note that cost estimate presented here is based on Royal HaskoningDHV's experience and judgement as a firm of practising professional engineers familiar with the coastal and maritime construction industry. It includes construction costs only and no allowance is made for contingencies. It would be reasonable to apply an average contingency of up to 40% for design development uncertainty and unforseen and uncontrollable items, such as those relating to ground and weather conditions.
The quantities used to develop the cost estimate have been gauged from typical concept arrangements and planform measurements made using available mapping and high level aerial photography.
The construction cost estimate can NOT be guaranteed as RHDHV have no control over Contractor's prices, market forces and competitive bids from tenderers. The cost estimate is for CONSTRUCTION ONLY and excludes items which should be considered in a cost plan such as site investigation fees, environmental assessment fees, design and tendering fees, project management fees, authority approval and permitting fees, and construction site supervision, works certification and administration fees.

Stockton CMP

Cost Estimate for CBA
Option 3b - Zone 1

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT ($)	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Vertical Structures**									
2.1	**Stage 1**						**875,000**			
3.1.1	Secant pile wall (including capping beam and ground anchors)	Based on construction cost for Kingscliff Project and Rawlinsons	**m**	35	20,000	700,000		1	35,000	every 5 years
3.1.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for dry construction)	m	35	5,000	175,000		1	8,750	every 5 years
3.2	**Stage 2**						**11,175,000**			
3.2.1	Secant pile wall	Based on construction cost for Kingscliff Project and Rawlinsons	m	441	20,000	8,820,000		5	441,000	every 5 years
3.2.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	441	5,000	2,205,000		6	110,250	every 5 years
3.2.3	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		6	7,500	every 5 years
4	**Relocation of Holiday Park Assets behind seawall**	New amenities block timing will depend on conditions and nourishment behaviour	item	1	500,000	500,000	**500,000**	3	NA	NA
5	**Maintenance of SLSC revetment**	Based on current estimates for maintenance works	m				**0**	1	144,000	every 4 years

Stockton CMP

Cost Estimate for CBA
Option 3b - Zone 2

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Vertical Structures**									
2.1	**Stage 1**						**3,750,000**			
3.1.1	Secant pile wall (including capping beam and ground anchors)	Based on construction cost for Kingscliff Project and Rawlinsons	**m**	150	20,000	3,000,000		1	150,000	every 5 years
3.1.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for dry construction)	m	150	5,000	750,000		1	37,500	every 5 years
3.2	**Stage 2**						**7,525,000**			
3.2.1	Secant pile wall	Based on construction cost for Kingscliff Project and Rawlinsons	m	295	20,000	5,900,000		5	295,000	every 5 years
3.2.2	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	295	5,000	1,475,000		6	73,750	every 5 years
3.2.3	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		6	7,500	every 5 years
4	**Removal and Disposal of Waste**	Provisional sum in case of discovery of General Solid Waste. No information available on quantities. Progressive removal would be required as it is exposed.	t	100	250	25,000		1	25,000	every 5 years
5	**Removal and disposal of carpark at the Monument**	Rawlinsons	m2	200	90	18,000		3	NA	

Stockton CMP

Cost Estimate for CBA
Option 3b - Zone 3

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST AND TIMING	MAINTENANCE TIMING
1	**Nourishment - refer serarate spreadsheet for whole project area nourishment cost estimate**									
2	**Maintenance of SLSC revetment**									
	Current planned maintenance works	Current planned works. Based on current estimates for maintenance works	item					1	$500,000	every 2 years

Stockton CMP

Cost Estimate for CBA
Option 3b - Zone 4

Prepared By: N Patterson
Checked By: G Blumberg
Date Issued: 16/06/2020

ITEM NO.	DESCRIPTION OF WORK INCLUDED	DETAILS	UNIT	QUANTITY	RATE	SUB TOTAL AMOUNT (Sub items x.x)	TOTAL AMOUNT	TIMING FOR CAPITAL PROJECT (YEAR)	MAINTENANCE COST	MAINTENANCE TIMING
1	**Footpaths and roadworks**						**100,000**			
1.1	Create culdesac at end of Barrie and Griffiths roadways		m	200	500	100,000		1	**10,000**	every 5 years
2	**Vertical Structures**									
	Stage 1						**1,050,000**			
2.1	Barrie Crescent/Stone St/Griffiths Ave secant pile wall and and rock wedge at Mitchell St flank	Based on construction cost for Kingscliff Project/Rawlinsons	**m**	40	20,000	800,000		1	**40,000**	every 5 years
2.1.1	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	40	5,000	200,000		3	**10,000**	every 5 years
2.2	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	1	50,000	50,000		6	2,500	every 5 years
	Stage 2						**11,400,000**			
3.2	Barrie Cres/Griffiths Ave/Eames Avenue secant pile wall	Based on construction cost for Kingscliff Project	**m**	450	20,000	9,000,000		4	**450,000**	every 5 years
3.2.1	Rock Toe Protection	Based on Contructed cost of Stockton SLSC seawall (factored for reduced profile)	m	450	5,000	2,250,000		6	**112,500**	every 5 years
3.1.2	Accessways on piles (3 accessways 2m wide)	FRP superstructure on concrete piles. Once full length of seawall is in place this access may be needed (earliest timing)	item	3	50,000	150,000		6	**7,500**	every 5 years
4	**Remove temporary emergency geocontainer structures**						**75,000**			
4.1	Stone St structure	Sand from geocontainers to be placed on the beach	m	30	1,000	30,000				
4.2	Griffiths Ave structure	Sand from geocontainers to be placed on the beach	m	45	1,000	45,000				

Appendix E – Terrestrial Sand Source Methodology and Costs

Royal HaskoningDHV
Enhancing Society Together

Memo

HASKONING AUSTRALIA PTY LTD
MARITIME & AVIATION.

To	:	City of Newcastle
From	:	RHDHV
Date	:	17/06/20
Copy	:	
Our reference	:	PA2395_StocktonCMP_TerrestrialNourishment_Option3_Final001
Subject	**:**	**STOCKTON CMP FEASIBILITY ASSESSMENT OF OPTION 3 BEACH NOURISHMENT FROM TERRESTRIAL SOURCES**

1. General

'Option 3' of the CMP includes sand nourishment from terrestrial sources, with the objective of providing the maximum sand volumes that can be reasonably sourced and placed based on current knowledge and recent experience.

This memo provides an assessment of terrestrial sand nourishment opportunities and constraints, with a view to establishing a nominal annual nourishment volume that would apply under Option 3.

2. Sand Sources

The suitability of sand for beach nourishment purposes is primarily dependent on the physical and chemical characteristics of both the native beach and source (or borrow) sand. In investigating the compatibility of potential terrestrial sand sources, RHDHV have undertaken a number of tasks as summarised below:

- assessment of the characteristics of native beach sand at Stockton Beach (based on previous investigations);
- identification of permissible criteria for the source sand;
- assessment of the potential sand sources from local quarry suppliers:
- calculation of Overfill Factors associated with the above terrestrial sand sources which have been identified as compatible.

Each of the above listed tasks is discussed in the following sections.

2.1 Characteristics of the Native Beach Material

In April 2011, WorleyParsons (2012) collected several samples of native beach sand along three transect profiles at Stockton Beach, with the transects located 900 m, 1700 m and 2500 m north of the breakwater. Median grain sizes (D_{50}) ranged from 0.27 to 0.47 mm, with finer sand generally found at the southern end. The average grain size (D_{50}) from these samples was 0.37 mm (excluding a gravelly sample collected in the nearshore zone at the northernmost transect), as shown in Figure 1.

The beach and nearshore sands extending to a depth of approximately 15 m at the southern end of Stockton Beach were described by Roy and Crawford (1980) as well to very well sorted fine to medium grained sands with grain sizes ranging from 0.18 to 0.35 mm. A uniform mean grain size of 0.25 mm was determined for beach and nearshore sands at the southern end of Stockton Beach (Roy & Crawford 1980). This grain size was used as a constant in the most recent coastal processes modelling undertaken by DHI (2006). MHL (1977) similarly found finer sands in the southern few kilometres closest to the breakwater, with many samples finer than 0.3 mm.

2.2 Nourishment Sand Criteria

Based on the characteristics of the native beach sand, assumed to be consistent in the proposed placement area with transects immediately to the north previously analysed (WorleyParsons 2012), criteria have been developed for compatible source sand for nourishment purposes. These criteria are outlined below.

The physical properties of the source material are required to meet the following technical specification criteria:

- Median Grain Size (D_{n50})
  The median grain size shall be 0.30 mm to 0.40 mm. This criterion accounts for the range of grain sizes found along the length of the beach, with progressively coarser material occurring with distance north of the breakwater. This criterion also has regard to the Coastal Engineering Manual (CERC 2006) which notes that the D_{50} of the borrow material should be within plus or minus 0.02 mm of the native sand D_{50}.
    -

- Fines Content
    - No discrete grab sample of surface or subsurface sand greater than 5 kg shall, following thorough mixing, exhibit a fines fraction greater than 5% by weight. Fine sized sediments shall be defined as being smaller than 75 microns in diameter.

- Excessively Coarse Material
    - No discrete grab sample of surface or subsurface sand greater than 50kg shall, following thorough mixing, contain a fraction greater than very coarse sand size which exceeds 2% by weight. The minimum size of very coarse sand shall be defined as 2 mm. Very coarse material may include shell.

- Colour and Composition
    - The beach nourishment material shall be comprised of carbonate and silica particles and shall not contain organic matter, demolition material or other debris.
    - The beach nourishment material shall have a colour, following placement and exposure to the elements, similar to the existing beach sand in the placement area.

2.3 Local Quarry Sand Suppliers

2.3.1 Material Properties (Previous Assessment)

Consultation with several local sand quarries was undertaken to assess the suitability of available products against material acceptance criteria. Sand products from the following local quarries were assessed:

- Macka's Sand and Soil Supplies;
- Boral Stockton Sand Quarry;
- Redisands (Salt Ash);
- Newcastle Sand (Williamtown); and
- Sibelco Sand Quarry in Salt Ash (Note: Sibelco only carry a maximum of 2,500 tonnes of their 3060 product at any one time, and orders greater than this will incur longer lead times).

Material data sheets relating to available products were provided by each of the quarries and assessed by RHDHV engineers.

Considering that all locally sourced terrestrial sands are quarried from the windblown dunes of Stockton Bight and are further processed (i.e. washed and screened), it is unlikely that these terrestrial sands would contain any contaminants, organic matter, excessive fines or excessive coarse material, or significant colour incompatibilities following placement. Therefore, the key criterion determining the compatibility of these quarried sands is the Particle Size Distribution (PSD) of the available sand products.

PSD curves for a range of sand products available from local quarries are plotted in Figure 1. It is evident that the majority of these products are characterised by a median grain size (D_{50}) ranging between around 0.30 and 0.40 mm, while two of the products comprise relatively fine sand with D_{50} values below 0.25 mm.

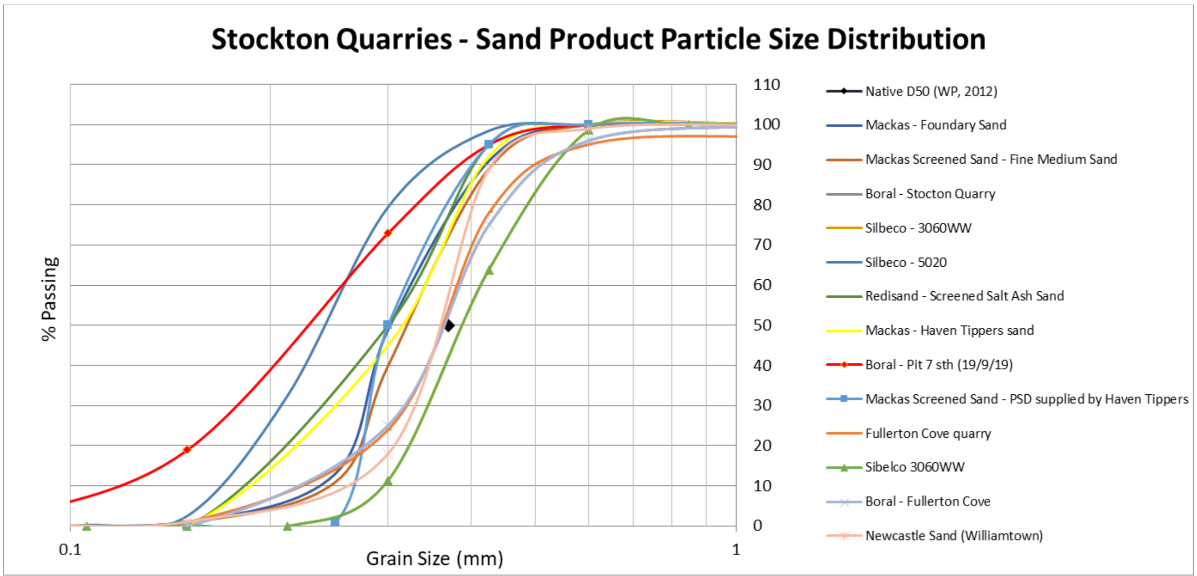

Figure 1: Stockton quarries - sand product PSDs

Using the criterion outlined in **Section 2.2**, it is evident that the majority of sand products available from local quarries would likely be compatible for nourishment purposes at Stockton Beach (refer Figure 1).

2.3.2 Overfill Factors

The Overfill Factor or Overfill Ratio (R_A) is the ratio of fill (nourishment) material required from a given borrow site compared to that required using the existing (native) beach sediments (CERC 2006). The Overfill Factor is based on differences in the mean grain size and sorting characteristics of both the native and nourishment (borrowed) sands.

Whilst the Overfill Factors provide an indication of compatibility between borrow and native sediment, more detailed assessment of the compatibility is recommended to inform detailed project design. For example, CERC (2006) notes that:

- Recent research and beach nourishment experiences have questioned the continued use of grain-size based factors, such as R_A and the renourishment factor (R_J), to estimate beach-fill performance (Dean 2000).
- Present guidance recommends that design be based on equilibrium beach profile concepts, an assessment of storm-induced erosion, and an assessment of wave-driven longshore transport losses; and that these methods be used to replace or complement the overfill and renourishment factor approaches (National Research Council (NRC) 1995).

Nevertheless, the Overfill Factor can be used to provide a useful indication of sand volume requirements for a nourishment project, particularly in the early stages of project design. As such, this approach has been adopted for the purpose of undertaking a high-level assessment of sand volume requirements associated with the placement of local quarry sand sources at Stockton Beach.

CERC (2006) recommends that for a sand nourishment project, ideally a nourishment (borrow) sand should have an overfill ratio of 1 to 1.05 relative to the native sand. However, CERC (2006) also notes that this may not always be possible and as a rule of thumb if the median grain size of the borrow sand is within 0.02 mm of the native sand median grain size it is considered compatible.

Overfill Factors were calculated for several of the potential quarry sand sources using methods outlined in the Shore Protection Manual (CERC 1984). The WorleyParsons (2012) grain size data was used to characterise the native beach sands for these calculations (mean grain size, D_{50} = 0.37 mm or 1.43 phi units). Overfill Factors typically ranged from 1.8 to 5 for quarries carrying larger quantities of sand (suitable for a nourishment campaign at Stockton). This indicates that the median grain size of quarry sand sources is generally finer than the native sand requiring 1.8 to 5 times as much sand to retain each 1 m^3 on the beach. It should be noted that some products were in the unstable range ($R_A > 10$).

Based on the above, an Overfill Factor of approximately 2.5 is recommended for adoption in the CMP for the purpose of assessing terrestrial sand nourishment at Stockton Beach using quarry sand sources. It is also recommended that a sensitivity analysis be carried out in the CBA using an Overfill Factor of 1. The Overfill Factor would need to be reviewed on a case by case basis during any future nourishment works in consideration of the material properties of proposed sand nourishment material.

2.3.4 Licensed Extractive Capacity

The extractive capacity of local quarries is stipulated in the Environment Protection Licences (EPLs) issued to each facility. For example, EPL 10132 for Boral Quarries Stockton (Fullerton Cove) authorises an annual sand extraction of 100,000 to 500,000 tonnes. The current annual extractive capacities licensed for each of the local quarries considered herein are listed in **Table 1**.

Table 1: Local Quarry Licensed Extractive Capacity

Quarry Sand Source	EPL Number	Annual Extractive Capacity (tonnes)[1]	Annual Extractive Capacity (m^3)[1]
Boral Stockton (Fullerton Cove)	10132	500,000	300,000
Macka's Sand and Soil (Salt Ash)	12108	50,000	30,000
Sibelco (Oyster Cove)	11633	150,000	90,000
Newcastle Sand (Williamtown)	21264	500,000	300,000
Redisand (Salt Ash)	13406	500,000	300,000
TOTAL	**-**	**1.7 M tonnes**	**1,020,000 (sourced) 408,000 (effective)[2]**
Assumed availability for nourishment of Stockton Beach	**20% of total licensed quantities**	**340,000 tonnes**	**200,000 (sourced) 80,000 (effective)[2]**

[1] Maximum quantity that can be extracted, processed or stored annually.

[2] Effective in situ volume of quarry sand following placement, based on adopted overfill ratio of 2.5.

Based on preliminary enquiries made with Boral Stockton (Fullerton Cove), it is understood that annual extractive operations are typically within around 15,000 tonnes of the upper licensed limit of 500,000 tonnes. For the purpose of the assessment undertaken herein, it has been assumed that up to around 20% of the current annual combined extractive capacity of 1.7 million tonnes could be secured for terrestrial sand nourishment at Stockton Beach (refer **Table 1**). This would require detailed negotiations with each quarry to secure such a substantial portion of their licensed quantities, confirmation that suitable products can be made available, and (potentially) modifications to the existing EPLs.

Therefore, it has been assumed that local quarry sources are currently capable of supplying 340,000 tonnes annually for the purpose of nourishing Stockton Beach, which is equivalent to a supplied volume of around 200,000 m^3. Based on the adopted overfill ratio of 2.5, the effective quantity of nourishment sand that could be placed on Stockton Beach is around 80,000 m^3 per year.

3. Methodology

3.1 General

The amount of nourishment sand placed in a single trucking campaign will be limited by budgetary constraints, environmental impacts of the trucking operations and how much sand can practically be accommodated on the sub-aerial beach.

The following is considered the most effective placement methodology given the current site constraints and opportunities. This approach was adopted for the December 2019 pilot exercise.

- nourishment sand trucked to the relevant project site (refer **Section 3.3**) and stockpiled in designated areas;
- an excavator loads sand into 40T site dump trucks for haulage on the beach;
- sand placed on the beach within the placement zone; and
- sand shaped using an excavator and/or D6 dozer to achieve the design beach profiles.

It should be noted that any lowering of the dune during the placement activities would need to be reinstated and revegetated at the conclusion of the works.

The finished sand profile will extend from the erosion scarp at the back of the beach down to the low water mark (or as close as practically possible) – refer to design profiles in **Section 3.1.2**. Within a 9-hour workday a high and a low tide will be encountered (~6 hrs apart). Strategic placement should therefore be undertaken by placing sand in the upper beach during higher tides and the lower beach during low tides. Material should also be initially placed on the upper beach area if access to the lower beach is problematic, then later redistributed by dozer/excavator when conditions are favourable.

When water levels are extreme (due to king tides or storm surge) or wave conditions are severe and wave runup prevents safe access onto the beach for trucks, construction downtime will occur. It is difficult to predict how the construction period will be affected by these factors.

Typically, in the summer months conditions are generally calmer though king tides do occur. The state of the beach will also affect the accessibility i.e. if the beach is particularly eroded and low level, the window of opportunity will be reduced, whereas if the beach has accreted and built up to some extent, the impact of tides and waves will be reduced.

3.2 December 2019 Pilot Exercise

A small pilot nourishment campaign was undertaken by Soil Conservation Services (SCS) in December 2019 using trucks and bulldozers in front of the Holiday Park. The nourishment exercise comprised:

- 5564 tonnes sand delivered to site. (equivalent to 3500 m^3 placed volume);
- Cost $389,753.10 GST inclusive. (approximately $100/$m^3$ ex GST);
- 173 loads to site – 32 T per truck and dog;
- approximately 346 truck movements.

The works were completed within a four (4) day period. Photographs taken during and immediately following the December 2019 nourishment exercise are provided in **Figure 2** and
Figure 3.

Figure 2: December 2019 nourishment activity in progress (date: 10/12/19)

Figure 3: December 2019 nourishment activity upon completion (date: 12/12/19)

3.3 Project Sites

It should be noted that the existing narrow beach widths in locations such as the Mitchell St and SLSC revetments would make it very difficult for machinery to access the full length of the study area. It may be necessary to end tip in other locations where access is limited. Sand placement may be required updrift of these narrow locations, with coastal processes relied on to subsequently distribute nourishment sand to these areas. Eventually, these sections may become wide enough to accommodate access for plant and machinery.

Based on the above, it has been assumed that machinery would not be able to access the sections of beach immediately seaward of the existing protective structures (SLSC and Mitchell St). Therefore, it would be necessary to provide project sites either side of these structures. This would also allow for truck movements and other construction activities to be more evenly distributed within the study area, which would lead to a more favourable amenity outcome. For example, the King St and Dalby Oval sites could operate on an alternate basis to ensure that significant sections of beach are available for recreational purposes at any given time.

Proposed project sites are summarised in **Table 2**. The lengths of shoreline that machinery could access from each project site are also listed in **Table 2**. The total length of shoreline that could be accessed by machinery is around 1,500 m (Note: the total shoreline length that requires nourishment sand is around 2,200 m, which extends from the breakwater to just north of Meredith St).

Table 2: Nourishment Project Sites

Project Site	CMP Zone	Accessible shoreline length	Comment
King St	Zone 1	500 m	Project site utilised during December 2019 Pilot Exercise (refer **Figure 4**). Could operate on an alternate basis with Dalby Oval site.
Dalby Oval	Zone 2	350 m	Construction of beach access thoroughfare through the dune would be required. Could operate on an alternate basis with King St site.
Corroba Oval	Zone 4	650 m	Construction of beach access thoroughfare through the dune would be required. Possibility of establishing sand pumping system at this location (refer **Section 3.6**).
TOTAL		**1,500 m**	Excludes sections of beach seaward of existing revetments (SLSC, Mitchell St). Entire length of study area shoreline is 2,200 m.

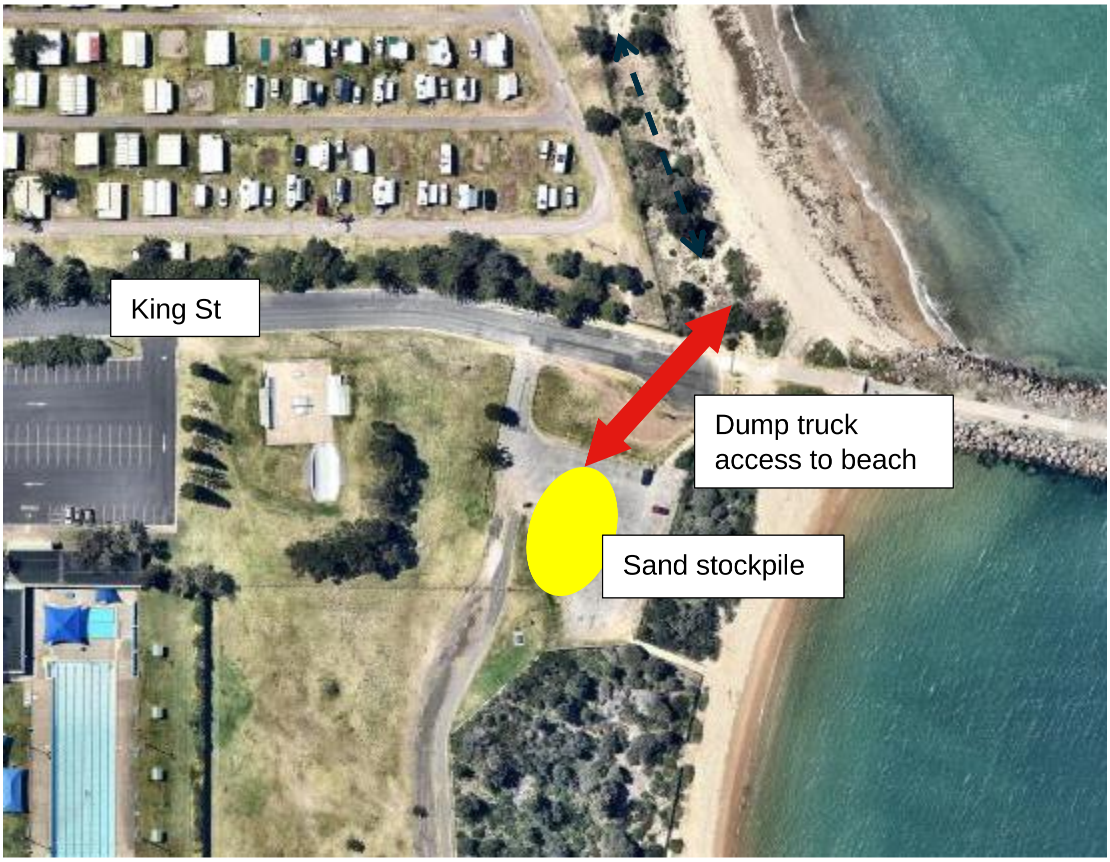

Figure 4: King St Site Plan (December 2019 Pilot Exercise)

3.4 Design Profiles

Terrestrial nourishment using land-based plant would be limited to the sub-aerial beach above 0m AHD. The objective of the design profile would be to nourish the full sub-aerial beach width while limiting the potential erosion scarp height formed as the new material was eroded. In practical terms, the design profile would also aim to build up sand volumes at the back of the beach where it has the best chance of being retained for a longer duration on the beach and providing a buffer to mitigate coastal erosion hazard (storm demand).

An example of a typical design profile for the sand placement is shown in **Figure 5**.

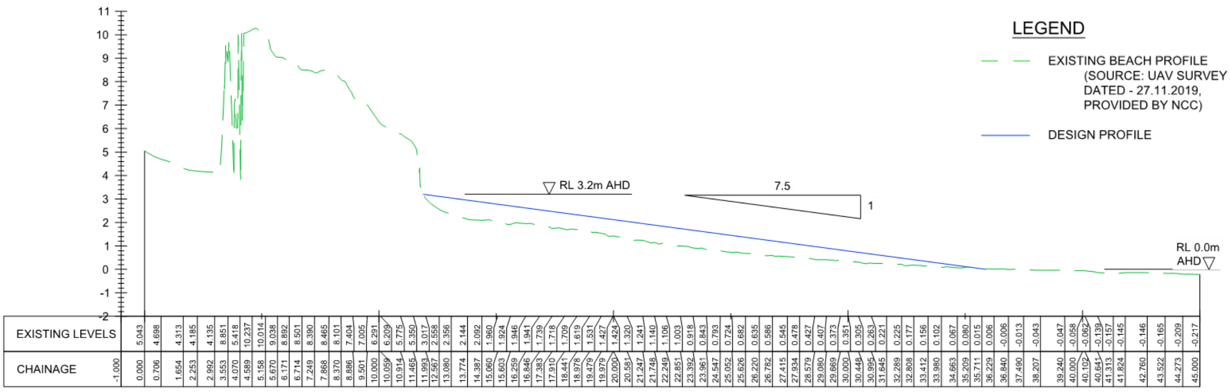

Figure 5: Example of a typical design beach profile (December 2019 campaign)

Based on an assessment of current beach widths (measured from the base of the dune to the RL 0 shoreline position), an average beach width of around 30 m is estimated for the sections of shoreline that are accessible to machinery (refer **Table 2**). RHDHV estimate that the volume of sand that can be practically accommodated on the sub-aerial portion of Stockton Beach in a single campaign is approximately 30 m^3/m, based on a maximum placement depth of 1 m. Higher placement rates would result in the formation of steep scarps that may result in public safety issues. Over the entire 1,500 m length of accessible shoreline, this equates to a total maximum nourishment volume of 45,000 m^3 for a single nourishment campaign.

Additional sand could be subsequently placed at intervals once coastal processes have redistributed the sand down the beach profile and alongshore. The capacity of subsequent nourishment campaigns would be expected to increase as more sand begins to ‘fill in’ the active beach profile and the beach widens compared to present conditions. Based on an assumed beach widening of up to around 5 m, and a typical placement depth of 1 m, it is estimated that an additional 5 m/m^3 could be placed on the beach at this time.

Based on the above, RHDHV estimate that, under a future widened beach condition, the maximum volume of sand that can be practically accommodated on the sub-aerial portion of Stockton Beach in a single campaign is approximately 35 m^3/m. Over the entire 1,500 m length of accessible shoreline, this equates to a total maximum nourishment volume of around 50,000 m^3 for a single nourishment campaign.

The timing between nourishment campaigns would depend on the rate of sand redistribution from the sub-aerial beach and across the overall beach profile. Following the December 2019 nourishment exercise undertaken in front of the Holiday Park, it was observed that the nourishment material was largely lost from the subaerial beach (with the exception of a small proportion of material at the very back of the beach) within the six-week period. During this period, conditions were moderate with no significant swell events (H_s typically less than 1.5 m).

These observations suggest that the rate of redistribution of subaerial nourishment placements is quite rapid (i.e. in the order of weeks to months), and that subsequent nourishment campaigns could be carried out in reasonably quick succession. However, it is expected that the rate of redistribution would decline with each nourishment campaign as more sand begins to 'fill in' the active beach profile.

In summary:

- **It is considered reasonable to assume that a maximum of one terrestrial nourishment campaign comprising 50,000 m^3 could be physically accommodated on the beach every three months.**
- **In practical terms, this would be expected to comprise multiple 'sub-campaigns' carried out from the three project sites at different times within each three-month period.**
- **A total of four (4) nourishment campaigns could be undertaken in a single year.**
- **Therefore, the total nourishment volume that could be physically accommodated on the beach each year is approximately 200,000 m^3.**
- **However, based on the adopted overfill ratio of 2.5, the effective quantity of nourishment sand that could be placed on Stockton Beach is around 80,000 m^3 per year.**
- **It is noted that these values are consistent with the sand quantities available from local quarries (refer Section 2.2.4).**

3.5 Logistical Constraints

As noted above, the maximum volume of terrestrial nourishment that could be physically accommodated on the beach in a single campaign is estimated to be around 50,000 m^3. Four (4) campaigns per year could be undertaken (i.e. approximately one campaign every three months). For the purpose of this assessment, it has been assumed that each nourishment campaign would be evenly spread across the three (3) project sites, i.e. approximately 17,000 m^3 at each site per campaign.

As noted in **Section 3.1.2**, the December 2019 campaign involved the placement of around 3,500 m^3 over a 4-day period. Assuming a five-day working week to avoid the need to undertake placement works on the weekend when public usage is highest, a weekly placement rate of around 4,400 m^3 is considered to be feasible. It is understood that the level of truck activity during the December 2019 operations was generally acceptable, although the short duration of this activity must be acknowledged.

The required project duration to place 17,000 m^3 of sand from each project site at a rate of 4,400 m^3/week is around four (4) weeks. This would be expected to provide sufficient flexibility for CN to manage trucking operations within each three (3) month campaign period without needing to increase the level of truck activity above the December 2019 levels. Example scenarios include (but are not limited to):

1. each project site could operate on a standalone basis of one (1) month each during each three (3) month campaign period; or,
2. the Corroba Oval site could operate concurrently with either of the other sites, which would permit project operations to be completed within a two (2) month period.

Council have stated that nourishment activities should not be undertaken during the school holiday periods, as well as public holidays and weekends. In each year, the available time to undertake nourishment activities is up to nine (9) months. Scenario 2 listed above involves trucking operations two out of every three months, or eight (8) months per year. This approach would be consistent with Council's stated objective.

Overall, it is considered that the level of truck activity required to place the available volumes of nourishment sand would not exceed the December 2019 conditions. Furthermore, operational scenarios are possible that would enable nourishment activities to cease during school holiday periods. As such, the proposed level of truck activity is not considered to be a significant constraint from a technical feasibility perspective, however the long-term nature of the works and associated impacts should be investigated further.

3.6 Alternative Sand Delivery Mechanism (Corroba Oval)

It may be worthwhile considering the option of delivering sand from the Corroba Oval project site via a slurry pumping system as an alternative to trucking along the beach. It is envisaged that the other project sites (King St and Dalby Oval) would operate concurrently as trucking sites as described above. Several potential advantages are associated with this option, including (but not limited to):

- pumping facilities may offer economies of scale benefits (subject to further assessment);
- avoids the need to truck sand along the beach and the associated safety and amenity impacts;
- increased flexibility around timing and rate of nourishment activities because the physical space constraints outlined in **Section 3.4** would not apply.

In addition to having trucks transporting sand directly onto the beach via the King St and/or Dalby Oval project sites, trucks would transport sand to a sand pumping station established near Corroba Oval. The sand would be pumped as a slurry via a buried pipeline to outlets at Dalby Oval frontage and Barrie Cres frontage.

A trial diesel pumping station and pipeline with a 100,000 m^3/year capacity could be established with a 5-year operational contract. RHDHV estimate the costs set out below for this option (based on 85,000 to 100,000 m^3 per year, with the remaining 100,000 to 115,000 m^3 delivered via trucking from the other two project sites).

3.6.1 Backpassing Costs

The estimated costs are set out below for this backpassing option.

For a trial diesel system (100,000 m^3/year capacity over a 5-year contract):

Capital Cost:

Mobilisation	$ 1.6M
Demobilisation	$ 0.35M
Total	**$ 1.95M**

Recurring Costs

Operating costs	$390,000/year ($32,500/month)
Unit rate for sand	$750,000/year ($7.5/m^3 for 100,000 m^3/year)
Power	$220,000 ($2.2/m^3)
Total	**$1.36M**/year for 5 years

For a permanent electrical system (85,000 m^3/year capacity):

Capital Cost:	**$4.5M**
Recurring Costs:	**$8/m^3** (operating costs including maintenance, power and unit rate for sand)

<u>Summary</u>

For the purpose of the present assessment to inform the Stockton CMP, it has been assumed that a trial diesel system (100,000 m^3/year capacity over a 5-year contract) would initially operate as per the details set out above. This would deliver 500,000 m^3 of nourishment over the first five years at an average cost rate of around $17.50/m^3.

A permanent system with an appropriate pumping capacity would then be installed, based on annual pumping requirements. A capital cost of around $4.5 million plus an ongoing rate of around $8/m^3 would apply for this option. However, further investigations would be required to assess the feasibility of pumping systems able to keep pace with the Bluecoast (2020) high estimated recession rates of 112,000 m^3/year.

These volumes would inevitably lead to adverse impacts at the borrow site, which would require further investigations.

As such, it is considered that this backpassing option may be constrained by:

- the maximum quantity of material that can be sourced from the borrow area without yielding adverse impacts;
- existing land zoning and regulatory provisions, although noting that sand would be sourced within the Newcastle LGA which would be expected to simplify the approvals process; and,
- pumping capacity of the permanent system, which may struggle to achieve maximum required rates of 112,000 m^3/year, subject to further investigations.

4. References

CEM (2006), *Coastal Engineering Manual*, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.

CERC (1984), *Shore Protection Manual*, Coastal Engineering Research Center. Waterways Experiment Station, US Army Corps of Engineers, Vicksburg, Mississippi.

WorleyParsons (2012), Stockton Beach Sand Scoping and Funding Feasibility Study, prepared for City of Newcastle. Report No. 301015-02514, April.

Appendix F – Marine Sand Source Methodology and Costs

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Classification:	Internal use only		

Addendum to Technical Note: RHDHV input information for a Cost Benefit Analysis for Stockton Beach (marine sand sources)

1 Background

In line with the Coastal Management Act 2016 and the NSW Coastal Management Manual Part A (the Manual), a Cost Benefit Analysis (CBA) will be undertaken in order to inform a Coastal Management Program (CMP) for Stockton Beach. The location under consideration is limited to between the area north of the Stockton Breakwater (northern training wall of the Hunter River), and the northern boundary of Meredith Street. This technical note describes input parameters for potential coastal management actions that include access to subaqueous marine sources of sand to be considered within the Cost Benefit Analysis.

While noting that marine sand sources are not currently available, there may be opportunities to access these sources into the future. City of Newcastle (CN) have requested that RHDHV provide estimates of costs and recommendations as to the potential methodology required to undertake provision of marine sands as a coastal management action. It is recommended that the cost estimates provided within this report are considered within the CBA, in order to quantify the alternative approaches to beach nourishment should such sources become available.

2 General Information

There are two basic approaches being considered for the supply of marine sand that will be described in further detail:

1. Offshore marine source accessed by a Trailing Suction Hopper Dredger (TSHD) method.
2. Inshore 'Marine' source in the South Arm of the Hunter River accessed by a Cutter Suction Dredger (CSD) method.

A TSHD is a self-propelled ship which is mainly used for dredging loose and soft soils such as sand, gravel, silt or clay. TSHDs have a hull in the shape of a conventional ship and are both highly seaworthy and able to operate without any form of mooring or spud. They are equipped with either single or twin (one on each side) trailing suction pipes. A pump system sucks up a mixture of sand or soil and water and discharges it into the 'hopper' or hold of the vessel.

The hopper can be emptied in a nearshore location by opening the doors or valves in the hopper bottom ("bottom dumping"), by using the dredging pump to deliver material to shore through a floating pipeline, or by projecting material towards the shore using a special bow jet. This latter method of placement is commonly referred to as "rainbowing", whereby sand is sprayed in a high arc towards the deposition location, resembling a sand-coloured rainbow.

The measure of size of a TSHD is the hopper capacity, which may range from a few hundred cubic metres to over 40,000 m^3. Through consideration of the site conditions and industry knowledge, four vessels ranging in size from 1,850 m^3 to 20,000 m^3 have been selected to undertake comparative analysis of scale, placement methods and cost.

A CSD is a stationary dredger which makes use of a rotating cutter head at the suction inlet to loosen the material to be dredged. The dredged material is usually sucked up by a wear-resistant centrifugal pump and discharged either through a pipeline to the shore (more typical) or into barges.

A CSD operates by swinging about a central working spud using two fore sideline wires leading from the lower end of the ladder to anchors. By pulling on alternate sides the dredger clears an arc of cut, and then moves forward by pushing against the working spud using a spud carriage. A generally smooth bottom can be achieved, and accurate profiles and side slopes are able to be dredged.

The size of a CSD is measured by the diameter of the suction pipe and by the installed machinery power. Pipe diameters generally range from 100 mm to 1,500 mm, and booster stations are utilised to improve productivity over longer pumping distances. Through consideration of site conditions and industry knowledge, four pipe diameters ranging from 500 mm to 900 mm and use of between one and three boosters have been selected to undertake comparative analysis of efficiency and cost.

3 Assumptions for TSHD

The following assumptions are made for offshore sand sources.

1. Adequate and appropriate offshore sand sources (borrow areas):
    - are available within 7.5 nautical mile sailing distance of the site
    - comprise areas where no rock or wrecks are shown on Admiralty Charts
    - contain minimal amount of fines[1] (<2%), noting that grainsize at the borrow area would need to be established by sampling.
    - are to be dredged by Trailing Hopper Suction Dredge (TSHD) methodology, with comparison of potential plant shown in **Table 1**
    - overflowing from the hopper to be allowed during dredging to maximise solids (sand) content in the hopper.

TSHD Sub-Options - Distances to Stockton Beach

- Bottom Dumping– suggested vessel including capacity and closest distance to the low water line at Stockton Beach
    - TSHD Albatros - 1,850 m^3 capacity, 250-350 m

[1] Fines is the collective term given to particle sizes less than 0.075mm (75 microns) and comprise silts and clays.

- TSHD Balder R - 6,000 m³ capacity, 500-600 m
- TSHD Volvox Asia - 10,000 m³ capacity, 1000-1150 m
- TSHD Rotterdam - 20,000 m³ capacity, 1200-1400 m

- Rainbowing – suggested vessel including capacity and closest distance to the low water line at Stockton Beach
  - TSHD Albatros - 1,850 m³ capacity, 200 m
  - TSHD Balder R - 6,000 m³ capacity, 450 m
  - TSHD Volvox Asia - 10,000 m³ capacity, 950 m
  - TSHD Rotterdam - 20,000 m³ capacity, 1150 m

Table 1 – Comparison of potential plant

Reference / Example Vessel	Rotterdam	Volvox Asia	Balder R	Albatros
TSHD Hopper Capacity m³	20,000	10,000	6,000	1,860
Installer Power kW	27,500	12,500	11,000	2,500
Loaded Draft m	11	10	7	4
Max Dredging Depth m	40-70-100	35	65	30
Distance: Pipeline along beach m	1300	1300	1300	1300
Distance: Pump-out to Stockton Beach m	1600	1250	900	500
Suitability of plant option	Y	Y	Y	Y NOTE: Marginal suitability due to potential water depth at sand source

2. Nourishment volumes of 500,000, 2,000,000 and 3,500,000 m³ have been used as input figures.

3. All Options Costs based on:
   - Working hours 24x7
   - No GST included
   - All costs are in 2019-dollar rates
   - Mobilisation/demobilisation costs are shared with one other proponent/project (e.g. Collaroy, Gold Coast.)

4. For direct placement and delivery of sand on the beach, there are 2 options:
   - Offshore connection in Stockton Bight by floating hose, submerged line to shore connection and Y-pieces on shore for spreading (all pump-out TSHDs), or;
   - An Inshore connection along the bank of the Steelworks Channel off Stockton Ferry Wharf (for large TSHD unit) or along the Hunter River near Stockton Boat Harbour (for TSHD of Albatros size) with floating line to the foreshore and landlines to the section of beach to be nourished (possibly bridge over road or trenching under the road or along foreshore)

4 Considerations

There are a number of variable factors that require consideration before providing recommendations for inclusion within a CBA. It is recognised that the objective of the nourishment program is a key factor, as this will guide design of sand placement, selection of methodology and plant, as shown in **Table 2**.

Table 2: Relative methodologies for sand placement

Method / benefit & cost	Placement	Constraint	Cost
THSD - Bottom Dumping	Nearshore	Vessel draft	Lowest
TSHD - Rainbowing	Nearshore	Vessel draft	Moderate
TSHD – Pumping	Onshore		High
CSD - Pumping	Onshore		Highest

It is understood that the desired beach state following works would be a combination of subaerial sand and subaqueous sand, requiring placement of sand in onshore and nearshore locations. It is considered likely that a combination of placement methods would be utilised to achieve the desired beach profile.

As a general guide, utilization of larger capacity plant will result in decreased costs per m^3 of sand, however larger vessels may be constrained by laden draft when seeking to place sand by bottom dumping and rainbowing, limiting how close they can safely approach the beach. The southern section of Stockton Beach is relatively shallow as shown in **Figure 1**, restricting the ability of deeper draft vessels (e.g. Volvox Asia and Rotterdam) to bottom dump in nearshore areas closer to the beach and therefore also requiring the use of more expensive placement methods.

Smaller vessels such as the Albatros provide the greatest flexibility for nearshore placement due to their shallow laden draft of 4m, however their smaller capacity requires significantly more vessel movements to the borrow area, adding to cost. In addition, this size vessel also has limitations in terms of maximum dredging depth to access marine sands (maximum dredging depth of 30 m – refer **Table 1**). Due to this combination of factors, it is considered that a mid-size TSHD such as the Balder R with a fully laden draft of 7 m would provide the widest range of benefits for nourishment of Stockton Beach.

Figure 1: 2018 AHD depth contours (Source: Bluecoast 2020)

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5 Cost Estimates for TSHD

Based on the discussion above, cost estimates and durations have been developed for a TSHD vessel of 6,000m³ capacity, for three modes of placement (bottom dumping, rainbowing, and pumping onshore) across three nominal quantities (500,000, 2,000,000 and 3,500,000 m³) as shown in **Table 3**.

Table 3: Cost estimates by placement mode and quantity

OPTIONS	**Hopper capacity m³**	**Destination**	**Quantity m³**	**Rate $/m³**	**Cost for Dredging $**	**Mob/Demob $**	**All Incl rate $/m³**	**Total cost per campaign $**	**Duration (weeks)**
TSHD - Bottom Dumping	6,000	Nearshore	**500,000**	7.13	3,562,500	5,100,000	17.33	**7,800,000**	2.5
TSHD - Rainbowing	6,000	Nearshore	**500,000**	10.50	5,250,000	5,100,000	20.70	**10,350,000**	3.5
TSHD - Pumping	6,000	Onshore	**500,000**	14.25	7,125,000	6,200,000	26.65	**13,325,000**	5.0
TSHD - Bottom Dumping	6,000	Nearshore	**2,000,000**	7.13	14,250,000	5,100,000	9.68	**19,350,000**	9.5
TSHD - Rainbowing	6,000	Nearshore	**2,000,000**	10.50	21,000,000	5,100,000	13.05	**26,100,000**	14.0
TSHD - Pumping	6,000	Onshore	**2,000,000**	14.25	28,500,000	6,200,000	17.35	**34,700,000**	17.5
TSHD - Bottom Dumping	6,000	Nearshore	**3,500,000**	7.13	24,937,500	5,100,000	8.59	**30,037,500**	16.5
TSHD - Rainbowing	6,000	Nearshore	**3,500,000**	10.50	36,750,000	5,100,000	11.96	**41,650,000**	24.0
TSHD - Pumping	6,000	Onshore	**3,500,000**	14.25	49,875,000	6,200,000	16.02	**56,075,000**	30.5

As noted previously, during a large scale offshore sand nourishment campaign it is likely that a suite of placement methods would be used to create the desired beach profile. This is termed 'profile nourishment' and seeks to create the natural beach profile from the outset so as to minimise cross shore redistribution of the placed sand.

For a nominal campaign of 3,500,000 m³, it is considered likely that approximately 55% of material may be able to be placed in the subaqueous zone by bottom dumping, a further 30% by rainbowing, and the remaining 15% by pumping to the subaerial onshore zone. **Table 4** provides an estimated total cost of a combined method profile nourishment campaign from an offshore sand source using a 6,000 m³ hopper capacity TSHD.

Table 4: Cost estimates for nominal 3,500,000 m³ sand nourishment campaign using 6,000 m³ TSHD

OPTIONS	Hopper capacity m^3	Destination	Quantity m^3	Rate $/$m^3$	Total cost per campaign $	Duration (weeks)
TSHD - Bottom Dumping	6,000	Nearshore	2,000,000	7.13	14,250,000	9.5
TSHD - Rainbowing	6,000	Nearshore	1,000,000	10.50	10,500,000	7
TSHD - Pumping	6,000	Onshore	500,000	14.25	7,125,000	5.0
Mobilisation / Demobilisation					6,200,000	
Total:			**3,500,000**		**38,075,000**	**21.5**

6 Assumptions for CSD

The following assumptions are made for the inshore sand source.

1. Adequate and appropriate inshore sand source:
   - is available within the South Arm of the Hunter River below the Tourle Street Bridge
   - control of fines (<75 microns) and grainsize will be subject to the levels in available Soil Reports, with limited options to search for cleaner sand
   - are to be dredged by Cutter Suction Dredge (CSD) methodology.

2. Nourishment volumes of 500,000, 2,000,000 and 3,500,000 m^3 have been used as input figures.

3. All Options Costs based on:
   - Working hours 24x7
   - No GST included
   - All costs are in 2019-dollar rates
   - Mobilisation/demobilisation costs are shared with one other proponent/project (e.g. a commercial/port development project in the South Arm)
   - No cost or time has been included for removing contaminated or clean silts at existing surface levels in the river, i.e. silts which overly the sand to be accessed for nourishment

7 Cost Estimates for CSD

It is noted that the CSD option is recommended for consideration if inshore (Hunter River South Arm) sources become available. Dredging utilising a CSD would be a more costly exercise, if all mobilisation / demobilisation costs are included, although the option offers some benefits in terms of duration, as shown in **Table 5**. Mob/demob costs are relatively high due to the long pumping distance involved (pipework and boosters).

In practice, the sand in the South Arm of the Hunter River would likely only be sourced on an opportunistic basis in concert with a major commercial development in the South Arm, in which case the mob/demob costs would be defrayed. In addition, as the CSD supplies sand to the onshore beach (and inner nearshore through relatively rapid redistribution), it may best form a part of a hybrid approach to nourishment.

Table 5: Cost estimates for Hunter River sourced sands by CSD (Two most cost effective options for each nominal dredge volume)

Options - CSD incl Boosters	Diameter pipe	Destination	Quantity m^3	Rate $/$m^3$	Cost for Dredging $	Mob/Demob $	All Inclusive rate $/$m^3$	Total cost per campaign $	Duration (weeks)
2-3 Boosters	500	Onshore	500,000	21.50	10,750,000	6,500,000	34.50	17,250,000	7.5
2 Boosters	600	Onshore	500,000	17.50	8,750,000	8,250,000	34.00	17,000,000	4.5
1 Booster	850	Onshore	2,000,000	14.50	29,000,000	14,000,000	21.50	43,000,000	8.8
1 Booster	900	Onshore	2,000,000	10.50	21,000,000	18,000,000	19.50	39,000,000	5.0
1 Booster	850	Onshore	3,500,000	14.50	50,750,000	14,000,000	18.50	64,750,000	22
1 Booster	900	Onshore	3,500,000	10.50	36,750,000	18,000,000	15.64	54,750,000	12.5

APPENDIX B – MASS NOURISHMENT BUDGETARY ESTIMATES

bluecoast
CONSULTING ENGINEERS

Technical Note

To: City of Newcastle
From: Evan Watterson
Copy:
Reference: P19028_NourishmentRates_TN0.0
Date: 18 June 2020
Subject: Nourishment costs from offshore marine sand sources

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1 Introduction

In line with the Coastal Management Act 2016 and the NSW Coastal Management Manual Part A (the Manual), the City of Newcastle (CN) are preparing a Coastal Management Program (CMP) for Stockton Beach. This technical note describes the nourishment costs from non-terrestrial sources used in the cost benefit analysis (CBA) for the Stockton CMP. It supplements the information in Royal HaskoningDHV's *Addendum to Technical Note: RHDHV input information for a Cost Benefit Analysis for Stockton Beach (marine sand sources)*, dated 15 April 2020, referred to herein as RHDHV's memo.

2 Background information

RHDHV's memo outlines two basic approaches including the dredging methods that can be used for beach nourishment from non-terrestrial sand sources as offshore marine sand sources and estuarine (Hunter River) sources and the reader is referred to this document for further information. Based on the assumptions and consideration outlined in the memo, RHDHV developed cost estimates.

To supplement this information Bluecoast Consulting Engineers (Bluecoast) consulted dredging contractors who operate the types of Trailer Hopper Suction Dredgers that could potentially undertake the initial and on-going mass nourishment works at Stockton using offshore marine sand sources. Noting that, at present, there is a range of legislative issues associated with this sand source that would prevent its implementation.

Based on the assumption outlined below the experienced dredging contractors provided budgetary estimates which were then used as supplementary inputs to inform cost sensitivity to capital and maintenance nourishment programs in the CBA.

3 Assumptions

The assumptions used to inform budgetary estimates were:

1. Native Stockton Beach sand is D50 = 0.35 to 0.40mm.
2. Nourishment sand source was assumed to be nearby (within 5NM) and offshore in depth less than 28m.
3. Placement is all nearshore but as close as possible to the shore, adopting:
    - 75% rainbowed
    - 25% is bottom dumped.
4. Total quantities ranging across:
    - 1.8M m^3 – as one-off mass nourishment; or
    - 2.4M m^3 – as one-off mass nourishment; or
    - 3.0M m^3 – as one-off mass nourishment; and
5. Optional – 5-10-yearly repeated nourishments of between 120,000m^3 and 1.0M m^3.

4 Nourishment rates

The budgetary rates provided in Table 1 are believed to represent realistic costs for the delivery of beach nourishment sand to Stockton Beach from potentially available offshore marine sand sources. The cost estimate cannot be guaranteed as Bluecoast have no control over tender prices, market forces and competitive bids from tenderers.

Table 1: Nourishment rates for CBA cost sensitivity analysis

Initial or maintenance nourishment campaign (2020)					
Nourishment volume (m^3)	0.12M m^3	1.0M m^3	1.8M m^3	2.4M m^3	3.0M m^3**
Mobilisation and demobilisation costs*	$0.6M-$4M	$0.6M-$4M	$0.6M-$4M	$0.6M-$4M	$0.6M-$4M
Rainbow rate ($/$m^3$)	$6.50	$7.00 - $8.00	$7.00 - $8.00	$7.00 - $7.50	$7.00 - $8.00
Bottom dumping rate ($/$m^3$)	$6.00	$6.00 - $7.00	$6.00 - $7.00	$6.50	$6.00

* Mobilisation and demobilisation costs can vary substantially depending on the location of the dredgers at the time of tendering the works.

** As a comparison the 2017 Gold Coast Mass Nourishment project delivered just over 3M m^3 of sand for a total cost of $13.9M, or a combined rate of $4.63/$m^3$. Most of the sand was rainbowed to the surf zone.

APPENDIX C – ASSET PROTECTION RISK AND BEACH NOURISHMENT

Technical Note

To:	City of Newcastle
From:	Evan Watterson and Heiko Loehr
Copy:	
Reference:	P19028_NourishmentRisks_TN1.0
Date:	18 June 2020
Subject:	Risks associated with the use of mass nourishment for coastal protection at Stockton Beach

1 Introduction

In line with the Coastal Management Act 2016 and the NSW Coastal Management Manual Part A (the Manual), the City of Newcastle (CN) are preparing a Coastal Management Program (CMP) for Stockton Beach. This technical note sets out a review of the risks associated with beach nourishment for the purpose of providing coastal erosion protection to backshore assets at Stockton Beach. It informs the cost benefit analysis (CBA) for the Stockton CMP. It supplements the information in Royal HaskoningDHV's technical note titled *Technical Note: RHDHV input information for a Cost Benefit Analysis for Stockton Beach – Revised 23/4/20*, dated 15 April 2020, referred to herein as RHDHV's technical note.

2 Mass nourishment scenarios and initial assessment

Broadly, two sand placement quantities and renourishment periods have been considered in the CBA. A simple analysis comparing the two strategies is outlined in Table 1. Based on this initial assessment, the risk profile for backshore assets at Stockton Beach is expected to be lower for the scenario with the higher initial quantity and longer renourishment period. This scenario is also more economical in terms of sand delivery due to the lower mobilisation/demobilisation costs. An even lower risk profile could be realised if the nourished profile is maintained by regular annual increments equivalent to the annual sand loss rate delivered thereafter.

Table 1: A simple risk profile comparison for two mass nourishment scenarios

Parameter	**Lower initial quantity**	**Higher initial quantity**
Initial nourishment volume (m^3)	1,800,000	2,400,000
Renourishment period (years)	5	10
Alongshore length (m) along 0m AHD contour plus an additional 200m based on RHDHV (2020a)	2,200	2,200
Length (m) along the -8m AHD contour plus 200m	2,000	2,000
Protection benefits (i.e. above base case) provided by the nourishment immediately following the works		
Nourishment volume per linear meter of nearshore compartment (i.e. full coastal profile) in year 0 (m^3/m)	857	1,143
Effective nourishment volume above AHD (i.e. sub-aerial storm demand) available in year 0 (m^3/m)[1]	286	381
Additional effective Average Recurrence Interval (ARI) storm demand provided in year 0[4]	>500-year (photogrammetry Block A) ~80-year (photogrammetry Block C)	>500-year (photogrammetry Block A) >100-year (photogrammetry Block C)
Protection benefits (i.e. above base case) provided by the nourishment at the end of the renourishment period		
Long term (full coastal profile) sand loss rate ($m^3/m/yr$) [2]	46.2	46.2
Nourishment volume per linear meter of nearshore compartment (i.e. full coastal profile) at the end of the nourishment period (m^3/m)[3]	626	681
Effective nourishment volume above AHD (i.e. sub aerial storm demand) available in the last year of the nourishment period (m^3/m)[1]	209	227
Additional effective ARI storm demand provided in the last year of the nourishment period[4]	>200-year (photogrammetry Block A) ~45-year (photogrammetry Block C)	>200-year (photogrammetry Block A) ~50-year (photogrammetry Block C)

Notes:

1. This is based on the typical proportion of 33% of the total nourishment volume being the effective volume above AHD (Carley and Cox, 2017).

2. This is based on the long-term volumetric rate of sand loss over the full profile of 112,000m^3/yr between the northern breakwater and the Hunter Water site. An additional allowance for loss due to sea level rise has been included to account for the flattening of the profile due to Bruun rule-based slope re-adjustment.
3. Nourishment sand is also assumed to be lost at the long-term historic rate with an additional allowance for sea level rise. Accelerated losses because of the nourishment sand itself have not been included.
4. This is the additional sub-aerial sandy buffer provided by the beach nourishment works. The existing sub-aerial beach, in unprotected areas of the shoreline, would also provide some coastal protection function. Storm demands are based on the values provided in Bluecoast (2020) with consideration of seawall end effects after Carley et al. (2010).

3 Immediate erosion hazard for a pre- and post-nourishment beach

An assessment of the immediate coastal erosion hazards for pre- and post-nourishment was undertaken using the NSW beach profile photogrammetry data (DPIE, 2020), which provide coverage of the sub-aerial part of the beach. The 2.4M m^3 initial mass nourishment campaign delivered by rainbowing to the beach face and surf zone and bottom dumping was adopted along with the lowest risk profile of delivery of a yearly increment equivalent to the long-term annual sand loss rate. The long-term rate of sand loss within the beach compartment considered for nourishment (i.e. the CMP area) is in the order of 110,000m^3/yr (Bluecoast, 2020). In effect, placement of 2.4M m^3 of sand to the compartment will revert the coastal profile back in time around 22-years. If 2020 is selected as the pre-nourishment beach then around 1998 is representative of a post-nourishment beach. Using this assumption, a probabilistic coastal hazard assessment was completed for a post-nourishment beach using a representative profile in the NSW photogrammetry data (DPIE, 2020).

The results are presented in Figure 1. They show that if 2.4M m^3 of sand was placed in the CMP area then the extent of the 1% Annual Exceedance Probability (or 100-year Average Recurrence Interval) coastal erosion as defined by the zone of reduced foundation capacity (ZRFC) would not reach any assets. The post-nourishment erosion extents are in a similar position to today's mean sea level (MSL) shoreline. In contrast, the pre-nourishment (2020) erosion extents would impact numerous backshore assets.

The post-nourishment probabilistic erosion hazard results aligns with the greater than 100-year (or more) of additional effective ARI storm demand protection calculated for year zero following the works in Table 1. By regularly placing the required annual sand volumes in the coastal profile this level of asset protection would be maintained.

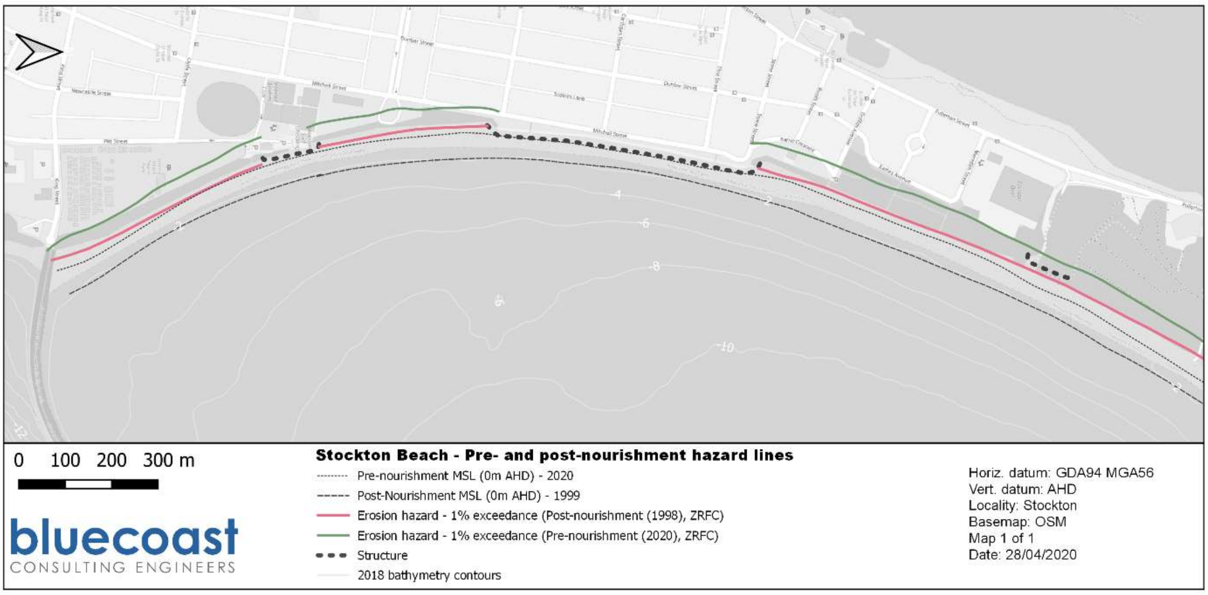

Figure 1: Pre- and post-nourishment 1%AEP immediate erosion hazard lines for Stockton Beach.

4 The nourished coastal profile

The immediate erosion hazard assessment for pre- and post-nourishment presented above considered only the sub-aerial beach (i.e. above 0m AHD). Shortly following the completion of beach nourishment works the nourished profile would be expected to readjust to an equilibrium shape with additional sand volume mostly in the sub-aqueous profile. Like the nourishment in the upper beach, the additional sand in the lower would provide a protective buffer against storm erosion.

Consideration has been given to the full nourished coastal profile down to the depth of closure. The assumption of the 2.4M m^3 of sand nourishment reverting the coastal profile back in time was applied to present a comparison of the pre-nourishment (2018 bathymetry) and post-nourishment (1995 bathymetry) in Figure 2. During a storm, sand that is eroded from the sub-aerial beach moves offshore into a storm bar causing waves to break further offshore dissipating their energy and protecting the beach against further erosion. It is noted that the post-nourishment profile has a 35m[1] wider surf zone and a milder slope of 1V:29H compare to the steeper 1V:24V slope in the pre-nourishment profile.

[1] The surf zone has been assumed to be between 0m AHD and -5m AHD.

The storm response of the post-nourishment (1995) profile is therefore expected to be more resilient, particularly in the case of successive storm, resulting in reduced erosion at the beach when compared to the pre-nourishment (2018) profile. This would be expected to improve the relative level of asset protection afforded by the nourished profile compared to that presented in the immediate hazard lines.

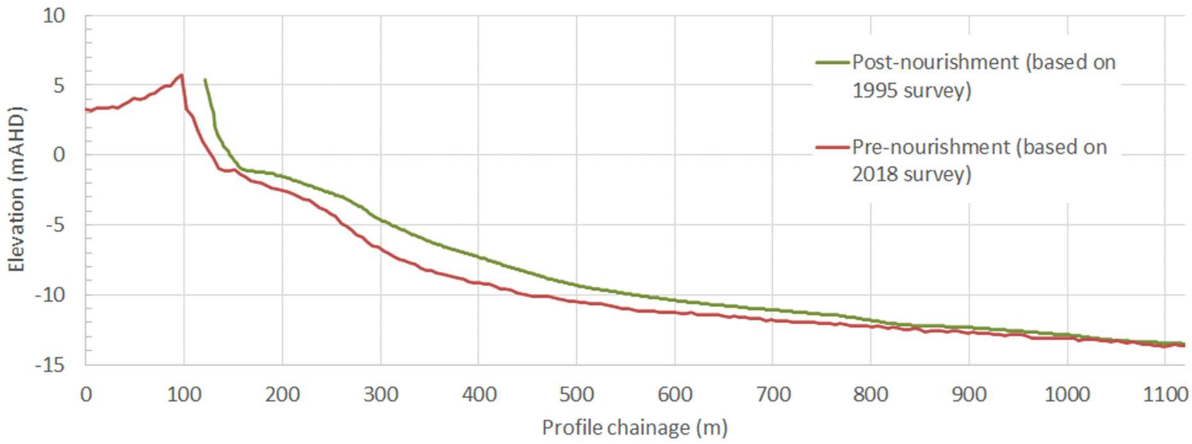

Figure 2: Adopted pre- and post-nourishment coastal profile for Stockton Beach.

This assessment of risk is considered adequate for the purposes of the CBA. However, it is recommended that storm response modelling be undertaken to quantify the storm response of the nourished profile using an appropriately calibrated and validated model during the planning and design stages of mass nourishment works.

5 References

Bluecoast (2020). *Stockton Beach coastal hazard assessment - Part B*. Report prepared for the City of Newcastle.

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DPIE (2020). *NSW Beach Profile Database* online at: http://www.nswbpd.wrl.unsw.edu.au/photogrammetry/about/

RHDHV (2020). *Addendum to Technical Note: RHDHV input information for a Cost Benefit Analysis for Stockton Beach (marine sand sources)*. Dated 15 April 2020.

APPENDIX D – SUMMARY OF KEY SENSITIVITY RESULTS

Option 1a

Original	**0.1**	**-$596,953,496**	**N/A**	**-1.7**
Cost Estimate +40%	0.1	-$856,898,165	N/A	-3.4
Cost Estimate +20%	0.1	-$726,925,831	N/A	-2.5
Cost Estimate – 20%	0.1	-$466,981,162	N/A	-1.1
PV Benefits +20%	0.1	-$586,371,861	N/A	-1.7
PV Benefits –20%	0.1	-$607,535,131	N/A	-1.7
PV Benefits –40%	0.0	-$618,116,767	N/A	-1.8
Delay by 1 Year	0.1	-$582,375,975	N/A	-1.7
Delay by 3 years	0.1	-$552,934,479	N/A	-1.6

Option 1b

Original	**1.5**	**$19,399,649**	**12.6%**	**0.8**
Cost Estimate +40%	1.1	$5,067,072	8.1%	0.3
Cost Estimate +20%	1.3	$12,233,360	10.0%	0.6
Cost Estimate – 20%	1.9	$26,565,938	16.3%	0.8
PV Benefits +20%	1.8	$30,445,867	15.6%	1.2
PV Benefits –20%	1.2	$8,353,431	9.5%	0.3
PV Benefits –40%	0.9	-$2,692,788	6.1%	-0.1
Delay by 1 Year	1.4	$15,150,049	11.1%	0.6
Delay by 3 years	1.3	$10,771,369	9.6%	0.4

Option 1c

Original	**0.9**	**-$8,995,207**	**5.5%**	**-0.2**
Cost Estimate +40%	0.6	-$33,793,205	2.4%	-1.0
Cost Estimate +20%	0.7	-$21,394,206	3.8%	-0.5
Cost Estimate – 20%	1.1	$3,403,792	7.7%	0.1
PV Benefits +20%	1.0	$1,604,751	7.3%	0.0
PV Benefits –20%	0.7	-$19,595,164	3.4%	-0.4
PV Benefits –40%	0.5	-$30,195,122	0.7%	-0.6
Delay by 1 Year	0.8	-$12,857,271	4.8%	-0.3
Delay by 3 years	0.7	-$16,415,609	4.4%	-0.3

Option 1d

Original	**1.3**	**$11,305,507**	**9.7%**	**0.4**
Cost Estimate +40%	0.9	-$5,396,534	6.0%	-0.3
Cost Estimate +20%	1.1	$2,954,487	7.6%	0.1
Cost Estimate – 20%	1.6	$19,656,528	12.6%	0.6
PV Benefits +20%	1.5	$21,917,630	12.0%	0.8
PV Benefits –20%	1.0	$693,385	7.2%	0.0
PV Benefits –40%	0.8	-$9,918,737	4.3%	-0.4
Delay by 1 Year	1.3	$10,575,324	9.6%	0.4
Delay by 3 years	1.2	$6,131,432	8.4%	0.2

Option 2a

Original	**0.1**	**-$387,620,536**	**N/A**	**-5.4**
Cost Estimate +40%	0.0	-$552,176,647	N/A	-10.7
Cost Estimate +20%	0.0	-$469,898,592	N/A	-7.8
Cost Estimate – 20%	0.1	-$305,342,481	N/A	-3.4
PV Benefits +20%	0.1	-$382,866,588	N/A	-5.3
PV Benefits –20%	0.0	-$392,374,485	N/A	-5.4
PV Benefits –40%	0.0	-$397,128,433	N/A	-5.5
Delay by 1 Year	0.1	-$367,901,389	N/A	-5.1
Delay by 3 years	0.1	-$330,690,326	N/A	-4.6

Option 2b

Original	**0.4**	**-$39,869,548**	**-3.1%**	**-1.1**
Cost Estimate +40%	0.3	-$65,325,263	N/A	-2.4
Cost Estimate +20%	0.3	-$52,597,405	-6.5%	-1.7
Cost Estimate – 20%	0.5	-$27,141,690	-0.5%	-0.6
PV Benefits +20%	0.4	-$35,115,599	-0.9%	-0.9
PV Benefits –20%	0.3	-$44,623,496	-7.7%	-1.2
PV Benefits –40%	0.2	-$49,377,444	N/A	-1.3
Delay by 1 Year	0.4	-$39,905,276	-5.2%	-1.1
Delay by 3 years	0.3	-$39,203,113	N/A	-1.0

Option 2c

Original	**0.3**	**-$59,956,370**	**N/A**	**-1.4**
Cost Estimate +40%	0.2	-$93,446,814	N/A	-3.0
Cost Estimate +20%	0.2	-$76,701,592	N/A	-2.1
Cost Estimate – 20%	0.4	-$43,211,147	-5.8%	-0.8
PV Benefits +20%	0.3	-$55,202,421	-6.9%	-1.3
PV Benefits –20%	0.2	-$64,710,318	N/A	-1.5
PV Benefits –40%	0.2	-$69,464,266	N/A	-1.6
Delay by 1 Year	0.3	-$59,088,261	N/A	-1.3
Delay by 3 years	0.3	-$56,751,944	N/A	-1.3

Option 3a

Original	**0.1**	**-$233,804,597**	**N/A**	**-5.4**
Cost Estimate +40%	0.0	-$334,061,044	N/A	-10.9
Cost Estimate +20%	0.1	-$283,932,820	N/A	-7.9
Cost Estimate – 20%	0.1	-$183,676,373	N/A	-3.4
PV Benefits +20%	0.1	-$230,437,293	N/A	-5.4
PV Benefits –20%	0.1	-$237,171,901	N/A	-5.5
PV Benefits –40%	0.0	-$240,539,205	N/A	-5.6
Delay by 1 Year	0.1	-$222,092,441	N/A	-5.2
Delay by 3 years	0.1	-$199,679,775	N/A	-4.6

Option 3b

Original	**0.1**	**-$71,760,461**	**N/A**	**-2.4**
Cost Estimate +40%	0.1	-$104,857,897	N/A	-4.9
Cost Estimate +20%	0.1	-$88,309,179	N/A	-3.5
Cost Estimate – 20%	0.2	-$55,211,742	N/A	-1.5
PV Benefits +20%	0.2	-$69,563,834	N/A	-2.3
PV Benefits –20%	0.1	-$73,957,087	N/A	-2.5
PV Benefits –40%	0.1	-$76,153,713	N/A	-2.5
Delay by 1 Year	0.1	-$69,553,966	N/A	-2.3
Delay by 3 years	0.1	-$65,040,041	N/A	-2.2